Potential Ventilation System Modifications
CoA B5 Report

NorthConnex Project

Lendlease Bouygues Joint Venture

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Appendices

Terms and Definitions

Term	Definition
BYCA	Bouygues Construction Australia Pty
Client	NorthConnex Project Company and NorthConnex State Works Contractor (together the Project Company Group) under the NorthConnex D&C Deed; The Hills Motorway Limited under the M2 Integration D&C Deed.
D&C	Design and Construction
Deed	As appropriate to the defined scope of the NorthConnex D&C Deed OR the M2 Integration D&C Deed
IC	Independent Certifier – APP Corporation Pty Limited engaged in accordance with either the NCX or M2I Independent Certifier Deeds.
IFC	Issued For Construction
LLBJV	Lend Lease Bouygues Joint Venture (Contractor)
LLEMS	Lend Lease Engineering Management System
M2I	M2 Integration
NCX	NorthConnex
NSW	New South Wales
NWRL	North west Rail Link
PCU	Passenger Car Unit – a standard, consistent basis for accounting for the amount of road space taken up by different size vehicles.
Piston effect	Air flow in a tunnel that is generated by, and in the direction of, moving vehicles.
PMP	Project Management Plan
PMS	Project Management System
Project	NorthConnex and M2 Integration Projects
Project Company	NorthConnex Company Pty Ltd, which acts on behalf of the Client's under both the NCX D&C Deed and the M2I D&C Deed.
Project Company Group	NorthConnex Company Pty Ltd (Project Company) and NorthConnex State Works Contractor Pty Ltd
QP	Quality Plan
Sub IC	Sub Independent Certifier - APP Corporation Pty Limited engaged in accordance with either the NCX OR M2I Sub Deed of Appointment of Independent Certifier.
SWTC	As appropriate to the defined scope of the Scope of Works & Technical Criteria defined as Exhibit A under the individual NorthConnex D&C Deed OR the M2 Integration D&C Deed

Executive Summary

The NorthConnex Project is a State significant infrastructure and critical State significant infrastructure project (SSI 6136) for which project approval was granted by the Minister for Planning on 13 Jan 2015. The approval is subject to a number of conditions. Condition of Approval B5 requires the following:

"The tunnel shall be designed and constructed so as to allow for potential future modification of the ventilation system if required. The proponent shall demonstrate by the production of a report, to the satisfaction of the Secretary, how this will be allowed for prior to finalising detailed design."

This Report has been prepared to identify the potential modifications that could be implemented in the future in the event that there are systemic exceedances of the air quality criteria required in the Conditions of Approval. Any modifications of the ventilation system may be triggered by Condition of Approval E6 and Condition of Approval E9

The tunnel ventilation system is designed to internationally recognised tunnel ventilation standards, namely PIARC for traffic density and throughput, with predicted vehicle emissions applicable to Australia, PIARC 'Road Tunnels: Vehicle Emissions and Air Demand for Ventilation' (2012R05EN). The design data exceeds by a considerable margin, approximately double, the predicted 2019 traffic volumes contained in the NorthConnex EIS.

It is unlikely that the design criteria adopted for the tunnel ventilation system will be exceeded during tunnel operations. However, in that unlikely event that the in-tunnel air quality or outlet air quality is systemically exceeded, larger capacity fans or additional jet fans in the tunnel carriageways, could be installed. This may require larger capacity axial fans installed at the outlets to provide better air quality.

In-tunnel air quality could be further improved by conversion of the emergency smoke outlets at Wilson Road and Trelawney Street to tunnel ventilation outlets, thereby providing a capability to extract air and simultaneously supplying fresh ambient air to the tunnel. This conversion of the emergency smoke outlets to permanent ventilation outlets would require an additional or Modified Environmental Approval.

Alternatively, if these measures are unable to address specific pollutants, such as particulate matter causing exceedances of the visibility criteria, or NO_2 concentrations leading to exceedances, then consideration could be given to provision of in-tunnel filtration, or provision of outlet filtration depending on the specific pollutants to be addressed. This modification to provide additional infrastructure to create the filtration systems would require an additional or Modified Environmental Approval.

The ventilation system as designed is consistent with the ventilation system as described in the EIS and further elaborated in the SPIR. The ventilation system, as designed, does not preclude any of the potential modification options identified in this Report

1. Introduction

1.1. Background

In March 2012, the NSW Government received an unsolicited proposal from Transurban to design, construct, operate, maintain and finance a tolled motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at West Pennant Hills in northern Sydney. The Westlink M7 Shareholders later joined Transurban to form a consortium to finance the Project.

On 25 October 2013, the NorthConnex Project was declared, by Ministerial Order, to be State significant infrastructure and critical State significant infrastructure under sections 115U (4) and 115V of the *Environmental Planning and Assessment Act 1997* (EP&A Act). The Order also amended Schedule 5 of State Environmental Planning Policy (State and Regional Development) 2011.

An Environmental Impact Statement (EIS) (AECOM July 2014) was then prepared and placed on public exhibition for 60 days between July and September 2014. Following consideration of submissions made during the EIS exhibition period, the Submissions and Preferred Infrastructure Report (SPIR) was then submitted to the Minister for Planning. Under Part 5.1 of the EP&A Act, approval of the NorthConnex Project was granted on 13 January 2015.

The NorthConnex Project involves the construction of a multi-lane motorway linking the M1 Pacific Motorway at Wahroonga to the Hills M2 Motorway at West Pennant Hills, including integration works with the Hills M2 Motorway (the Project).

The Lend Lease Bouygues Joint Venture (LLBJV) has been awarded the contract to design, construct, and commission the NorthConnex Project.

1.2. Report Authors

This Report has been prepared jointly by Bernard Connell, Senior Design Manager, Civil and Surface Works and Trent Murrihy, Design Manager, Mechanical and Electrical Services, of LendLease Bouygues Joint Venture.

Both authors are highly experienced and technical experts in their respective fields.

1.3. Purpose of this Report

This report shall be used to demonstrate the manner in which future modifications to the NorthConnex tunnel ventilation can be designed such that the tunnel and tunnel ventilation system could be modified in the future, should there be systemic failures of the ventilation system.

The requirements of Condition of Approval B5 apply to the State significant infrastructure project that is approved, that is a twin tube two lane tunnel with shoulders.

This Report does not consider the ventilation requirements that may be required for a future three lane configuration, if and when that conversion occurs. The future three lane configuration of the tunnel, and its associated air quality would be subject to a separate Environmental Planning Assessment and approval process at that time. Similarly, no assessment is undertaken of ventilation requirements for a connection to the Hills M2 Motorway east of Pennant Hills Road. When adopted at some stage in the future, this will be subject to a separate Environmental Planning Assessment and approval process at that time.

The intention of CoA B5 can be ascertained from the Secretary's Environmental Assessment Report, Jan 2015. The Executive Summary of this report states:

"The Department has also recommended a condition that requires the Proponent to demonstrate how the tunnel ventilation system could be modified in the future should it be required. These modifications could include installation and operation of additional fans, air intakes, conversion of the Wilson Road and Trelawney Street emergency smoke extraction facilities to ventilation outlets, or filtration."

The Department has further advised that the intent of the Condition is not to preclude technically feasible potential future modifications.

