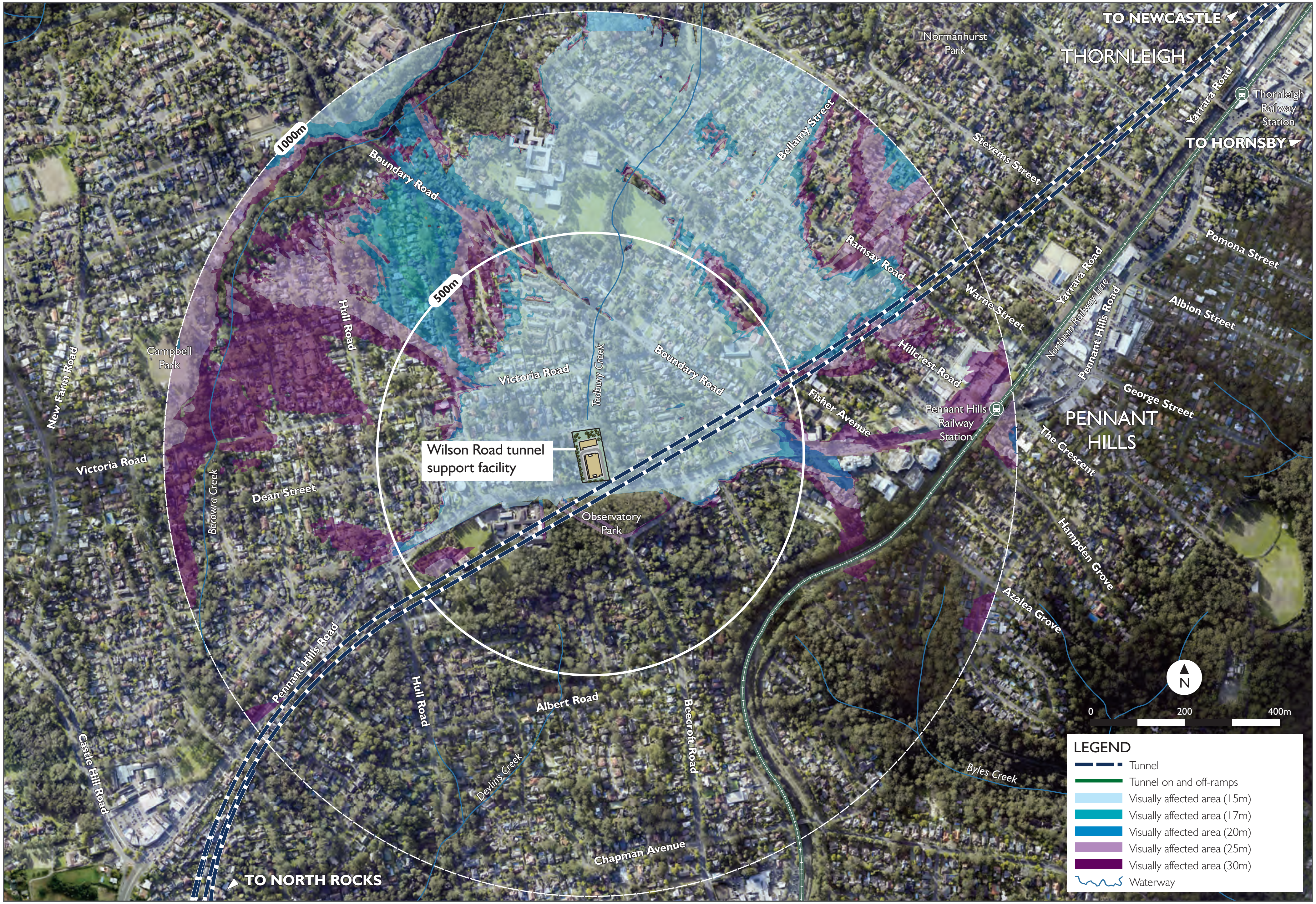

Figure 3-8 Wilson Road ventilation outlet visual envelope map

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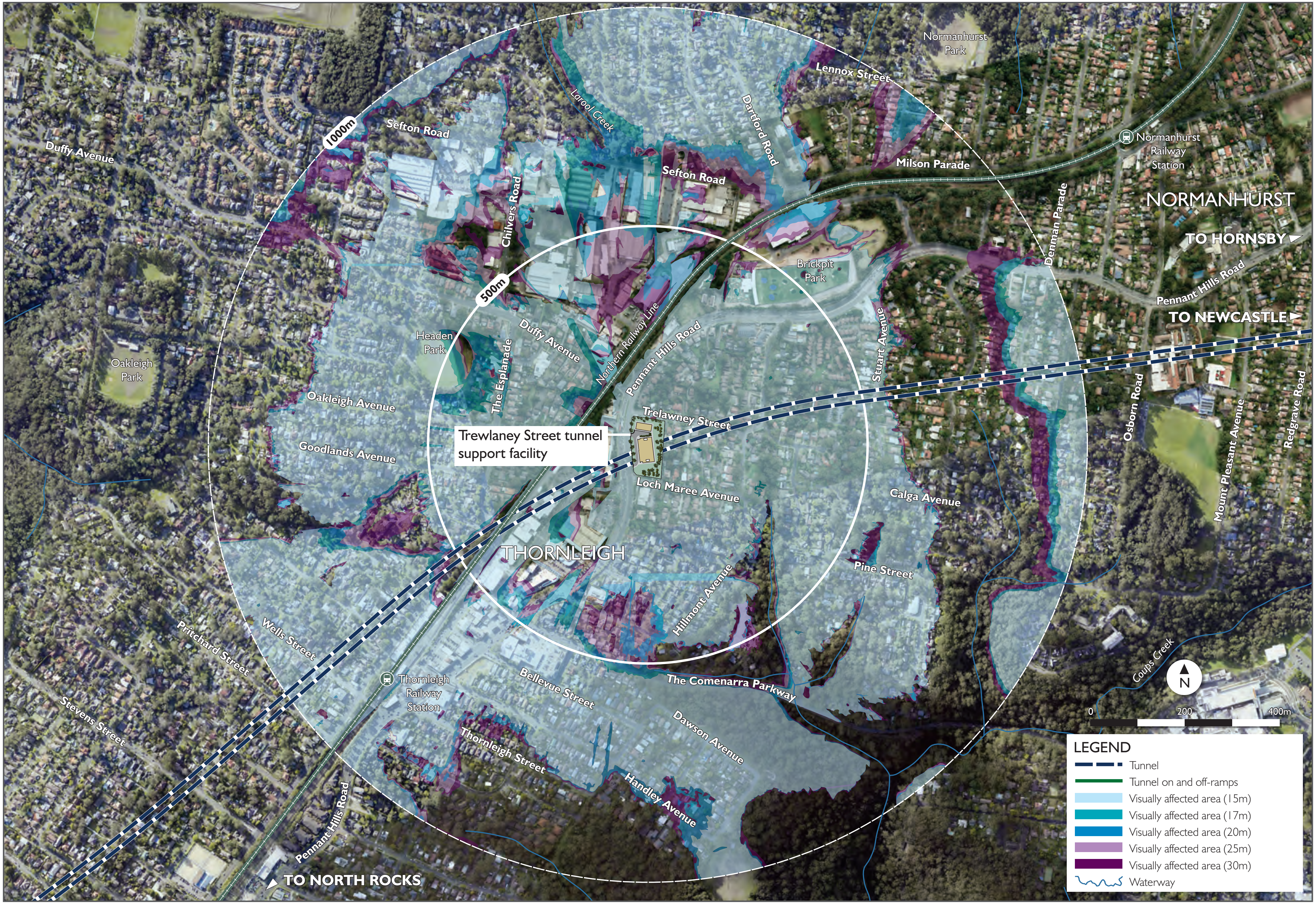

Figure 3-9 Trelwaney Street ventilation outlet visual envelope map

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Engineering considerations

The construction of additional ventilation outlets is unlikely to introduce new engineering challenges, subject to further design consideration, noting that ventilation outlet designs have already been considered for the northern and southern ventilation outlets. However, additional engineering complexity would be introduced with the need to provide air intakes at the intermediate ventilation outlet sites, in addition to the other project infrastructure required at those locations (eg separation of the shaft for ventilation outlet air and air intake).

Capital and operating costs

Estimated additional capital and operating costs associated with intermediate ventilation outlets are summarised **Table 3-16**. Costs have been listed for individual intermediate ventilation outlet locations (ie the conversion of the Wilson Road and Trelawney Street tunnel support sites have been listed separately).

Additional operating costs for each of the intermediate ventilation outlet options are largely the result of electricity costs.

Table 3-16 Estimated increase in capital and operating costs for intermediate ventilation outlets

Intermediate ventilation outlet location	Increase in project capital cost	Increase in project operating cost
Provision of a mid point ventilation outlet	$100 million to $150 million, subject to further design development	$3.5 million per annum, depending on ventilation flow rates
Conversion of the Wilson Road tunnel support facility	$20 million to $60 million, subject to further design development	$3.5 million per annum, depending on ventilation flow rates
Conversion of the Trelawney Street tunnel support facility	$20 million to $50 million, subject to further design development	$3.5 million per annum, depending on ventilation flow rates

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3.2.5 Scenario 4 – Changes in ventilation flow rates

The project's ventilation system has been designed to achieve specified in-tunnel air quality outcomes for traffic volumes up to and including the maximum traffic throughput capacity of the project's main alignment tunnels. The ventilation system design criteria are provided in Table 7-95 of the environmental impact statement and are reproduced below. Further details of these criteria, including how they have been applied to the design of the project's ventilation system are provided in **Section 2.5** of this report.

Table 3-17 Ventilation system design criteria

Average traffic speed (km/h)	Operational mode	CO design criteria (15 minute)	NO_2 design criteria (15 minute)	Visibility (extinction coefficient)
80	Normal traffic conditions. Vehicles are moving freely with no congestion effects	50 ppm (57.5 mg/m^3)	0.5 ppm (0.94 mg/m^3)	<0.005 m^{-1}
60		50 ppm (57.5 mg/m^3)	0.5 ppm (0.94 mg/m^3)	<0.005 m^{-1}
40	Congested traffic conditions. Vehicles have slowed as a result of traffic congestion, caused by a vehicle accident or incident. Congestion management measures would be implemented as average traffic speeds fall towards 40 km/h.	60 ppm (69 mg/m^3)	0.8 ppm (1.51 mg/m^3)	<0.005 m^{-1}
0 to 20	Significantly congested traffic conditions. Vehicles have slowed significantly as a result of traffic congestion, caused by a vehicle accident or incident. Congestion management measures would be in place.	87 ppm (100 mg/m^3)	1.0 ppm (1.88 mg/m^3)	<0.005 m^{-1}

In-tunnel exposures to vehicle emissions could be changed through the design and operation of the project's ventilation system in one of three ways:

- Increasing the capacity of the project's ventilation system.
- Applying more stringent ventilation design criteria to the ventilation system design.
- Operating the ventilation system at increased flow rates within the existing design capacity of the project.
- Changing the configuration of the ventilation system (for example, to a transverse or semi-transverse system, rather than longitudinal ventilation).

Changing design criteria/ increasing ventilation capacity

The last two of the options listed above would essentially be the same. As discussed above, the project's ventilation system has been designed to achieve the in-tunnel air quality outcomes summarised in **Table 3-17**. A change to these criteria would necessitate a change in project design to provide additional ventilation capacity. Because the ventilation design criteria are comparable to or better than other road tunnels around the world, there is no reasonable justification for applying more stringent criteria or requiring addition ventilation capacity to be provided in the project design.

Changing design criteria/ increasing ventilation capacity

Operating the project within its current ventilation design capacity, but at higher ventilation flow rates than have been applied to the ambient and in-tunnel air quality assessments presented in the environmental impact statement, is an option that is already available. The project has been design and has committed to achieving the ventilation design criteria specified in **Table 3-17**. The project would also be operated to achieve in-tunnel air quality conditions that may be specified in conditions of approval for the project, if applied by the Minister for Planning.

Because the ventilation design criteria are comparable to or better than other road tunnels around the world, there is no reasonable justification for operating the project's ventilation system at higher ventilation flow rates than necessary to achieve these criteria. Constantly or frequently operating the ventilation system at greater flow rates than necessary would introduce potentially significant operating costs based on increased energy requirements.

A detailed ventilation control strategy would be developed during the detailed design phase and implemented during operation of the project to ensure that acceptable in-tunnel air quality is maintained. The control strategy would be developed to include three distinct operational modes:

- **Normal operation** for the management and control of in-tunnel air quality under all traffic scenarios, including fluid free flowing traffic conditions and congestion.
- **Breakdown mode** where a breakdown has caused the tunnel to be blocked or severely restricted
- **Emergency operation** for the management and control of smoke in the event of a fire, for the safe egress of occupants and access for emergency services.

During normal operation, the project's ventilation system would automatically operate and adjust the ventilation flow rates within the tunnel and at the ventilation outlets to maintain in-tunnel air quality within acceptable limits.

The ventilation system would have a fixed number of ventilation levels which would generally correspond with the number of exhaust fans (at the ventilation outlets) in combination with the supply fans (within the main alignment tunnels and ramps) in the system. For example, a 'level 1' operation may involve the operation of one exhaust fan, and a 'level 5' operation may involve the operation of four exhaust fans. The number of ventilation levels and fan operating combinations would be determined during the detailed design of the project.

Jet fans ('supply fans') in the main alignment tunnels and ramps would operate to maintain longitudinal ventilation and to balance air flow in each tunnel section, such that in-tunnel air quality is maintained within acceptable limits.

The following key inputs will be used to determine the level of ventilation required at any given time and for any given traffic scenario:

- **Time of day** – The ventilation system would activate the level of ventilation required based on the time of day, increasing the level of ventilation in the tunnel in the lead up to peak hours, and reducing the level at off peak times such as during the night.
- **Traffic speed and density** – Vehicle detectors located within the roadway of the project tunnels and approaches would provide real-time input for traffic speed and traffic density in the project tunnels. This combination of vehicle speed and number of vehicles per hour would be used to select and confirm the level of ventilation required, possibly increasing above the level estimated by the 'time of day' schedule, if necessary. The combination of traffic speed, density and ventilation level would be pre-programed into the ventilation system using an algorithm to ensure that acceptable in-tunnel air quality is maintained to prevent emissions from the project's portals.
- **Data from in-tunnel air quality monitoring sensors** - Air quality monitoring sensors would be located throughout the project tunnels to identify and provide a complete understanding of in-tunnel air quality during operation. As a minimum, these sensors would provide continuous monitoring for carbon monoxide, nitrogen dioxide, visibility and in-tunnel air flow.

  If the air quality monitoring sensors detect that vehicle emissions concentrations are approaching the pre-set limits (ie actions triggers below maximum allowable in-tunnel air quality criteria to provide an 'early warning' and action system), feedback would be given to the ventilation system to increase the ventilation rate to the next ventilation level. This would continue in order to maintain in-tunnel air quality and to ensure compliance with the air quality criteria is always achieved.
- **Incident detection** – The project would be equipped with an automatic video incident detection (AVID) system. AVID is a close circuit television (CCTV) system but has the additional capability of detecting and actively alerting tunnel operators to incidents within the tunnel as they occur. The AVID system has the ability to detect a range of tunnel incidents including stopped vehicles, pedestrians or the presence of smoke in the project tunnels.

  The AVID system would quickly alert the tunnel operators to an incident in the project tunnels, so that they can implement the appropriate incident management plan. For example, in the event of a stopped vehicle, the operators can quickly identify its location and respond by implementing a traffic management plan and increasing the level of ventilation if required. It would also assist them to address the driver through the public address system or motorist emergency telephone.

  Unlike surface roads, road tunnels are constantly managed from a central control room with an operations team to ensure that action can be taken quickly and effectively in the event of an alarm or incident. With respect to the emergency devices such as the deluge system, these would be automatically operated in the event of an incident.

  Where there is a major incident such as a crash which results in the tunnel being blocked, the relevant tunnel would be closed and vehicles diverted to surface roads. The close tunnel would only be reopened once the incident is cleared. This action would be taken quickly (response time would be in minutes from alert) to minimise the number of vehicles in the tunnel.

  In the event of a fire incident the whole tunnel in both directions would be closed and vehicles diverted to surface roads until the incident has been dealt with.
- **Traffic and ventilation management** - It is envisaged that congested, slow moving traffic conditions would be rare in the project. However, where average traffic speeds drop below 40km/h, the tunnel operators would have the ability to implement traffic

management procedures as a further means to manage vehicle emissions and air quality within the tunnel, in conjunction with the tunnel ventilation system.

Subject to the conditions of approval that may be applied to the project by the Minister for Planning, the NorthConnex project would regularly report (real time) on the performance and compliance with the air quality criteria. This would include in-tunnel air quality, air discharged from the ventilation outlets and ambient air external to the project tunnels.

In-tunnel air quality reporting would provide a direct clear comparison between the actual monitored air quality exposure within the tunnel against the maximum allowable air quality criteria to demonstrate that compliance is achieved at all times.

Changing the configuration of the project's ventilation system

Broadly, there are four types of ventilation systems for road tunnels:

- Natural ventilation.
- Fully transverse mechanical ventilation.
- Semi-transverse mechanical ventilation.
- Longitudinal mechanical ventilation.

The NorthConnex project has been designed as a longitudinal mechanical ventilation system.

Natural ventilation

For short tunnels with low traffic volumes, natural ventilation is often sufficient. Natural ventilation relies on prevailing winds, a difference in air pressure between tunnel portals, and in some cases a slight convective, or 'chimney effect'. Where traffic flows are uni-directional, the piston effect generated by moving traffic also assists in tunnel ventilation. Naturally ventilated tunnels emit in-tunnel air from the tunnel portals. The majority of road tunnels around the world are naturally ventilated. Given the length of the NorthConnex project, natural ventilation would not be sufficient to maintain acceptable in-tunnel air quality.