The structure of the Report is as follows:

i. Consideration of what are systemic exceedances of the air quality criteria, and how they could arise;
ii. An outline of the NorthConnex tunnel ventilation concept design and system usage for tunnel jet fans, outlet axial fans, and intermediate inlet axial fans;
iii. The operational traffic management and enforcement provisions to assist in-tunnel air quality;
iv. Identification of any constraints that would be infeasible or unreasonable to change;
v. Modification Concepts that are potentially available, and an assessment of each concept as to meeting the objectives stated in the Secretary's Assessment Report to meet a 'readily rectified' criterion;
vi. The guideline principles on prioritising the adoption of any modifications required; and
vii. Identification of Potential Modifications.

1.4. Summary of the EIS and SPIR Assessments

The EIS provided a Technical Paper specific to the issue of in-tunnel air quality, outlet air quality, and ambient air quality impacts arising from the ventilation outlets. This Paper is contained in Appendix G of the EIS. The assessment was further clarified in Section 2 of the SPIR (page 47 et seq).

The key issues relating to the tunnel ventilation system can be grouped as:

- Vehicle emissions
- Air quality;
- Traffic predictions at Motorway opening 2019, and after 10 years (2029); and
- Ventilation System Design Criteria.

Vehicle Emissions

The SPIR (Section 2.8, page 129 et seq) outlines further and clarifies adjustments made to the emissions inventories.

A key point is that the predicted percentage ratio of heavy vehicles declines between motorway opening in 2019 and the future 10 year growth in 2029. The rise in vehicles is predominantly both petrol and diesel fuelled light vehicles. Overall vehicle numbers though will increase.

Table 2-17 Summary of fuel type (2019)

Vehicle type	Petrol	Diesel
Cars	85.1%	14.9%
Light duty vehicles	34.4%	65.6%
Heavy vehicles	5.1%	94.9%

Table 2-18 Summary of fuel type (2029)

Vehicle type	Petrol	Diesel
Cars	77.1%	22.9%
Light duty vehicles	20.8%	79.2%
Heavy vehicles	2.6%	97.4%

Air Quality

The in-tunnel air quality is directly affected by the ambient air drawn into the tunnel, either by the piston effect created by the vehicles or by air drawn in by the jet fans. The ambient air quality assumed in the EIS modelling has been confirmed in the SPIR as a 'conservative case". As noted in Section 2.11.1 - '*Where the major road air quality modelling results were higher than background air quality data, the modelled air quality results were applied rather than the background air quality data from monitoring stations".*

Traffic Predictions

Traffic predictions at both 2019 (Motorway Opening) and after 10 years (2029) were presented in graphical form for both light vehicles and heavy vehicles in Section 2.7 of the SPIR. As expected, the traffic volumes vary over the daily 24 hour period, and have similar but different value peaks for each direction.

In 2019 the AM peak is approximately 1790 PCU southbound out of the 23,100 PCU daily, and the PM peak is approximately 1930 PCU northbound out of the 22,900 PCU daily. In 2029, the AM peak is predicted to be approximately 2300 PCU southbound out of the 29,400 PCU daily, with the PM peak predicted to be approximately 2360 PCU northbound out of the 28,950 PCU daily.

These traffic predictions show a predicted 2029 peak volume of 2360 PCU northbound which is substantially less than the design criteria of 4000 PCU.

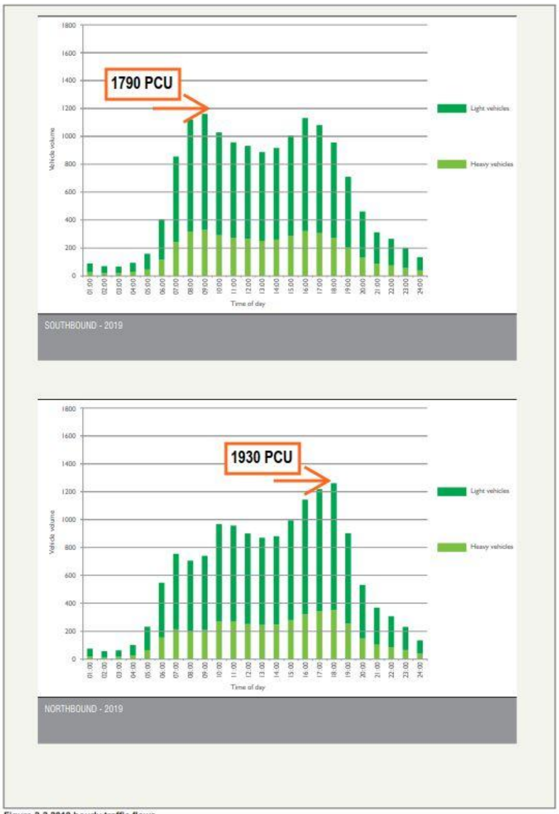


Figure 2-2 2019 hourly traffic flows

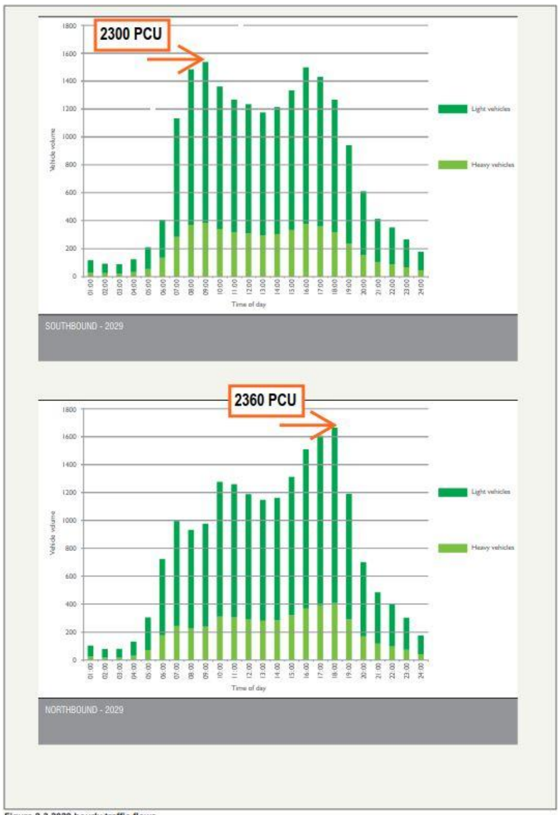


Figure 2-3 2029 hourly traffic flows

As noted on discussion of the Design Analysis A in the SPIR (page 124), the actual traffic forecasts would require *"..the triggers that may lead to this level of variance in traffic volumes (demography, land use, major additions to the road network, traffic generating developments) are not expected within the timeframes considered as part of the assessment of the project."*

Ventilation System Design Criteria

The EIS undertook an assessment of the ventilation system based on the maximum theoretical vehicle capacity throughput of the mainline tunnels. As outlined in Section 8.11 of the SPIR (page 1021 et seq) "*To provide confidence about the performance of the project in the event that actual traffic demand exceeds the forecasts in the future, the air quality impact assessment also considers 'Design Analysis A'. This design analaysis is based on the project operating at the maximum theoretical capacity during the peak hour (4000 passenger car units). Design Analysis A therefore represents a credible upper limit to the potential operation of the project. Although it is considered unlikely that design analysis A would eventuate in reality, based on traffic forecasting, it provides a 'worst-case scenario for the purpose of assessment of potential air quality impacts. The environmental impact statement demonstrates that design analysis A would meet applicable air quality criteria."*

That is 4000 pcu/hour at 60km/hr, and this is irrespective of actual traffic volumes. This is known as Design Analysis A, and is summarised in the SPIR (page 128) and illustrated in Fig 2-5. An annotated version is included in this Report:

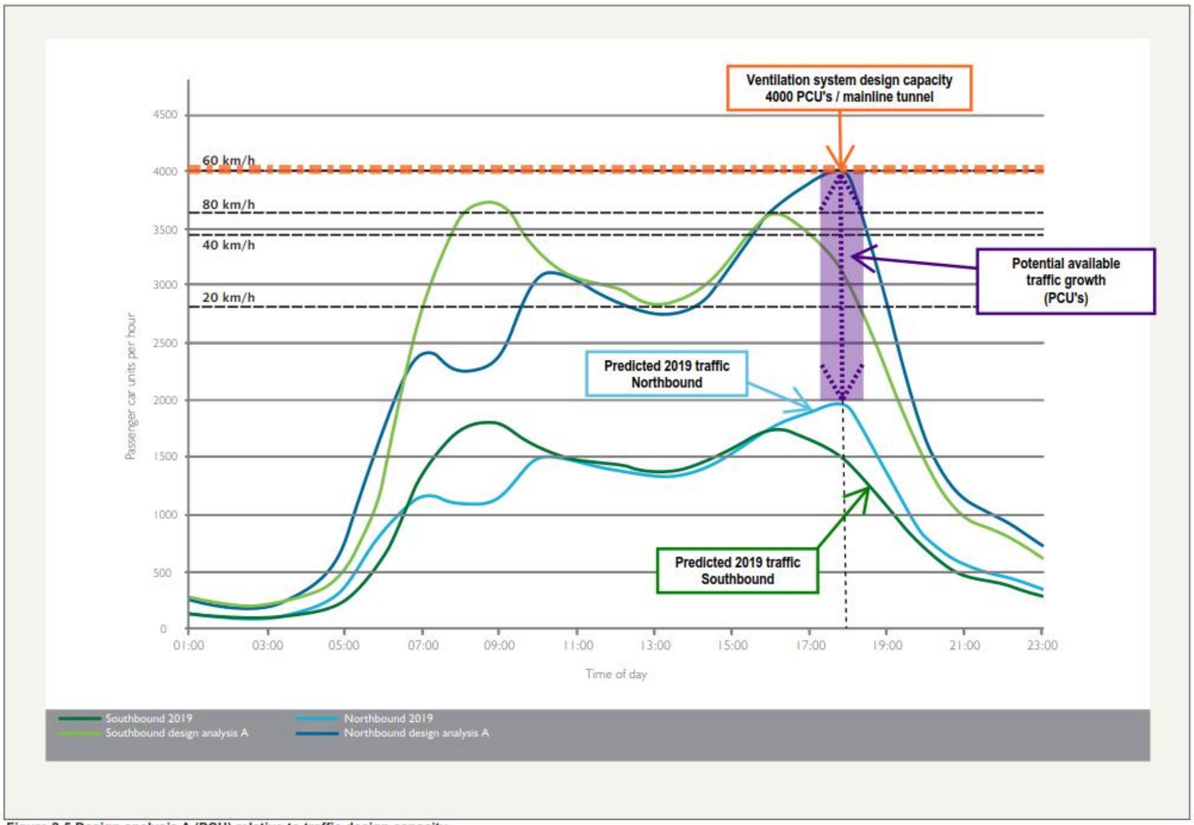


Figure 2-5 Design analysis A (PCU) relative to traffic design capacity

Report by the Advisory Committee on Tunnel Air Quality, NSW

The Secretary, Department of Planning & Environment requested the Chief Scientist and Engineer (as Chair of the Advisory Committee on Tunnel Air Quality - ACTAQ) for the ACTAQ to provide advice on the appropriateness of the air quality modelling and predicted air quality outcomes contained in the EIS for the NorthConnex Project. The Final Review Report was provided to the Secretary 04 December 2014.

The review was conducted by Dr Ian Longley, National Institute of Water and Atmospheric Research, Auckland,, New Zealand and Professor Peter Sturm, Graz University of Technology, Austria. Dr Longley is an Independent Expert for the ACTAQ. Dr Sturm is a Technical Advisor to the ACTAQ.

The main findings of the review of the EIS and SPIR are as follows:

i. The description of how in-tunnel air quality is assessed and maintained is now consistent and clear;
ii. The ventilation design incorporates sufficient spare capacity to provide the operators with sufficient flexibility to meet in-tunnel exposure standards.

2. Systemic Exceedances of Tunnel Ventilation Requirements

The tunnel ventilation system has been designed on a set of criteria and standards that provide a robust and integrated systems design. It incorporates a comprehensive integrated method of automatically sensing traffic flows and speed, a number of in-tunnel air monitoring system points, and automatic adjustment of tunnel jet fans to maintain the required air flow to provide the specified in-tunnel air quality.

Maximum vehicle volumes are a 60kmph traffic volume of 4000 PCU / hr / 2-lane tunnel carriageway. As traffic speeds decrease the vehicle volumes per unit of time decrease so that 20kmph traffic volume is 2838 PCU / hr / 2 lane carriageway.

As demonstration of system compliance with the stipulated air quality goals, the tunnel ventilation system air quality is required to be monitored, and any exceedances of the air quality criteria are to be notified within 24 hours. The requirements on Notification and Reporting of In-Tunnel Air Quality are detailed in Condition E5 and E6.

Similar monitoring, notification and reporting are required for the ventilation outlets as detailed in Condition E10 and E13. Note, Condition E12 requires that the ventilation outlet limits be reviewed every 5 years, and the current approved limits may be lowered (made more stringent) if there are improvements in vehicle fleet emissions.

Ambient air quality goals are detailed in Condition E8, with notification and reporting requirements detailed in Condition E9.

When notified of exceedances the Secretary, DoPE, shall consider the circumstances of the event, including:

i. The nature of the event, including details relating to the cause
ii. The duration of the event;
iii. The extent and severity of the event
iv. The frequency of the event, including whether an event with the same or similar circumstances has occurred previously.
v. The measures employed to minimise the concentration levels or to improve the visibility levels.

Based on an assessment of the circumstances, the Secretary, DoPE, may request a Tunnel Air Quality Management Systems Effectiveness Report. This ‘Systems Effectiveness’ Report is to detail:

- Overall performance and concentration levels in the tunnel or outlets over the preceding 6 months, providing average and maximum levels and the respective time periods
- Details where pollutant levels during operations have exceeded the specified limits
- Consideration of how the tunnel air quality management can be improved including installation of additional ventilation management facilities outlined in this ‘Potential Modifications’ Report.

3. Nature of Potential Exceedance Events

Exceedances of air quality limits could occur from a number of likely events, some of which have a level of predictability as to when they would occur, or others that are likely to occur but the actual occurrence cannot be predicted. These events have been classed as:

- External Events; and
- Internal Events

Therefore the potential events have been categorised as follows:

- External Predictable Events: Traffic congestion on downstream Motorways in holiday or other periods. There is extensive information available on the characteristics of peak traffic periods to assist the traffic management systems coordinated with the management of tunnel ventilation .

- Internal Predictable Events: Consequent to the above predictable event there is a potential consequent slow moving traffic within the tunnel in holiday or other periods. Again, there is extensive information available on the characteristics of peak traffic periods to assist. the traffic management systems coordinated with the management of tunnel ventilation

- External Un-Predictable Events: These could arise from:
  - Bushfires, or dust events,
  - adverse weather patterns (thermal inversions that may affect air dispersion),
  - unpredicted loss of power to a wide area (both supplies); and
  - major downstream traffic accidents, either within the tunnel or external to the tunnel, blocking lanes and causing prolonged congestion.