Fully transverse mechanical ventilation

Fully transverse ventilation includes two ducts in addition to the main traffic tunnel. One duct brings in 'fresh' ambient air, which is supplied typically from below or near the base on the main traffic tunnel. The air passes vertically the main traffic tunnel before being extracted at or above the main traffic tunnel and passing into an exhaust duct. The exhaust duct carries in-tunnel air comprising vehicle emissions to a ventilation outlet(s). Fresh air is provided by the supply duct and removed by the exhaust dust at many locations along the main traffic tunnel (typically spaced at around 10 metre intervals)

The supply and exhaust ducts of a fully transverse ventilation system contribute a significant additional cross-sectional area to the road tunnel (potentially up to 50 per cent more). Additional ventilation capacity is typically required in fully transverse ventilation systems to offset the pressure loss across the many fresh air supply and exhaust offtake points. This additional ventilation capacity, and the fact that fully transverse ventilation systems do not take advantage of the piston effect generated by traffic, means that these types of ventilation systems are more capital intensive and more expensive to operate.

For the NorthConnex project, the extra excavation required to provide a fully transverse ventilation system would have a considerable impact on the cost and construction program for the project. It would also increase spoil management and disposal requirements by up to 50 per cent. A longer construction program with greater spoil handling requirements would increase impacts on local communities, particularly in relation to construction noise and construction traffic.

Fully transverse ventilation systems also typically include both supply and exhaust ventilation buildings. This requirement introduces additional surface disturbance and associated environmental and land use impacts.

Semi-transverse mechanical ventilation

Semi-transverse ventilation systems are similar to fully transverse systems, except that the main traffic tunnel is used as the exhaust duct (rather than constructing a separate exhaust duct). Fresh air is supplied to the main traffic tunnel via a supply duct with outlets at many locations along the tunnel. Semi transverse ventilation systems emit in-tunnel air from tunnel portals or dedicated ventilation outlets.

Semi transverse ventilation systems have similar, but not all, of the space and energy usage disadvantages of fully transverse systems. As the main traffic tunnel acts as the exhaust duct, the system is able to take advantage of some of the energy saving efficiency of using the piston effect of traffic flow. This is offset by supply air system inefficiencies as supply air needs to be distributed through a duct rather than using the full cross sectional area of the tunnel as is the case with a longitudinal system.

A semi-transverse ventilation solution is undesirable for the NorthConnex project for similar reasons as a fully transverse system.

Longitudinal mechanical ventilation

Longitudinal ventilation consists of jet fans mounted at a number of points along the tunnel length. Air is drawn in at one portal and is accelerated along the tunnel to exhaust at the other. For the majority of the world’s tunnels that have longitudinal mechanical ventilation, tunnel air is exhausted via the tunnel portal. A minority of tunnels with longitudinal mechanical ventilation have vertical ventilation outlets which disperse the tunnel air vertically and at high velocity to ensure that pollutants are dispersed over a far wider area rather than allowing exhausting the emissions through the portal. Depending on traffic mix, gradient and length some tunnels have more than one ventilation outlet per tunnel.

In uni-directional tunnels, such as the NorthConnex project, the piston effect of traffic movement provides additional momentum to tunnel air pushing it toward the ventilation outlet point. As a result, this type of tunnel ventilation system is the most energy efficient method of mechanically ventilating road tunnels and has been adopted for the majority of road tunnels worldwide.

The use of a longitudinal system for NorthConnex has been adopted due to its high efficiency and proven performance on long uni-directional tunnels. Whilst very effective for normal operation, the longitudinal system is also very effective in controlling smoke in fire conditions.

3.2.6 Scenario 5 – Treatment of in-tunnel air or ventilation discharges

The application of in-tunnel air treatment technology involving particulate matter filtration has been considered for application to the project's main alignment tunnels. As outlined in **Section 3.1** of this report, de-nitrification technologies are still in the early stages of development, and have not been demonstrated at this time as viable at the scale and efficiency required for operational treatment of road tunnel air. For this reason, de-nitrification technologies have not been considered further for potential application to the NorthConnex project.

For the purpose of this analysis, it has been assumed that particulate matter filtration technology would be installed as part of the infrastructure at the Wilson Road and Trelawney Street tunnel support sites. Infrastructure at these sites would augmented to provide sufficient ventilation capacity (through the ventilation shafts and ventilation fans) to operate the particulate matter filtration technology.

At each tunnel support facility, air would be drawn from the relevant main alignment tunnel and passed through a bank of electrostatic precipitators before being returned to the main alignment tunnel downstream of the air extraction point. Auxiliary plant would be required to support the particulate matter filtration facilities, including:

- A wash water treatment plant, to treat and manage an estimated 504 kL/ year of water per particulate matter filtration plant (ie a total of around 1,008 kL/ year assuming that a particulate matter filtration plant is installed in each main alignment tunnel).
- An electrical room housing high voltage generating panels associated with the electrostatic precipitators at each tunnel support site (Wilson Road and Trelawney Street).

The particulate matter filtration plants would be automated and would require minimal operator input.

For the purpose of this analysis and the conceptual design of the particulate matter filtration plants, it has been assumed that the following treatment outcomes would be achieved:

- An 80 per cent reduction in PM_{10} at the point of treatment.
- An 80 per cent reduction in $PM_{2.5}$ at the point of treatment.

As discussed in **Section 3.1** of this report, particulate matter filtration employing electrostatic precipitators may experience reduced treatment efficiency and effectiveness at lower particulate matter concentrations and for smaller particle sizes.

It is also important to recognise that a minimum flow rate of air through the main alignment tunnels needs to be maintained. Therefore, it is not possible to redirect and treat all of the air from the main alignment tunnels through the particulate matter filtration plant. Taking this into account, and based on the ventilation design and expected operation under forecast traffic flows, it is anticipated that up to around 75 percent of the volume of in-tunnel air could be redirected and treated at each of the tunnel support sites. Assuming an 80 per cent reduction in particulate matter load in the treated air, a net reduction in particulate matter of around 60 per cent could be expected (ie 80 per cent of 75 percent of the particulate matter load at the point of offtake for treatment).

Further design development and analysis would be required to optimise the project's ventilation design and operation, should particulate matter filtration be installed. However, for the purpose of this analysis, a net reduction in particulate matter of 60 per cent at the

Wilson Road and Trelawney Street tunnel support sites has been adopted as an indicative basis for comparison of ventilation design options and alternatives.

Ambient air quality

With a reduction in PM_{10} and $PM_{2.5}$ loads at the Wilson Road and Trelawney Street tunnel support facilities of around 60 percent, the reduction in mass emission rate at each ventilation outlet would be reduced as summarised in **Table 3-21** (refer to the following section of this report for a discussion of in-tunnel air quality). Data in the table is presented as the percentage of the relevant mass emission rates used in the air dispersion modelling included in the environmental impact statement.

Table 3-18 Relative reductions in mass emission rates at the ventilation outlets

Pollutant	Reduction in mass emission rate at the ventilation outlet (as a percentage of EIS mass emission rates)			
	2019 Southbound	2029 Southbound	2019 Northbound	2029 Northbound
PM_{10}	62.3%	62.4%	59.5%	59.5%
$PM_{2.5}$	62.5%	62.3%	59.5%	59.5%

Changes in ambient air quality impacts from the project with the application of particulate matter filtration would be proportional to the change in mass emission rates from the project's ventilation outlets. Assuming that all other operational factors for the ventilation outlets remain the same, scaled ambient air impacts for the project based on the change in mass emission rates above, would be as summarised in **Table 3-22**. These scaled ambient air quality impacts assume continuous operation of the particulate matter filtration plants and constant particulate matter removal efficiencies.

Table 3-19 Scaled ambient air quality impacts

Parameter	EIS design[1]	With particulate matter filtration at Wilson Road and Trelawney Street
Northern ventilation outlet		
PM_{10} (annual average) ($\mu g/m^3$)	0.057	0.034
Percentage of criterion (30 $\mu g/m^3$)	0.19%	0.11%
$PM_{2.5}$ (annual average) ($\mu g/m^3$)	0.054	0.032
Percentage of advisory reporting standard (8 $\mu g/m^3$)	0.68%	0.40%
NO_2 (annual average) ($\mu g/m^3$)	0.96	0.96
Percentage of criterion (62 $\mu g/m^3$)	1.54%	1.54%
Southern ventilation outlet		
PM_{10} (annual average) ($\mu g/m^3$)	0.046	0.029
Percentage of criterion (30 $\mu g/m^3$)	0.15%	0.10%
$PM_{2.5}$ (annual average) ($\mu g/m^3$)	0.044	0.027
Percentage of advisory reporting standard (8 $\mu g/m^3$)	0.55%	0.34%
NO_2 (annual average) ($\mu g/m^3$)	0.51	0.51
Percentage of criterion (62 $\mu g/m^3$)	0.81%	0.81%

[1] This data represent the outcomes of applying the project design in the environmental impact to the screening assessment approach, rather than a reproduction of results from the environmental impact statement.