  These un-predicted events will require different responses that actively manage the tunnel traffic (such as, diverting traffic to recognised detour routes), increase in tunnel ventilation to ensure that air quality limits are maintained, or are restored as quickly as possible.

- Internal Irregularities and Abnormalities in Measurements: There are 'potential exceedances' that may arise from a number of factors such as:
  - Measurement of elevated local concentrations due to the turbulent airflows that will result from vehicle movements and the interaction with tunnel equipment;
  - Order of accuracy of the measurement method and equipment.

There is another potential category, 'Un-anticipated Errors in Design Information". This is highly unlikely but could arise from errors from:

- Tunnel traffic volumes higher than the ventilation design assumptions;
- Vehicle emissions being substantially different from the design assumptions, either from changes in fleet mix, changes in assumed heavy vehicle volumes, or fuel types;
- Conversion ratios adopted for NOx and NO_2, visibility to solid particles, and the VOC to CO ratio.

4. Tunnel Ventilation Design Requirements and Concept Design

4.1. Design Criteria

The tunnel M&E Systems are designed to meet a two lane configuration based on defined criteria of a maximum traffic volume and speed, and defined emissions data. A summary of the design criteria for the Tunnel Ventilation System is included in Appendix 2 of this report.

Passenger Car Unit

A key determinant is the theoretical maximum capacity of a traffic lane, and by extension, the theoretical maximum capacity of the mainline tunnel. International standards for traffic capacity are based on a 'passenger car unit'.

As outlined in the EIS and concisely explained in Section 2.5.1 of the SPIR (page 58), " *'Passenger car units' is a standard, consistent basis for measuring the 'space' taken up by different size vehicles. For example:*

- *A standard passenger vehicle is one passenger car unit.*
- *An articulated truck is 2.9 passenger car units.*
- *A truck and dog is two passenger car units.*

This relationship between the theoretical motorway lane 'throughput capacity' and average traffic speed is illustrated in Figure 2-1. The figure shows that:

- *A maximum motorway lane capacity of 2,000 passenger car units per lane per hour is achievable at an average traffic speed of 60km/h. This means that 2,000 passenger car units could pass a fixed monitoring point on a motorway lane every hour if traffic is travelling at 60km/h.*
- *At an average traffic speed of 80km/h, a greater stopping distance is required between vehicles. Because of this, only 1740 passenger car units would pass the same fixed point on a motorway lane per hour.*
- *At an average speed of 40km/h, a shorter stopping distance is required between vehicles, but the vehicles are moving more slowly. Because of this, only 1849 passenger car units would pass the same fixed point on a motorway lane per hour. For 20km/h, this figure would drop further to only 1419 passenger car units per hour."*

NorthConnex mainline tunnels are two lanes, therefore the theoretical capacity of the mainline tunnel is doubled to 4,000 passenger car units per hour at 60km/h.

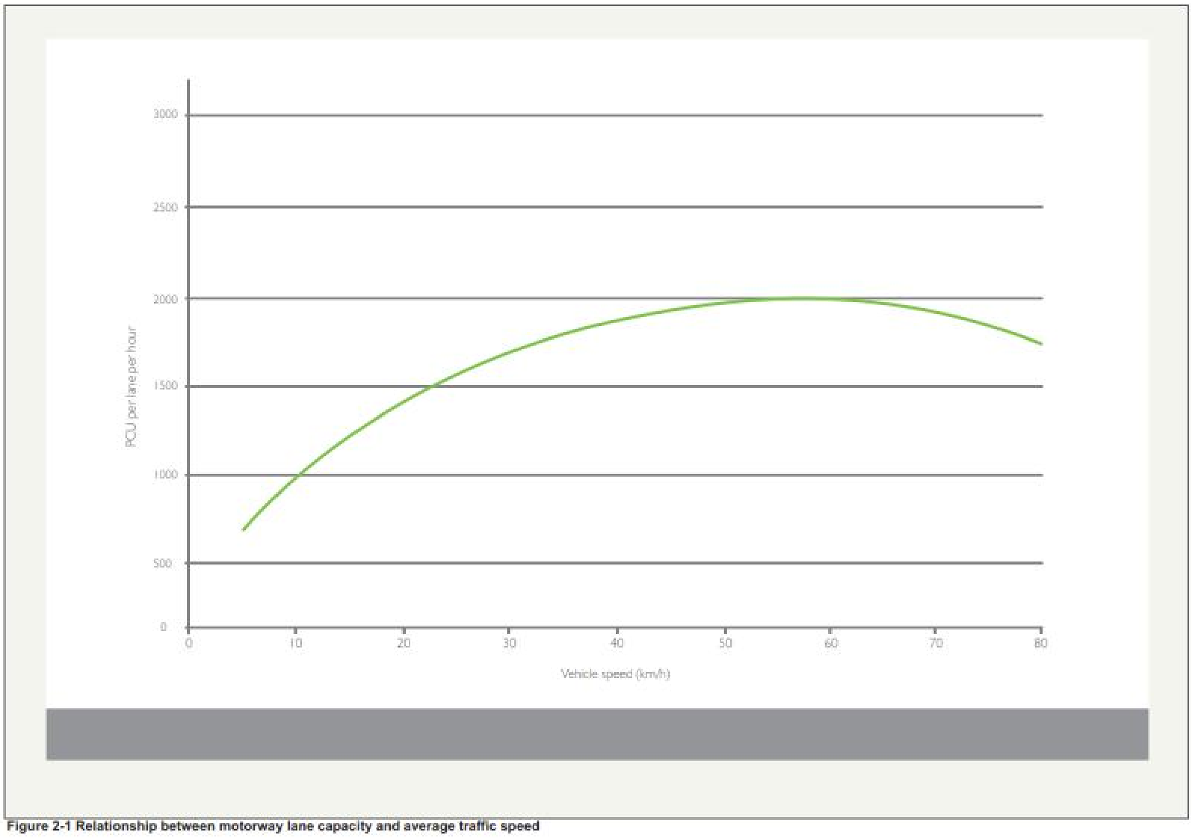


Figure 2-1 Relationship between motorway lane capacity and average traffic speed

Tunnel Alignment Design

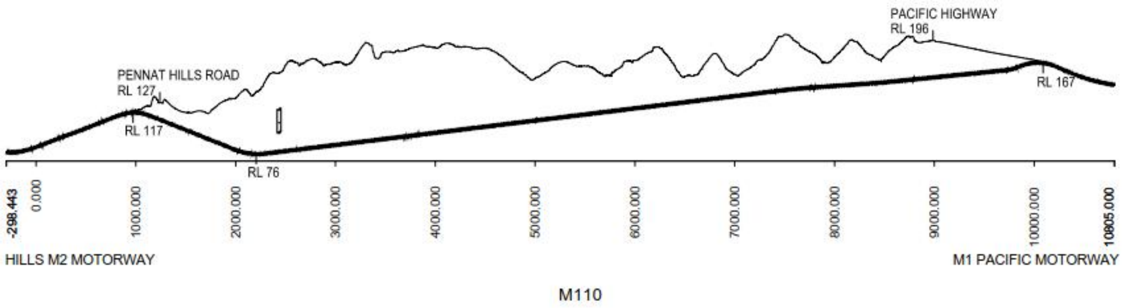
A tunnel vertical alignment is a contributor to vehicle emissions. The physical alignment of the NorthConnex tunnel has been designed to minimise, as far as is reasonably practicable, the effects of gradient on the vehicle emissions.