In-tunnel air quality

Table 3-23 summarises the calculated in-tunnel concentrations of NO_2, PM_{10} and $PM_{2.5}$ under scenarios including installation of particulate matter filtration at the Wilson Road and Trelawney Street tunnel support sites. This data has been developed for direct comparison with Table 7-101 in the environmental impact statement, and is based on the same assumptions and calculation methodology (refer to **Chapter 2** for further discussion of this methodology and interpretation of outputs). The table shows only in-tunnel pollutant concentrations for each main alignment tunnel in the relevant peak hour in 2019 and 2029 (ie a worst-case in-tunnel air quality scenario based on forecast traffic flows).

Table 3-23 shows that:

- Particulate matter filtration would not affect in-tunnel air quality for the first two thirds of each main alignment tunnel, based on the location of the filtration plants at the Wilson Road and Trelawney Street tunnel support facilities.
- In-tunnel concentrations of particulate matter would reduce by around 60 per cent at the point of filtration, based on an assumed particulate matter removal efficiency of 80 per cent, the design of the project's ventilation system and the need to maintain air flow through the main alignment tunnels (and therefore not treat all of the in-tunnel air).
- The net effect of particulate matter filtration, taking into account the assumptions about its efficiency and effectiveness, would be to reduce particulate matter concentrations to around 63 per cent at the southern ventilation offtake and around 60 per cent at the northern ventilation offtake in 2019 and 2029.
- These calculations may be significantly affected by how the project's ventilation system is operated, and by traffic volumes (noting the discussion in **Section 3.1** of this report about particulate matter removal efficiencies at different initial concentrations, and for different size particles).

Table 3-20 Indicative in-tunnel air quality with application of particulate matter filtration

Black – design as presented in the EIS including updates to fuel mix and no change to ratio of NO2 to NOx (10%)
Red – design including particulate matter filtration

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)									
NO_2*	0.044	0.111	0.14	0.162	0.186	0.210	0.232	0.282	0.422
	0.044	0.111	0.14	0.162	0.186	0.210	0.232	0.282	0.422
PM_{10}	0.040	0.087	0.127	0.164	0.200	0.238	0.275	0.318	0.391
	0.040	0.087	0.127	0.164	0.200	0.095	0.132	0.175	0.248
$PM_{2.5}$	0.039	0.085	0.122	0.158	0.195	0.231	0.267	0.308	0.369
	0.039	0.085	0.122	0.158	0.195	0.092	0.128	0.169	0.230
Southbound main alignment tunnel at 9 am (2029)									
NO_2*	0.049	0.124	0.156	0.183	0.209	0.235	0.261	0.317	0.473
	0.049	0.124	0.156	0.183	0.209	0.235	0.261	0.317	0.473
PM_{10}	0.051	0.109	0.156	0.203	0.249	0.296	0.343	0.397	0.472
	0.051	0.109	0.156	0.203	0.249	0.118	0.165	0.219	0.294
$PM_{2.5}$	0.050	0.102	0.148	0.192	0.236	0.280	0.324	0.375	0.446
	0.050	0.102	0.148	0.192	0.236	0.112	0.156	0.207	0.278
Northbound main alignment tunnel at 6 pm (2019)									
NO_2*	0.005	0.112	0.235	0.358	0.481	0.604	0.719	0.784	0.875
	0.005	0.112	0.235	0.358	0.481	0.604	0.719	0.784	0.875
PM_{10}	0.033	0.092	0.156	0.220	0.284	0.347	0.410	0.46	0.515
	0.033	0.092	0.156	0.220	0.284	0.139	0.202	0.252	0.307
$PM_{2.5}$	0.031	0.087	0.147	0.207	0.269	0.329	0.387	0.434	0.487
	0.031	0.087	0.147	0.207	0.269	0.132	0.190	0.237	0.290
Northbound main alignment tunnel at 6 pm (2029)									
NO_2*	0.005	0.123	0.258	0.393	0.529	0.664	0.79	0.861	0.963
	0.005	0.123	0.258	0.393	0.529	0.664	0.79	0.861	0.963
PM_{10}	0.041	0.111	0.186	0.261	0.337	0.412	0.484	0.543	0.610
	0.041	0.111	0.186	0.261	0.337	0.165	0.237	0.296	0.363

$PM_{2.5}$	0.039	0.104	0.176	0.247	0.318	0.389	0.457	0.518	0.576
	0.039	0.104	0.176	0.247	0.318	0.156	0.224	0.285	0.343

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

Human health risks

Assuming that the particulate matter filtration plants operate continuously and constantly at the assumed removal efficiency, changes in human health impacts would be proportional to the predicted reductions in annual average $PM_{2.5}$ concentrations (which would in turn be proportional to the change in mass emission rates from the project's ventilation outlets).

Table 3-24 summarises estimated increases in incidence of primary health indicators assuming the installation of particulate matter filtration plants, and includes equivalent data from the environmental impact statement without the use of filtration.

Table 3-21 Estimated increases in incidence of primary health effects (per year) – installation of particulate matter filtration

Primary health indicator	Baseline incidence per year (per 100,000)	Normal incidence variability (cases per year)	EIS (2019)	With particulate matter filtration
Northern interchange				
Mortality from all causes (≥ 30 years of age)	1,087	1	0.03	0.018
Rate of hospitalisation with cardiovascular disease (≥ 65 years of age)	23,352	40	0.02	0.012
Rate of hospitalisation with respiratory disease (≥ 65 years of age)	8,807	17	0.005	0.0030
Southern interchange				
Mortality from all causes (≥ 30 years of age)	1,087	1	0.03	0.019
Rate of hospitalisation with cardiovascular disease (≥ 65 years of age)	23,352	40	0.02	0.012
Rate of hospitalisation with respiratory disease (≥ 65 years of age)	8,807	17	0.004	0.0025

Other environmental and land use impacts

Relevant environmental and land use impacts (other than air quality and human health risks) for potential installation of particulate matter filtration plants at the Wilson Road and Trelawney Street tunnel support sites are presented in **Table 3-25**.

Table 3-22 Assessment of other environmental and land use impacts – installation of particulate matter filtration plants

Environmental and land use impacts	Assessment
Visual amenity impacts	An increase in the scale of the tunnel support facilities at Wilson Road and Trelawney Street sites to accommodate power supply and waste water management/ treatment systems would increase the bulk at these sites and associated visual impacts. Given that both sites are already proposed to be developed as tunnel support sites, only a minor additional deterioration in visual amenity would be anticipated.
Noise and vibration impacts	Both the Wilson Road and Trelawney Street tunnel support facilities are predicted to operate well below operational noise criteria. This, in addition to the ability to include appropriate noise attenuation in the design of additional surface infrastructure, would result in a negligible change in potential noise impacts relative to the assessment presented in the environmental impact statement.
Land acquisition	Subject to detailed design, surface infrastructure is anticipated to be able to be accommodated within the Wilson Road and Trelawney Street tunnel support facility sites, without the need for further land acquisition.
Land use impacts	Additional surface infrastructure at the Wilson Road and Trelawney Street sites is unlikely to increase land use impacts above those already presented and assessed in the environmental impact statement.
Construction impacts	Construction impacts are expected to be similar to those presented in the environmental impact statement, noting that construction at the Wilson Road and Trelawney Street sites is already proposed. Additional underground construction activities are unlikely to generate surface impacts.

Engineering considerations

Application of particulate matter filtration systems to the projects main alignment tunnels would increase the engineering design and operational complexity of the project. The ventilation system would be more complex, with a need to manage air flow rates through the main alignments as well as through in-tunnel offtake and re-entry infrastructure. Additional engineering is likely to be required to offset and manage the pressure drop across the filtration units.

Operationally, additional plant would be required, including the electrostatic precipitators, as well as the associated power supply and water management/ treatment systems.

Capital and operating costs

Estimated additional capital and operating costs associated with the installation of particulate matter filtration plans are summarised in **Table 3-26**. Costs include installation and operation of a filtration plant for each main alignment tunnel.

Operational costs including consumable materials, water supply and electricity. The cost of electricity required to operate the filtration plants if the major contributor to operational costs.

Table 3-23 Estimated increase in capital and operating costs for intermediate ventilation outlets

In-tunnel air treatment	Increase in project capital cost	Increase in project operating cost
Use of in-tunnel particulate matter filtration in both main alignment tunnels	$125 million, subject to further design development	$4 million per annum

3.2.7 Summary of scenario analysis

Each of the ventilation options and alternatives considered above has been qualitatively evaluated relative to the project presented and assessed in the environmental impact statement. The qualitative performance indicators presented in **Table 3-27** have been used to visually represent the relative performance of each option and alternative.

Table 3-28 summarises the outcomes of the qualitative comparative analysis of each option and alternative, in terms of ambient and in-tunnel air quality, human health risks, other environmental and land use impacts, engineering considerations and cost.