The tunnel connects the Hills M2 Motorway near the junction of Pennant Hills Rd to the M1 Pacific Motorway between the North Shore Rail overbridge and Edgeworth David Rd overbridge. The tunnel provides free flow mainline to mainline connections to both Motorways. There are on-ramps and off-ramps connecting to Pennant Hills Road at both the north and south ends of the tunnel.

The vertical alignment of the tunnel is dictated by two principle constraints:

- Topographical level difference between the Hills M2 northbound connection to the M1 Motorway northbound connection of approximately 50m, and
- Placing the tunnels below the NWRL tunnels to optimise the vertical gradient. There is a resulting vertical climb of approximately 91m over about 7.5km in the northbound tunnel. The resulting northbound gradient is approximately 1 percent, with a short length of 4 percent to exit the tunnel to the M1 Motorway.

The effect of the tunnel gradient on the vehicle emissions such that the northbound mainline tunnel requires more jet fans than are required in the southbound mainline tunnel. That is predominantly uphill northbound versus predominantly downhill southbound.



2.2 Northbound Mainline Tunnel – Diagrammatic Alignment

Key determinants of the ventilation system design are:

1. The number of vehicles and the sensitivity of the predicted numbers
2. The fleet mix, particularly the fuel type and the proportion of Heavy Goods Vehicles (HGV)
3. Air quality in the tunnel, and at the outlets prior to dispersion
4. The ambient air quality outside the tunnels. First as the source of 'fresh air', and second as the environment for dispersion of the tunnel air from the outlets.

The sensitivity of the base data is potentially affected by significant changes in the total number of vehicles, and then the proportion of Heavy Goods Vehicles to the remaining vehicles. The tunnel ventilation design adopts the PIARC recommendation of a maximum theoretical throughput 4000 PCU /hr at 60 km/h for each carriageway northbound and southbound.

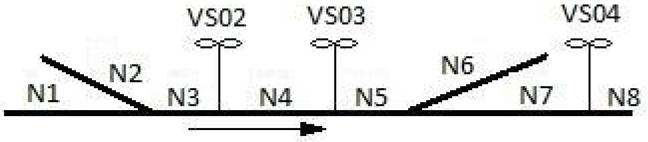
4.2. Tunnel Ventilation Concept

The tunnel ventilation concept at the highest level is essentially two basic components. They are a longitudinal ventilation system of the tunnel carriageway, with extraction to an outlet at the end. The tunnel ventilation system is made up of a number of components that are automatically controlled to meet the normal and emergency ventilation requirements of the system. These components include:

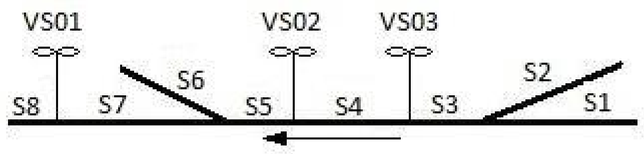
- Jet Fans (installed within the tunnel for longitudinal airflow control);
- Axial Fans (installed within the ventilation station for extraction or supply of air);
- Attenuators (installed within the ventilation station to limit the transmission of noise);
- Dampers (installed to control the flow path of air); and
- Sensors (installed to provide feedback to the control system).

The systems control incorporates a manual override to enable operator intervention and direct control.

The mainline entry, on-ramp entry tunnel, intermediate emergency extraction or air supply points, off ramp exit tunnel, and mainline exit tunnel divides the carriageway ventilation into eight sections.



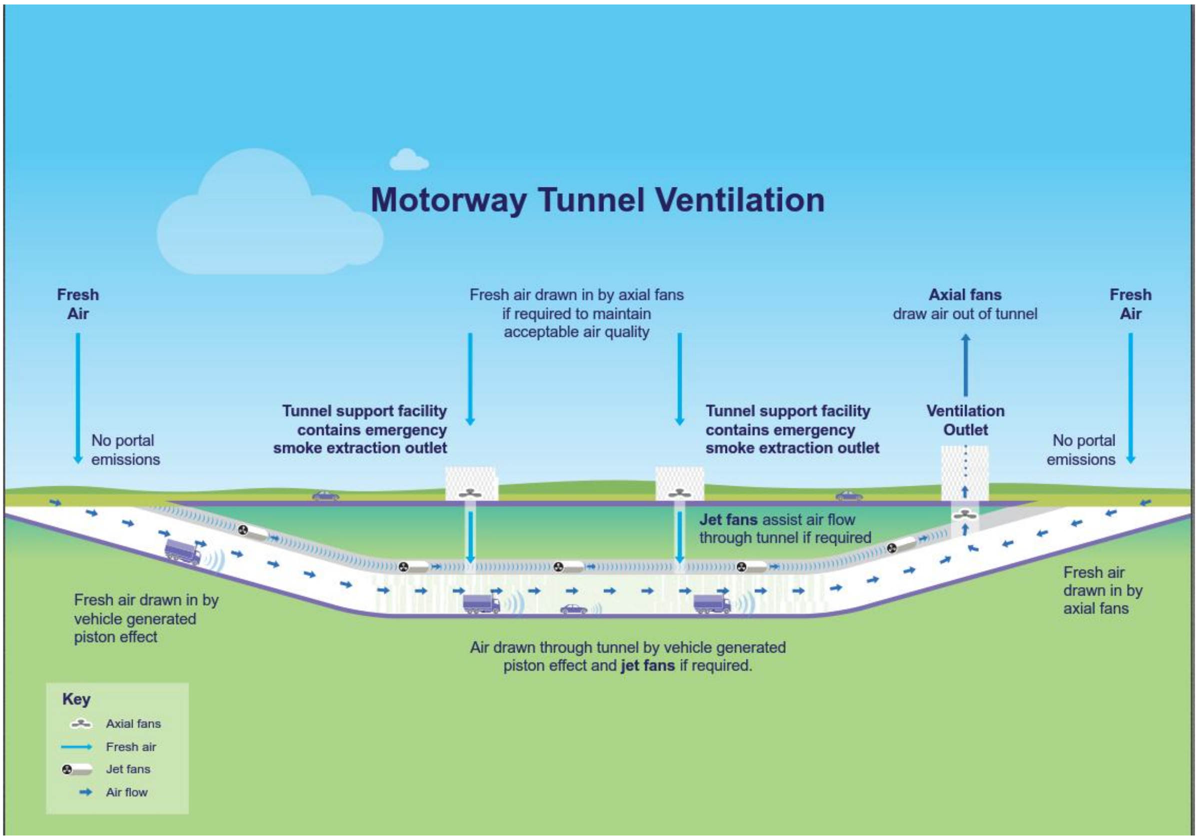
4.1 - Northbound Tunnel Sections



4.2 - Southbound Tunnel Sections

The concept entails that ambient air is drawn in at the portals and is moved by a combination of piston effect from vehicles and air movement by entraining air through action of the jet fans. Air is moved in the direction of the traffic flow, except for the exit ramps where air is drawn down the ramp to the mainline tunnel.

Air quality is automatically measured at a number of set points along the tunnel to provide direct real time air quality data to the Control System.



4.3 Diagram – Submissions and Preferred Infrastructure Report

4.3. System Usage – Concept Design

4.3.1. Jet Fan Usage

Jet fans are automatically controlled to achieve the set points programmed into the tunnel ventilation control system (part of the tunnel control system). If a change in airflow set points is required, this can be achieved by updating the values programmed into the tunnel ventilation control system, subject to the capacity of the existing system.

The capacity of the jet fan system is being designed based on the PIARC maximum traffic throughput of 2000 pcu/hr/lane at 60km/h which the speed is providing the maximum throughput of vehicles per hour. That is, each tunnel mainline carriageway is designed for 4000 PCU / hr.

Based on the traffic mix specified (cars and heavy goods vehicles), this equates to approximately 3200 vehicles per hour per 2-lane tunnel. Note: EIS and SPIR predicted traffic volumes at 2019 are significantly less than this, in the order of 50%.

On these predicted traffic volumes, under free flowing conditions the number of jet fans required in the northbound tunnel is approximately 19 out of the 80 jet fans installed (approximately 25% of the installed jet fan capacity), with the southbound tunnel using a similar percentage of the installed jet fan capacity under the corresponding scenario.

4.3.2. Axial Fan Usage – Intermediate Smoke Extraction Stations

Each of the Smoke Extraction ventilation stations at Wilson Road and Trelawney Street used for extraction of smoke or other pollutants in an emergency have four (4) axial fans designed in a three duty plus one standby configuration. In an emergency, extraction rates will be controlled to maintain tenable conditions within the Incident Tunnel.

The EIS and SPIR identified that during congested conditions, fresh air would be supplied at these locations to the tunnels, but no extraction of contaminated air. This would be achieved by running the extract fans in reverse, which is supply air to the tunnel, instead of exhausting smoke. The amount of air that can be provided at these points, without extracting air, is limited to approximately 200m^3/sec into either tunnel.

4.3.3. Axial Fan Usage – North and South Ventilation Stations

Each of the main portal ventilation stations used for extraction of vitiated air from the tunnel are installed with five (5) off axial fans designed in a four duty plus one standby configuration to provide a total nominal 800m^3/sec flow rate at the Northern Ventilation Facility and a 800m^3/sec flow rate at the Southern Ventilation Facility. For energy consumption reasons however, the system will operate all five (5) fans at a reduced speed to provide the duty airflow. It should be noted that the HV cabling in the tunnels will be sized for a maximum electrical demand of 25MVA whereas the current estimate of the required duty is 22MVA.

If an increased flow rate is required from the existing fans, this may be possible by operating the five (5) off fans at an increased speed. The extra amount that could be obtained is not expected to be significant, and in any case can only be confirmed subject to final fan selections.

A consequence of operating all five (5) off axial fans at higher speeds includes potential impacts to ambient noise levels. It may be possible to mitigate the impact of the additional noise through installation of additional noise attenuation into the existing ventilation facilities.

Similar to the jet fan usage described above, the installed capacity of the axial fan system is based on the PIARC maximum traffic throughput rather than the predicted traffic levels for the tunnel. In this case the defining scenario for the axial fan system is the PIARC maximum traffic throughput of approximately 1740 pcu/hr/lane at 80km/h or approximately 1500 vehicles per hour per lane based on the traffic mix. Given the predicted traffic numbers are significantly below this nominated throughput, the axial fan capacity required in the northbound tunnel is approximately 640m^3/sec to meet the 2019 and 2029 predicted traffic volumes compared to the 800m^3/sec of the installed capacity provided at the Northern Ventilation Facility. This equates to approximately 80% of the installed axial fan capacity.

5. Operational Traffic Management and Vehicle Enforcement Provisions

There are a number of measures that assist in maintaining air quality within the tunnel that are not part of the ventilation system. These are:

- Smokey Vehicle Enforcement – being provided as part of the NorthConnex Project within both mainline tunnels;
- Traffic management devices such as ramp metering of the on-ramps, lane closure medians external to the tunnel to limit the amount of traffic entering the tunnel in the case of heavy congestion and slow traffic

6. Modification Concepts

6.1.1. Considerations for Ventilation Modifications

Notwithstanding the robust design of the ventilation system (as outlined in the SPIR Section 7.1.1.3, it is designed for approximately double the 2019 predicted traffic volumes), the intent of Condition B5 is to consider what modifications or additional improvements are capable of being provided so that the air quality limits are able to be maintained, if there are repeated exceedances of air quality limits.

These modifications to the overall tunnel ventilation design have potential effects on a number of other tunnel systems, and potentially impacts to the tunnel civil design if additional space is required. The ventilation system, power distribution system and control system are intimately linked, so changes made to the ventilation system will have an impact on these other systems. For example, an increase in the number of jet fans within the tunnel increases the overall power demand, and potentially an increase in the size of the power reticulation system.

6.1.2. Constraints on Potential Modifications

The constraints associated with the civil and associated services design also need to be considered. Several of these are either infeasible or unreasonable to alter. Examples of this include

- The cross sectional area of the tunnel mainline carriageways and tunnel ramps;
- The cross sectional area of the ventilation outlets
- The cross sectional area of the ventilation inlets, both the entry portals and the intermediate facilities at Wilson Road and Trelawney Street.
- Potential constraints on the spatial enlargement for additional equipment. Plus, a detailed assessment would be required on any additional attenuation of the building fabric that may be required from a change in equipment, or equipment operational scenarios.
- The available capacity of the energy supply from the Utility Network, and whether there is additional capacity available above the current provision of 66kV / 22 MVA per supply available without an upgrade of the system.
- Within the Motorway energy network supply what provisions are made for spare capacity, and then spare conduits and cable routes to provide additional HV power between substations.
- From the Substations supply what provisions are made for spare capacity, and then spare conduits and cable routes to provide additional LV power from the substations.
- Limits on the spacing of longitudinal jet fans due to in-tunnel noise limitations (for audibility and intelligibility) and proximity to existing tunnel devices.

Potential Future Modifications

Future modifications are expected to be required as a result of ‘Unpredicted Events’ as outlined in Section 3. Potential future modifications to the tunnel ventilation system have been classified into different categories:

- OPERATIONAL - Reconfiguration of system usage and controls: those accomplished by reconfiguration of the existing design;

- ADDITIONAL EQUIPMENT - Provision of additional components, such as jet fans, with potential impacts on existing M+E systems;
- EXPANSION OR CONVERSION OF EXISTING INSTALLATIONS - Provision of substantial additional system components: those accomplished by significant construction of additional system components and altering the civil works; and
- ADDITIONAL TREATMENT – Installation of filtration either for in-tunnel air, or outlet air, or both to target specific issues with air quality.

Condition of Approval B5 is not specific as to what future modifications are required to be implemented, but the Secretary's Assessment Report lists for consideration a number of potential modifications to ensure that the Approved Air Quality Limits are maintained. These include:

- Installation and operation of additional fans,
- Additional air intakes,
- Conversion of the Wilson Road and Trelawney Street emergency smoke extraction facilities to ventilation outlets, or
- Filtration.

The Assessment Report outlines an expectation:

"….. it is critical that the design is future-proofed, to ensure that any air quality issues arising through operation of the tunnel can be readily rectified. The Department has therefore recommended a condition requiring the Proponent to demonstrate how the tunnel ventilation system can be modified in the future in the unlikely event of systemic failure."

Any modification or modifications implemented may require an adjustment of the ventilation operational controls and / or emergency mode controls. This can only be assessed based on the actual design of the modification.