Scenario 4 (alternative ventilation designs) has not been evaluated in detail because, based on the discussion presented earlier in this section, none of the ventilation design alternatives (with the exception of the current project ventilation design) are considered feasible or viable for the NorthConnex project.

Table 3-24 Qualitative performance indicators

Symbol	Description
↑↑↑	An outcome that is significantly improved from the outcomes presented in the environmental impact statement for the project.
↑↑	An outcome that is moderately improved from the outcomes presented in the environmental impact statement for the project.
↑	An outcome that is slightly improved from the outcomes presented in the environmental impact statement for the project.
•	An outcome that is the same or broadly equivalent to the outcomes presented in the environmental impact statement for the project.
↓	An outcome that is slightly worsened from the outcomes presented in the environmental impact statement for the project.
↓↓	An outcome that is moderately worsened from the outcomes presented in the environmental impact statement for the project.
↓↓↓	An outcome that is significantly worsened from the outcomes presented in the environmental impact statement for the project.
!	An outcome that is unacceptable because it does not comply with applicable legislation, criteria or other project requirement.

In considering each of the ventilation options and alternatives, an analysis of whether each is feasible and reasonable has been conducted. In this context:

- 'Feasible' relates to engineering factors and whether the particular option can be built, or practically implemented.
- 'Reasonable' relates to whether, based on application of judgement and a balanced merit assessment, the benefits of the option outweigh its disbenefits, taking into account:
  - The degree to which the option reduces in-tunnel and ambient exposures to vehicle emissions.
  - The environmental and land use impacts of the option.
  - The cost and complexity of the option.

With the exception of significant changes to the project's ventilation design (Scenario 4) (for example, to a naturally, fully transverse or semi-transverse ventilation), all of the options considered in this analysis are feasible. A decision on whether to pursue any of the options is therefore a question of reasonableness.

Table 3-25 Comparative analysis of ventilation options and alternatives

Option/ alternative	Ambient air quality	In-tunnel air quality	Human health risks	Visual amenity impacts	Noise and vibration impacts	Land acquisition	Land use impacts	Construction impacts	Engineering	Cost
Scenario 1 – ventilation outlet height										
Northern ventilation outlet +2 metres	●	●	●	●	●	●	●	●	●	↓
Northern ventilation outlet +5 metres	↑	●	↑	↓	●	●	●	●	●	↓
Northern ventilation outlet +10 metres	↑	●	↑	↓↓	●	●	●	●	●	↓
Northern ventilation outlet +15 metres	↑	●	↑	↓↓	●	●	●	●	●	↓
Southern ventilation outlet +2 metres	●	●	●	●	●	●	●	●	●	↓
Southern ventilation outlet +5 metres	↑	●	↑	↓	●	●	●	●	●	↓
Southern ventilation outlet +10 metres	↑	●	↑	↓↓	●	●	●	●	●	↓
Southern ventilation outlet +15 metres	↑	●	↑	↓↓	●	●	●	●	●	↓
Scenario 2 – relocation of ventilation outlets										
Asquith Industrial Area (northern ventilation outlet)	●	●	●	↑	●	↓↓	●	↓↓	↓↓↓	↓↓↓
Pennant Hills Golf Course (southern ventilation outlet)	↑	●	↑	↓↓	●	↓↓	↓	↓	↓↓	↓↓
Scenario 3 – additional ventilation outlets										
Mid point ventilation outlet	↑	↑	↑	↓↓	●	↓↓	↓	↓↓	↓	↓↓
Conversion of Wilson Road and Trelawney Street facilities	↑	↑	↑	↓	●	↓	↓	↓	↓	↓↓
Scenario 5 – treatment of in-tunnel air										
Use of in-tunnel particulate matter filtration in both main alignment tunnels	↑	↑	↑	↓	●	●	●	●	↓↓	↓↓↓

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Scenario 1 – Increased ventilation outlet height

All increases in ventilation outlet would improve ambient air quality impacts and associated human health risks. The degree of improvement would increase with additional ventilation outlet height, with the greatest incremental improvement identified at around an additional five to ten metres. Height increases above this level show a decline in incremental benefit with increased height. Increasing the height of the project's ventilation outlets does not affect in-tunnel air quality.

The key environmental impact associated with increased ventilation outlet height is potential visual impacts. Based on an assessment of the visual envelope mapping, a five metre increase in ventilation outlet height has been identified as the threshold around which visual impacts would transition from acceptable and manageable, to levels that are considered unacceptable.

Based on the net improvement in ventilation performance with increased ventilation outlet height, the additional visual impacts associated with increases of 10 metres or more would not be acceptable.

On the basis of this analysis, ventilation outlet height increases up to five metres would be feasible and reasonable.

An increase in ventilation outlet heights of five metres (for both the southern and the northern ventilation outlets) has been adopted for the NorthConnex project. Further details of this project design changes, and a revised environmental impact assessment, are presented in **Section 9.2** of this report.

Scenario 2 – Relocation of the ventilation outlets

Relocation of the northern ventilation outlet into the Asquith Industrial Estate would provide no tangible air quality or human health benefit. It would also not reduce in-tunnel exposures to vehicle emissions. This option would introduce significant additional capital and operating costs. With respect to land acquisition and construction impacts, this option would have a greater impact than presented in the environmental impact statement for the project.

On the basis of this analysis, relocation of the northern ventilation outlet to the Asquith Industrial Estate is feasible, but not reasonable.

A screening level air quality impact assessment has identified that relocating the southern ventilation outlet into the Pennant Hills Golf Course, or land around the south west corner of the golf course, would reduce the air quality impacts of the project. However, slightly better improvements in air quality could be achieved by increasing the height of the ventilation outlet.

Relocation of the southern ventilation outlet would increase visual impacts through disaggregation and distribution of the built form. It would also require additional land acquisition, with potential flow on impacts with respect to the operation of the Pennant Hills Golf Course.

The relocation would increase engineering complexities, and increase construction related impacts.

On the basis of this analysis, relocation of the southern ventilation outlet to the Pennant Hills Golf Course (or adjacent land) would be feasible, but not reasonable.

Scenario 3 – Intermediate ventilation outlets

All intermediate ventilation outlet options would improve in-tunnel air quality. All options would also reduce ambient air quality impacts to varying degrees, and the associated human health risks. Broadly, the screening level assessment presented in this report indicates around a 20 per cent reduction in ambient air quality (particulate matter) impacts and human health risks with inclusion of a mid point ventilation outlet, and around 50 per cent reduction for conversion of the Trelawney Street and Wilson Road facilities. These predicted reductions are relative to already very low predicted impacts. It is recognised that these options would not reduce the total pollution load emitted by the project, but would redistribute it at a lower concentration across a larger population.

In terms of in-tunnel air quality, the installation of a mid point ventilation outlet would reduce maximum concentrations of in-tunnel pollutants by around 20 to 25 per cent. Conversion of the Wilson Road and Trelawney Street facilities would result in a reduction of around 50 to 70 per cent, depending on the pollutant, direction of travel and traffic forecast scenario (2019 or 2029).

A mid point ventilation outlet would introduce environmental and land use impacts that have not previously been contemplated, while conversion of the Wilson Road and Trelawney Street tunnel support facilities would increase environmental and land use impacts relative to those presented in the environmental impact statement. Based on submissions received in response to the public exhibition of the NorthConnex project, provision of intermediate ventilation outlets is unlikely to be received favourably by affected stakeholders.

Installation of intermediate ventilation outlets would require a fundamental redesign of the project, including construction and operational infrastructure, construction planning and urban design.

All intermediate ventilation outlet options would introduce moderate additional capital and operating costs. The ventilation design for a mid point ventilation outlet would introduce additional complexity into the ventilation design, particularly in relation to the introduction of additional air into the project tunnels to offset removal of in-tunnel air at the intermediate ventilation outlets, and management of ventilation flows within the tunnels around these points. Some additional ventilation design complex would also be associated with reconfiguration of the Wilson Road and Trelawney Street tunnel support facilities to include concurrent air intake and ventilation emissions.

Although these options would result in a relative decrease in in-tunnel and ambient exposures to vehicle emissions, these reductions are considered low in absolute terms. Given the introduction of other undesirable environmental and land use impacts, and engineering complexity, improvements in in-tunnel and ambient air quality associate with these options are not considered sufficient to offset their undesirable implications.

On the basis of this analysis, an intermediate ventilation outlet(s) would be feasible, but not reasonable.

Scenario 4 – Ventilation flow rates

Changes in ventilation design to include natural, fully transverse or semi-transverse ventilation are not feasible or reasonable.

The ventilation design criteria are comparable to or better than other road tunnels around the world, and there is therefore no reasonable justification for applying more stringent criteria or requiring addition ventilation capacity to be provided in the project design.

Changes in ventilation design and/ or ventilation design criteria are feasible, but not reasonable.