6.1.3. Assessment Methodology of the Potential Modifications

The assessment of each of the potential modifications will provide a high level review as follows:

1. Can the proposed modification be readily implemented
2. Identification of potential constraints or limitations that arise from the ventilation system design and the overall Motorway design. What are the technical constraints on future implementation
3. A broad qualitative ranking of costs. This will be assessed only as low, medium, or high with potential timeframes and additional approvals that may be required
4. Can the current ventilation system design be modified or augmented in the future and outline in what form
5. A qualitative assessment on the capability to implement the potential modification.

This broad assessment will be provided with each potential modification described.

6.1.4. Potential Modification #1 – Higher Capacity or Additional Jet Fans

This potential modification would require the provision of additional jet fans, or capacity of jet fans, within the tunnels to improve longitudinal air flow control. It may also include additional or larger capacity axial fans in the ventilation outlet facility in conjunction with this installation.

Additional jet fans may be required if the assumed design criteria change significantly. That is, the fleet mix increases the vehicle emissions, or the number of vehicles changes beyond the 4000 PCU's per tunnel (3200 vehicles based on the nominated fleet mix). This would require a higher airflow in the same cross-sectional area to increase the volume of air in a given period to dilute vehicle emissions.

Note, the EIS and SPIR are based on an assumed vehicle fleet mix of 28% heavy vehicles in 2019, dropping to 25% in 2029. The proportion of diesel fuelled vehicles is also based on assumed linear extrapolation of 2013 data to determine this proportion.

Additional Capacity of Jet Fans

- A higher airflow in the tunnel requires additional thrust which can only be achieved by replacing existing fans with higher capacity fans of the same diameter, or installing additional jet fans.
- It would be possible to accommodate smaller additional jet fans within the tunnel, so as to fit within the existing spatial provisions. It is expected that a smaller jet fan of nominally 1200mm diameter and 1250N thrust could be installed within the existing tunnel cross section (1600 nominal diameter fans are proposed in the tunnel, these require roof niches to maintain carriageway clearance). A theoretical spacing of jet fans is approximately 120m, subject to a detailed assessment.
- The power system capacity will need to be reviewed in the event additional jet fans are installed.
- Depending on the number and location of fans, these additional fans may require an upgrade to the power supply and reticulation. Additional space and substation equipment upgrades may be required to power the additional jet fans. Subject to future design, it may be more practical to power from the above ground substations where the required spatial provisions could be facilitated easier than from a tunnel substation. The implication of this approach is the longer cable runs from the surface to within the tunnel, with an increased cable size.

Assessment of Modification # 1

The number of jet fans provided meets the emissions and traffic volumes required by PIARC, which is the 4000 PCU/hr for each carriageway. As noted in the Secretary's Assessment Report the purpose is to "demonstrate how the tunnel ventilation system can be modified in the future in the unlikely event of systemic failure."

There is uncertainty as to how the fleet mix or forecast traffic volumes would change, or other unanticipated events cause unpredicted exceedances such that additional jet fans are required (the SPIR, Section 2.7.3 estimated the traffic volumes would need to double the predicted 2019 volumes). However, in the unlikely event they do, then providing additional jet fans would represent an effective solution.

Broad assessment summary:

1. The proposed modification can be readily implemented using small diameter jet fans;
2. The localised power supply and reticulation would require confirmation, and is dependent on the specific section of the tunnel carriageway where the air quality exceedances require rectification
3. The costs would be in the medium range, subject to confirmation of sufficient available power

4. The current ventilation design is capable of being modified without significant alteration. A timeframe to implement is likely to be up to 12 months as a minimum with detailed design, procurement, and implementation over a series of carriageway closures.
5. The potential modification is capable of implementation

6.1.5. Potential Modification #2 – Additional Capacity of Outlet Axial Fans

This potential modification would require the provision of larger capacity axial fans in the ventilation outlet facility.

Larger capacity fans may be required if the assumed design criteria change significantly. That is, the fleet mix increases the vehicle emissions, or the number of vehicles changes beyond the 4000 PCU's per tunnel (3200 vehicles based on the nominated fleet mix). This would require a higher airflow to increase the volume of air in a given period to dilute vehicle emissions, and a consequent increase in air volume discharged out of the outlet.

Note, the EIS and SPIR are based on an assumed vehicle fleet mix of 28% heavy vehicles in 2019, dropping to 25% in 2029. The proportion of diesel fuelled vehicles is also based on assumed linear extrapolation of 2013 data to determine this proportion.

Additional Capacity of Axial Fans

- Increasing the total extracted volume of vitiated air from the tunnel could be achieved by replacing the original axial fan units with larger capacity fan units. The physical size of the fan assembly may not increase significantly, but the size of the electric motor would increase and this would affect the power supply system. Depending on the additional capacity required, a larger fan motor may not increase the overall footprint required by the fan.
- In addition to a power upgrade, modifications of the fan's ancillary items within the ventilation station may need to be made to accommodate larger fans should they be required. For example an increased velocity would require a reassessment of the fan noise attenuation. Larger fans may have a different noise spectrum resulting in the need for different building fabric attenuation. This may result in augmentation or alteration of the existing building fabric.
- The ventilation outlet could be configured to maintain a similar range of discharge velocities to ensure dispersion is maintained.

<u>Assessment of Modification #2</u>

The number of axial fans provided meets the emissions and traffic volumes required by PIARC. As noted in the Secretary's Assessment Report the purpose is to *"demonstrate how the tunnel ventilation system can be modified in the future in the unlikely event of systemic failure."*

There is uncertainty as to how the fleet mix or forecast traffic volumes would change such that additional axial fan capacity is (the SPIR, Section estimated the traffic volumes would need to double the predicted 2019 volumes). However, in the unlikely event they do, then providing larger or higher capacity axial fans, potentially in combination with additional jet fans, would represent an effective solution. Upgrading of axial fans located in surface buildings may be more readily achieved.

Broad assessment summary:

1. The proposed modification can be readily implemented using larger capacity axial fans;
2. The discharge velocity in the current cross sectional area of the outlet would require confirmation, plus any resultant noise attenuation. The localised power supply and reticulation would require confirmation of the power requirements of the larger fans
3. The costs would be in the medium range, subject to confirmation of sufficient available power
4. The current ventilation design is capable of being modified without significant alteration. A timeframe to implement is likely to be up to 12 months as a minimum with detailed design, procurement, and implementation over a series of carriageway closures.
5. The potential modification is capable of implementation

6.1.6. Potential Modification # 3 – Conversion of Wilson and / or Trelawney to Ventilation Outlets and Air Intakes

This modification would provide both exhaust of tunnel air and a supply of fresh air to the tunnel at intermediate points.

The amount of fresh air supplied into the tunnel can now be increased as tunnel air is now extracted. The limiting factor may be the number of fans, but it is assumed for the purposes of assessment that the number of fans for exhaust is 3 + 1 (as currently provided) and 3+1 for supply. That is the number of fans provided is doubled.

The physical provisions required to implement are significant and entail:

- separate exhaust and supply shafts and provision of a supply air path into the same tunnel (assumed to be 45m^2 – 50m^2 cross section)
- separate exhaust outlet and supply intakes (assumed to double the building floor area by increase in plan or increase in height)
- potentially additional fans and consequent building footprint or height if the required air supply and quantity of exhaust exceeds the capacity of the existing fans, as noted above.

For the purposes of this assessment it is assumed the outlet would be 20m above Pennant Hills Rd at both locations.