Scenario 5 – In-tunnel air treatment

Installation of particulate matter filtration plants would reduce the load of particulate matter in the main alignment tunnels, with a consequential reduction in ambient air quality impacts and associated human health risks. The reductions in ambient air quality impacts and human health risks are comparable to the improvements identified for other options, including the addition of intermediate ventilation outlets and increases in ventilation outlet height. These other options would, however, not improve in-tunnel air quality (as would be the case with the installation of particulate matter filtration plants).

Based on the analysis presented in this report, assuming that the particular matter removal efficiencies assumed would be achieved in practice, a reduction in particulate matter load at the ventilation offtakes of around 40 per cent could be achieved (ie a reduction to around 60 per cent of the particulate matter load that would be experienced if filtration technology were not installed). This reduction in particulate matter in the project tunnels is slightly better than with the installation of a mid point ventilation outlet (around 20 to 25 per cent reduction at the end of the project tunnels) and not quite as good as conversion of the Wilson Road and Trelawney Street site to ventilation outlets (around 50 to 70 per cent at the end of the project tunnels). Relevantly, in-tunnel filtration technology would only address particulate matter concentrations, rather than the full suite of pollutants that would be reduced with the installation of intermediate ventilation outlets. Based on in-tunnel air quality alone, this would suggest that an intermediate ventilation outlet may be preferable to in-tunnel filtration if the key intended outcome is a significant improvement in in-tunnel air quality. Other factors, including engineering practicality, cost and other environmental and land use impacts would however need to be factored into this consideration.

In-tunnel particulate matter filtration would increase some environmental impacts, including in relation to waste generation and waste water management/ treatment. The increased scale of surface infrastructure would increase the bulk of proposed tunnel support facilities, with some increases in visual impacts. The higher energy consumption would increase indirect greenhouse gas impacts and may increase air quality impacts at the generation source (depending on decision about the purchase of electricity). Compared with other ventilation design options that are anticipated to generated better in-tunnel and ambient air quality outcomes, installation of in-tunnel filtration is relatively costly both from an capital and operating expenditure perspective. As noted above, equivalent or better in-tunnel and ambient air quality outcomes may be achievable with one or more other ventilation design options (other than in-tunnel filtration) at lower cost and engineering complexity.

Additional engineering complexity would be introduced with the installation of in-tunnel filtration, particularly in terms of ventilation design and management. Electricity supply and wastewater management would be new components that would need to be accommodated within the project design.

In-tunnel particulate matter filtration would add significant additional capital and operating costs to the project.

In summary:

- Other ventilation design options would result in greater reductions in air quality and human health risks at significantly lower capital and operating cost.
- In-tunnel particulate matter filtration would reduce part of the load of in-tunnel vehicle emissions (ie only particulate matter, with other pollutants unaffected)
- The in-tunnel air quality criteria applied to the design of the project, which are comparable to best practice adopted and accepted elsewhere in Australia and throughout the world, would be achieved without particulate matter filtration. Therefore since the conventional ventilation system is effective, the benefit of providing an in-tunnel filtration system is considered negligible.
- If in-tunnel air quality levels could not be achieved with the proposed ventilation system, the most effective engineering solution would be the introduction of additional ventilation outlets and additional air supply. This is a proven solution, more sustainable and reliable than tunnel filtration systems. These alternatives would also be a more cost effective approach.

On the basis of this analysis, installation of particulate matter filtration would be feasible, but not reasonable.

4 Clarifications – Other issues

This chapter includes clarifications of issues other than in relation to air quality and ventilation system design, which have been addressed in **Chapter 2** and **Chapter 3** of this report, respectively.

The clarifications presented in this chapter relate to:

Project scope and design

- Use of generators to power road headers during the initial stages of construction before connection to main power supply (refer to **Section 4.1**).
- Location of the ventilation offtake from the southbound main alignment tunnel to the southern ventilation outlet (refer to **Section 4.2**).
- Use of the Darling Mills Creek construction compound (C2) for the temporary storage of construction materials (refer to **Section 4.3**).

Noise and vibration

- Operational noise barriers at the southern interchange near Coral Tree Drive (refer to **Section 4.4**).
- Construction noise mitigation and management measures (refer to **Section 4.5**).

4.1 Use of generators to power road headers prior to mains power connection

4.1.1 Description

The environmental impact statement discusses the power supply for road headers during the construction period in two principal locations:

- The construction air quality assessment in Section 7.3 of the environmental impact statement and the Technical Working Paper: Air Quality (Appendix G of the environmental impact statement) identify that '*road headers would be driven by mains power supply and would therefore not generate exhaust emissions*'.
- The project description in Section 5.3 of the environmental impact statement identifies that '*prior to the connection of mains power supply to the tunnel support sites, road headers would be powered by diesel generators*'.

To clarify this issue, the road headers would be powered by diesel generators prior to the connection of main power supply (ie before the mains supply for the construction plant and equipment is fully available). The approval through the relevant power supply authority and the construction of the power supply routes to the construction compounds would not be completed prior to the commencement of tunnelling works.

As such, there may be a period of construction where the power requirements for road headers would contribute to exhaust emissions. For the majority of the construction period, however, the road headers would be powered by mains power and would not generate exhaust emissions.

Diesel generators (four 1.25 MVA generators) powering the road headers would be used at:

- Southern interchange compound (C5).
- Northern interchange compound (C9).

There is also potential for generators to be required at the Wilson Road compound (C6) and the Trelawney Street compound (C7). However, at this stage project programming indicates that mains electricity supply may be available at these sites prior to the operation of road headers, in which case generators would not be required.

These generators would be located within the acoustic sheds at the four compounds to mitigate potential noise generation.

4.1.2 Environmental assessment

Potential construction air quality impacts have been assessed qualitatively in the environmental impact statement through a description of the proposed works, identification of plant and equipment and potential emissions sources. Proactive and reactive mitigation measures have been identified to reduce the potential for adverse impacts to local air quality and sensitive receivers.

The assessment has considered the potential for exhaust emissions from diesel powered plant and equipment and has identified a range of environmental management measures in order to reduce these potential impacts. These management measures would be also applied to the use of diesel generators to power the road headers before connection to mains power supply.

In addition to exhaust emissions, the use of diesel generators also has the potential to contribute to construction noise levels. The noise contributions from the use of diesel generators would be minor in the context of other noise sources during the early stages of construction and are not anticipated to increase predicted construction noise impacts beyond the levels presented in the environmental impact statement. Appropriate measures would be implemented such as acoustic screening of the generators to comply with the construction noise levels as described in section 7.2 of the environmental impact statement.

4.2 Southern ventilation offtake

4.2.1 Description

Submissions in response to the exhibition of the environmental impact statement and feedback received during community consultation have sought information on the location of the southern ventilation offtake. These submissions and feedback have identified that the ventilation offtake is not shown in figures in the environmental impact statement.

The ventilation offtake is a separate tunnel used to transport the in-tunnel air from the main alignment tunnel to the ventilation facility located at the southern end of the motorway operations complex.

The location of the ventilation offtake is shown in **Figure 4-1**. The ventilation offtake is around 150 metres long. The offtake is a separate tunnel used to transport the air and emissions from the southbound tunnel to the ventilation outlet located in the motorway operations complex. The large axial fans at the ventilation outlet draw the air from the project tunnels along the offtake tunnel. Similar arrangements are in place for tunnels like the Cross City Tunnel and Lane Cove Tunnel.

4.2.2 Environmental assessment

This clarification does not alter the environmental assessment or predicted impacts, as presented in the environmental impact statement.

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Figure 4-1 Southern ventilation off-take location

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4.3 Storage of materials at the Darling Mills Creek construction compound (C2)

4.3.1 Description

The Darling Mills Creek construction compound (C2) is described in the environmental impact statement as consisting of basic workforce amenities. These amenities would include toilets and a lunch room.

Ongoing design refinement and construction planning has identified the need for storage of construction materials at the Darling Mills Creek compound. Construction materials are to be securely stored under the bridge in the general vicinity of the workforce amenities. A revised indicated construction site layout for the Darling Mills Creek compound is shown in **Figure 4-2** (under the bridge across Darling Mills Creek).

4.3.2 Environmental assessment

This clarification does not alter the environmental assessment or predicted impacts, as presented in the environmental impact statement.

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Figure 4-2 Indicative Darling Mills Creek viaduct construction compound revised layout

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4.4 Positioning of noise barriers near Coral Tree Drive

4.4.1 Description

The operational noise impact assessment presented in Section 7.2 and Appendix F of the environmental impact statement was undertaken based on the height of existing noise barriers.

As part of the operational noise assessment, a noise barrier analysis was conducted. This analysis considered whether it was be feasible and reasonable to increase the height of existing noise barriers relative to their surveyed reduced level height, and the potential benefits of doing so based on anticipated road traffic noise levels at adjacent receiver locations.

The noise barrier analysis identified that the existing noise barrier located adjacent to the southern side of the Hills M2 Motorway and running parallel to Coral Tree Drive (NWM2WB08) should be maintained at its current height. This would result in maintaining a noise barrier in this location which is currently around 3.6 metres to six metres in height (above existing ground level).

In the vicinity of the noise barrier near Coral Tree Drive (NWM2WB08), the following works are required:

- Moving the existing on-ramp slightly to the north in order to facilitate the new motorway to motorway connection from the NorthConnex southbound tunnel to the Hills M2 Motorway westbound carriageway. The existing on-ramp from Pennant Hills Road would generally maintain its same elevation.
- A new tunnel portal and the NorthConnex southbound carriageway connecting to the Hills M2 Motorway westbound carriageway.

Due to the south to westbound motorway connection emerging from underground, there would be a significant change in elevation of the roadway in this location. The works in this area would require the existing ground level to be lowered.

The change in ground level in this area would mean that in order to maintain the height of the existing noise barrier (consistent with the reduced level of the top of the noise barrier), a new noise barrier would need to be installed at a height of more than 15 metres above the new lower ground level. A new noise barrier of this height is not considered feasible or reasonable, and would be likely to result in other impacts which are not desirable such as significant overshadowing, visual amenity implications and construction impacts to nearby receivers.

To resolve this issue, further consideration has been given to available feasible and reasonable noise mitigation measures for receivers in this location (along Coral Tree Drive). This has included further analysis of feasible and reasonable noise barrier heights, and consideration of eligibility for at-property acoustic treatments where relevant.

The assessment of feasible and reasonable noise barrier heights is provided in **Section 4.4.2** below. The assessment concludes that the following noise barriers should be provided:

- A six metre high noise barrier (NWM2WB08 North) on the re-aligned Pennant Hills Road to Hills M2 Motorway on-ramp.
- A new five-metre high noise barrier (NWM2WB08 South) adjacent to the on-ramp connecting the NorthConnex southbound tunnel to the Hills M2 Motorway westbound carriageway.

The assessment also identifies six properties eligible for consideration of at-property acoustic treatments. These properties are in addition to those already identified as eligible in the environmental impact statement. This is a preliminary assessment based on the current design of the project at this location. During detailed design, further work would be conducted to identify potential additional meaures or alternatives to mitigate or avoid elevate noise impacts for the receivers along Coral Tree Drive

The locations of the re-alignment and new noise barriers, and the additional properties eligible for consideration of at-property acoustic treatments are shown in **Figure 4-7**.

4.4.2 Environmental assessment

Further assessment of potential noise mitigation measures, including noise barriers and potential at-property acoustic treatments, has been carried out for residential receivers around Coral Tree Drive in noise catchment area NCA10.

A comparison of noise reductions for a range of noise barrier heights has been carried out for noise barrier NWM2WB08, located adjacent to the Hills M2 Motorway and parallel to Coral Tree Drive. Separate assessments have been considered for the barrier on the realigned Pennant Hills Road on-ramp (NWM2WB08 North) and the new barrier adjacent to the on-ramp connecting the NorthConnex southbound tunnel to the Hills M2 Motorway westbound carriageway (NWM2WB08 South). The assessment has been conducted for the design year (2029).

NWM2WB08 North

Figure 4-3 shows the relationship between potential noise barrier height and reductions in road traffic noise (insertion loss) as well as predicted exceedance of the road traffic noise criterion at adjacent residential receivers.

Figure 4-4 shows the maximum insertion loss at any receiver and the maximum sound pressure level at any receiver. Over the varying barrier heights the specific receiver may not be the same, hence the decrease in insertion loss is not necessarily consistent with the maximum noise level.

The Environmental Noise Management Manual (RTA, 2001) requires assessment of noise barriers as follows:

- Identification of a 'target barrier', being the noise barrier which achieves compliance with applicable road traffic noise criteria at all receivers.
- Where the 'target barrier' is not feasible and/ or reasonable, identification of an 'assessed barrier', being the noise barrier which achieves the lowest feasible and reasonable road traffic noise levels at affected receivers. For an 'assessed barrier' to be considered reasonable, it must:
  - For noise barriers that are less than five metres high, have a minimum insertion loss (reduction in noise across the noise barrier) of around 5 dB(A) to be considered reasonable.
  - For noise barriers that are equal to or greater than five metres high, have a minimum insertion loss of around 10 dB(A) to be considered reasonable.

Notwithstanding the approach summarised above, Roads and Maritime has adopted a policy of not reducing the height of existing noise barriers, even if the target barrier and/ or the assessed barrier are less than the height of the existing barrier.

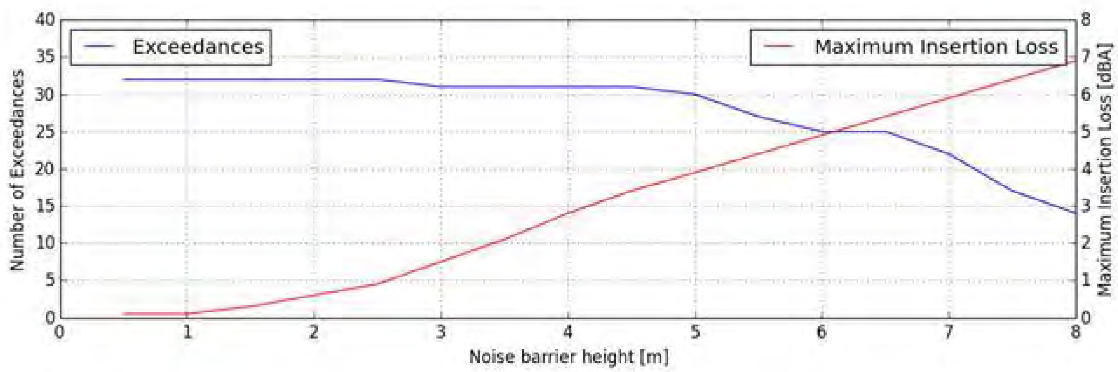

Figure 4-3 **Maximum insertion loss and criterion exceedance as a function of noise barrier height (NWM2WB08 North)**

Figure 4-3 shows that the 'target barrier' height is greater than eight metres (the point where exceedances of the applicable road traffic noise criteria fall to zero). The Environmental Noise Management Manual specifies that noise barriers greater than eight metres in height are not considered visually acceptable. Therefore, there is no feasible and reasonable target barrier for NWM2WB08 North.

In terms of a potential 'assessed barrier', **Figure 4-3** shows that:

- A 5 dB(A) insertion loss is achieved with a noise barrier height of around six metres.
- A 10 dB(A) insertion loss is achieved with a noise barrier height greater than eight metres.

At this location, a noise barrier would ordinarily not be considered viable based on the Environmental Noise Management Manual. However, considering a noise barrier currently exists in this location, Roads and Maritime policy is to provide a replacement barrier. Based on this policy, a noise barrier of six metres is considered viable at it meets the minimum insertion loss of 5 dB(A).

Potential noise barrier heights have also been assessed for reasonableness based on:

- Total noise benefit (TNB) – being the sum of the decibel reductions achieved (taking account of all road traffic noise sources) at all residential and other noise sensitive receivers.
- Total benefit per unit barrier area (TNBA) – being the 'total noise benefit' divided by the total area of the noise barrier.
- Marginal benefit value (MBV) – for a particular noise barrier height being the increase in total noise benefit (TNB) divided by the increase in the barrier height or area.

For this location, **Figure 4-4** illustrates the benefits of different noise barrier heights in terms of total noise benefit (TNB), total benefit per unit barrier area (TNBA) and marginal benefit value (MBV).

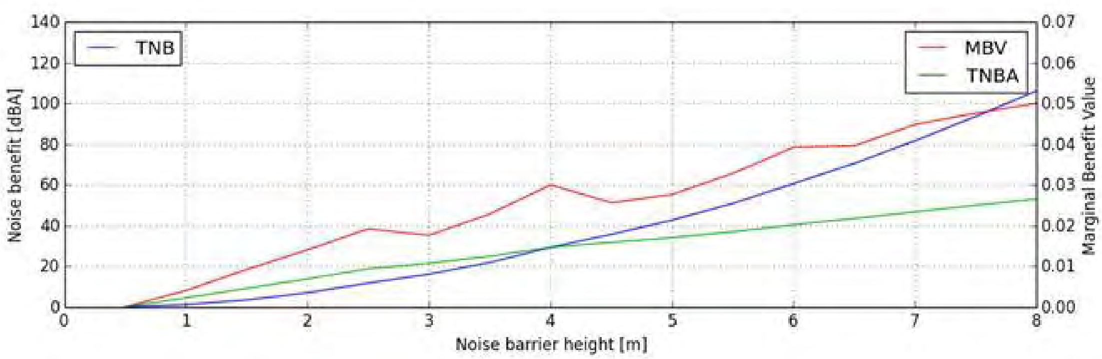

Figure 4-4 Potential noise benefits as a function of noise barrier height (NWM2WB08 North)

As shown in **Figure 4-4**, the marginal benefit value peaks at around four metres, then again at six metres and continues to rise beyond eight metres, while the total noise benefit per unit barrier area peaks at greater than eight metres. Of these values:

- A noise barrier greater than eight metres in high is not considered visually acceptable, and is therefore not considered reasonable.
- As identified above, a noise barrier five metres in height would not achieve the minimum insertion loss of 5 dB(A) specified by the Environmental Noise Management Manual.
- A noise barrier of six metres in height would achieve an insertion loss of 5 dB(A). Due to the unique circumstances of this noise barrier being a replacement for an existing barrier, a six metre barrier is considered to be appropriate.

Because there is no reasonable 'target barrier', the 'assessed barrier' with a height of six metres has been recommended for noise barrier NWM2WB08 North.

NWM2WB08 South

Figure 4-5 shows the relationship between potential noise barrier height and reductions in road traffic noise (insertion loss) as well as predicted exceedance of the road traffic noise criterion at adjacent residential receivers.

Figure 4-5 shows the maximum insertion loss at any receiver and the maximum sound pressure level at any receiver. Over the varying barrier heights the specific receiver may not be the same, hence the decrease in insertion loss is not necessarily consistent with the maximum noise level.

The Environmental Noise Management Manual (RTA, 2001) requires assessment of noise barriers as follows:

- Identification of a 'target barrier', being the noise barrier which achieves compliance with applicable road traffic noise criteria at all receivers.
- Where the 'target barrier' is not feasible and/ or reasonable, identification of an 'assessed barrier', being the noise barrier which achieves the lowest feasible and reasonable road traffic noise levels at affected receivers. For an 'assessed barrier' to be considered reasonable, it must:
  - For noise barriers that are less than five metres high, have a minimum insertion loss (reduction in noise across the noise barrier) of around 5 dB(A) to be considered reasonable.
  - For noise barriers that are equal to or greater than five metres high, have a minimum insertion loss of around 10 dB(A) to be considered reasonable.

Notwithstanding the approach summarised above, Roads and Maritime has adopted a policy of not reducing the height of existing noise barriers, even if the target barrier and/ or the assessed barrier are less than the height of the existing barrier.

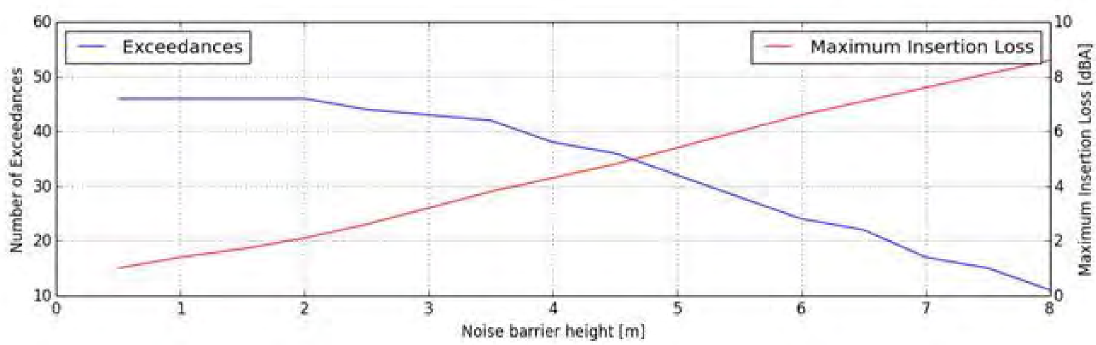

Figure 4-5 Maximum insertion loss and criterion exceedance as a function of noise barrier height (NWM2WB08 South)

Figure 4-5 shows that the 'target barrier' height is greater than eight metres (the point where exceedances of the applicable road traffic noise criteria fall to zero). The Environmental Noise Management Manual specifies that noise barriers greater than eight metres in height are not considered visually acceptable. Therefore, there is no feasible and reasonable target barrier for NWM2WB08 South.

In terms of a potential 'assessed barrier', **Figure 4-5** shows that:

- A 5 dB(A) insertion loss is achieved with a noise barrier height of around 4.5 metres.
- A 10 dB(A) insertion loss is achieved with a noise barrier height greater than eight metres.

At this location, a noise barrier around 4.5 metres to five metres high is therefore considered to be a viable 'assessed barrier' because it achieves the insertion loss required by the Environmental Noise Management Manual. A higher noise barrier (above five metres) is not considered viable because in order to achieve the insertion loss specified by the Environmental Noise Management Manual, the noise barrier would need to be eight metres in height, which is not considered visually acceptable.

Potential noise barrier heights have also been assessed for reasonableness based on:

- Total noise benefit (TNB) – being the sum of the decibel reductions achieved (taking account of all road traffic noise sources) at all residential and other noise sensitive receivers.
- Total benefit per unit barrier area (TNBA) – being the 'total noise benefit' divided by the total area of the noise barrier.
- Marginal benefit value (MBV) – for a particular noise barrier height being the increase in total noise benefit (TNB) divided by the increase in the barrier height or area.

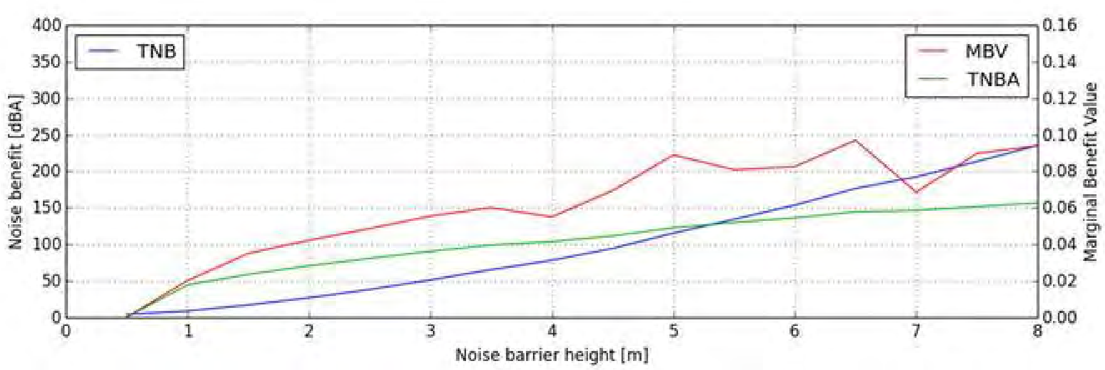

Figure 4-6 **Potential noise benefits as a function of noise barrier height (NWM2WB08 South)**

As shown in **Figure 4-6**, the marginal benefit value peaks at around five metres and around 6.5 metres, while the total noise benefit per unit barrier area peaks at greater than eight metres. Of these values:

- A noise barrier greater than eight metres in high is considered visually acceptable, and is therefore not considered reasonable.
- A noise barrier 6.5 metres in height does not achieve the minimum insertion loss of 10 dB(A) specified by the Environmental Noise Management Manual, and is therefore not considered reasonable.
- A noise barrier five metres in height would achieve the minimum insertion loss of 5 dB(A) specified by the Environmental Noise Management Manual. A noise barrier five metres in height is therefore considered to be reasonable and the 'assessed barrier' for (NWM2WB08 South).

Because there is no reasonable 'target barrier', the 'assessed barrier' with a height of five metres has been recommended for noise barrier NWM2WB08 South.

At-property acoustic treatment

Based on the consideration of noise barriers above, there is no combination of 'target barriers' in this location which would result in all receivers achieving compliance with the applicable traffic noise criteria. As such, further consideration has been given to the properties at this location eligible for consideration of at-property treatment. This assessment for both daytime and night-time noise levels is provided **Table 4-33** and **Table 4-34** respectively.

This assessment has identified an additional six properties which are eligible for consideration of at-property acoustic treatment. These properties are identified in **Figure 4-7**. It is noted that this assessment is based on the preferred tender design. Further consideration would be given to feasible and reasonable operational noise mitigation measures based on the detailed design of the project.

Additional considerations

By incorporating a six metre high noise barrier for the northern location and a five metre high noise barrier for the southern location noise levels would generally not appreciably increase from existing noise levels for nearby receivers. However there are six residual receivers that are predicted to experience noise level increases of more than 2 dB(A) as a result of the project. Noise levels at these receivers are predicted to increase by up to 3.1 dB(A) with the proposed design. The noise assessment above has shown that noise barriers greater than eight metres in height would be required to eliminate this noise increase via conventional means. Noise barriers of such a significant height are generally considered to be not feasible or reasonable due to the unacceptable visual impacts.

Extensive investigations have been undertaken by others into providing different capping formations on the top of noise barriers to improve the noise reduction performance. There have been many different configurations in noise barrier capping, however they reduce noise using the same mechanisms. The noise insertion loss is improved by affecting the diffraction path over the top of the barrier and sometimes providing additional absorption at the point of diffraction. While reductions of 5 dB(A) and greater have been reported in some instances, it is more likely that reductions of 1 dB(A) to 2 dB(A) would be achievable.

In this context, providing capping on the northern barrier adjacent to Coral Tree Drive has the potential to further reduce the predicted noise levels from the project. Further investigations should be undertaken at the detailed design stage of the project to ensure that all feasible and reasonable noise mitigation is provided to minimise the noise impact on receivers located on Coral Tree Drive.