In order to maintain the smoke extraction capability of the emergency smoke extraction facility, a separate supply shaft would be constructed alongside the current building. This would ensure that the essential safety provision of smoke extraction in an emergency is maintained. However, the requirement to maintain this would be confirmed with a risk analysis considering the risk and consequence if the capability is not available during the defined construction period.

The NorthConnex design does not make any provision for this modification. However, there are no substantial impediments to implementation. Depending on the final design required, additional land may be required, as well as managed tunnel closures to implement the interface works, and upgrade of power supplies, system controls, and cabling.

Assessment of Modification # 3

This Modification proposes a mode of operation, i.e. exhaust tunnel air at the intermediate points, which is not approved in the Project Approval.

Conversion of the Wilson Road or Trelawney Street facilities to a ventilation outlet would require a separate environmental assessment and subsequent approval under the Environmental Planning and Assessment Act.

That along with the substantial construction entailed with the additional buildings and civil shaft construction, does not meet the objective of being 'readily rectified'.

Broad assessment summary:

1. The proposed modification can only be implemented with a Modified Approval of the Project. It is likely there would be local community concern regarding conversion of these facilities to permanent ventilation outlets;

2. The discharge velocity and discharge height would require assessment, and any building alterations identified.
3. The costs would be in the medium range, subject to confirmation of the required alterations
4. The current ventilation design is capable of being modified without significant alteration. An additional supply shaft would be required for the fresh 'ambient' air as it is assumed that the existing shaft is not able to be segmented while maintaining the essential smoke exhaust function. Adits at the surface would be required as well. A timeframe to implement is likely to be between 12 months to 36 months as a minimum with environmental assessment, approval processes, detailed design, procurement, and implementation.
5. The potential modification is capable of implementation if approved as a Modification to the Project Approval, and substantial construction activities,

6.1.7. Potential Modification # 4 – Tunnel Air Filtration

Tunnel filtration is a means of addressing vehicle emissions. It is a broad concept, but can be summarised as these two methods of 'air cleansing':

- Electrostatic Precipitation of particulate matters; and
- Chemical treatment of gaseous pollutants.

As outlined in the NorthConnex Submissions and Preferred Infrastructure Report, these filtration types have mixed success, with electrostatic precipitation used to address issues with particulate matter in certain road tunnels. The limitations to filtration systems are that they target specific pollutants, but are not able to remove all or the full range of road tunnel pollutants. It may address specific localised air quality issues, but is not a holistic treatment.

Irrespective, for the purposes of assessment, it is assumed that any of the exhaust facilities would provide a filtration system that provides a take-off point and resupply point as required. The physical provisions that would be required to implement a filtration treatment are significant and entail:

- Separate exhaust off-take and re-supply intakes assumed to be 50m^2 free area each
- Separate exhaust and supply shafts (if located on the surface)
- Potentially additional fans if the required air supply and quantity of exhaust exceeds the capacity of the existing fans (if located on the surface)
- Provision of electrostatic filters in the air path, plus provision of a separate NOX treatment downstream;
- If located below ground, a large cavern would be required to house the equipment, both for electrostatic precipitation, and a downstream NOX treatment (for assessment purposes, assumed to be an activated carbon with potassium hydroxide).
- Provide a 'Clean Air' return path to the tunnel through a re-supply shaft or tunnel.

These facilities will require frequent access for waste removal of precipitated particulate matter, replenishment of potassium hydroxide, and regeneration of the activated carbon, system maintenance and cleaning, provision of additional power supply, and large volume spaces to house the equipment. For these reasons it is preferable they are located at the surface.

These building volumes would be additional to the existing exhaust buildings at Wilson Road and Trelawney Street.

The NorthConnex design does not make any provision for this modification. However, there are no substantial impediments to implementation. Depending on the final design and filtration treatment required, additional land is most likely to be required at Wilson Road. This would need to be combined with managed tunnel closures to implement the interface works, the upgrade of power supplies, system controls, and cabling.

<u>Assessment of Modification # 4</u>

This modification proposes a mode of operation, i.e. filtration of tunnel air at the tunnel intermediate or end points, which is not approved in the Project Approval. Also, given that NO_2 and NOX treatment is currently not a proven technology, it may not achieve the objective of achieving the NO_2 average limits.

This, along with the additional land acquisition, the substantial construction entailed with the additional buildings and civil connections or shaft construction, does not meet the objective of being a 'readily rectified' modification.

Broad assessment summary:

1. The proposed modification can only be implemented with a Modified Approval of the Project. It is likely there would be local community concern regarding conversion of these facilities to significantly larger and bulkier permanent buildings;
2. An assumption is that filtration system be located on the surface to facilitate regular and frequent servicing and maintenance. It is also assumed that additional property may be required, or the building volumes and heights be substantially increased to house the equipment.
3. The construction capital costs would be high to very high, subject to confirmation of the required alterations. In addition the operating costs of consumables, and in particular energy consumption, are very high over the life of the filtration system.
4. The current ventilation design is capable of being modified without significant alteration assuming that it utilises the existing fans at the intermediate exhaust facilities. A timeframe to implement is likely to be between 12 months to 36 months as a minimum with environmental assessment, approval processes, detailed design, procurement, construction, and implementation.
5. The potential modification is capable of implementation if approved as a Modification to the Project Approval, and substantial construction activities.

6.1.8. Potential Modification # 5 – Tunnel Outlet Filtration

For the purposes of assessment, it is assumed that the current exhaust facilities would provide a filtration system that provides a take-off point and resupply point as required. The physical provisions that would be required to implement a filtration treatment are significant and entail:

- Separate exhaust off-take and re-supply intakes assumed to be 80m^2 free area each
- Separate exhaust connections via adits and shafts (if located on the surface)
- Potentially additional fans if the required air supply and quantity of exhaust exceeds the capacity of the existing fans (if located on the surface)
- Provision of electrostatic filters in the air path, plus provision of a separate NOX treatment downstream;
- If located below ground, a large cavern would be required to house the equipment, both for electrostatic precipitation, and a downstream NOX treatment (for assessment purposes, assumed to be an activated carbon with potassium hydroxide.
- Provide a 'Clean Air' return path to the outlet through a shaft or tunnel.

These facilities will require frequent access for waste removal of precipitated particulate matter, replenishment of potassium hydroxide, and regeneration of the activated carbon, system maintenance and cleaning, provision of additional power supply, and large volume spaces to house the equipment. For these reasons it is preferable they are located at the surface.

These building volumes would be additional to the existing exhaust buildings at the Southern Ventilation Facility, and Northern Ventilation Facility. If the intermediate facilities are operating as exhaust outlets then Wilson Road, Trelawney Street would require additional building volumes as well.

The NorthConnex design does not make any provision for this modification. However, other than additional land, there are no substantial impediments to implementation. Depending on the final design and filtration treatment required, additional land is most likely to be required at Southern Ventilation Facility, Wilson Road, and Northern Ventilation Facility. This would need to be combined with managed tunnel closures to implement the interface works, the upgrade of power supplies, system controls, and cabling.

<u>Assessment of Modification # 5</u>

This modification proposes a mode of operation, i.e. filtration of tunnel air at the tunnel outlet, which is not approved in the Project Approval. Also, given that NO_2 and NOX treatment is currently not a proven technology, it may not achieve the objective of achieving the NO_2 average limits.

This, along with the additional land acquisition, the substantial construction entailed with the additional buildings and civil connections or shaft construction, does not meet the objective of being a 'readily rectified' modification.

Broad assessment summary:

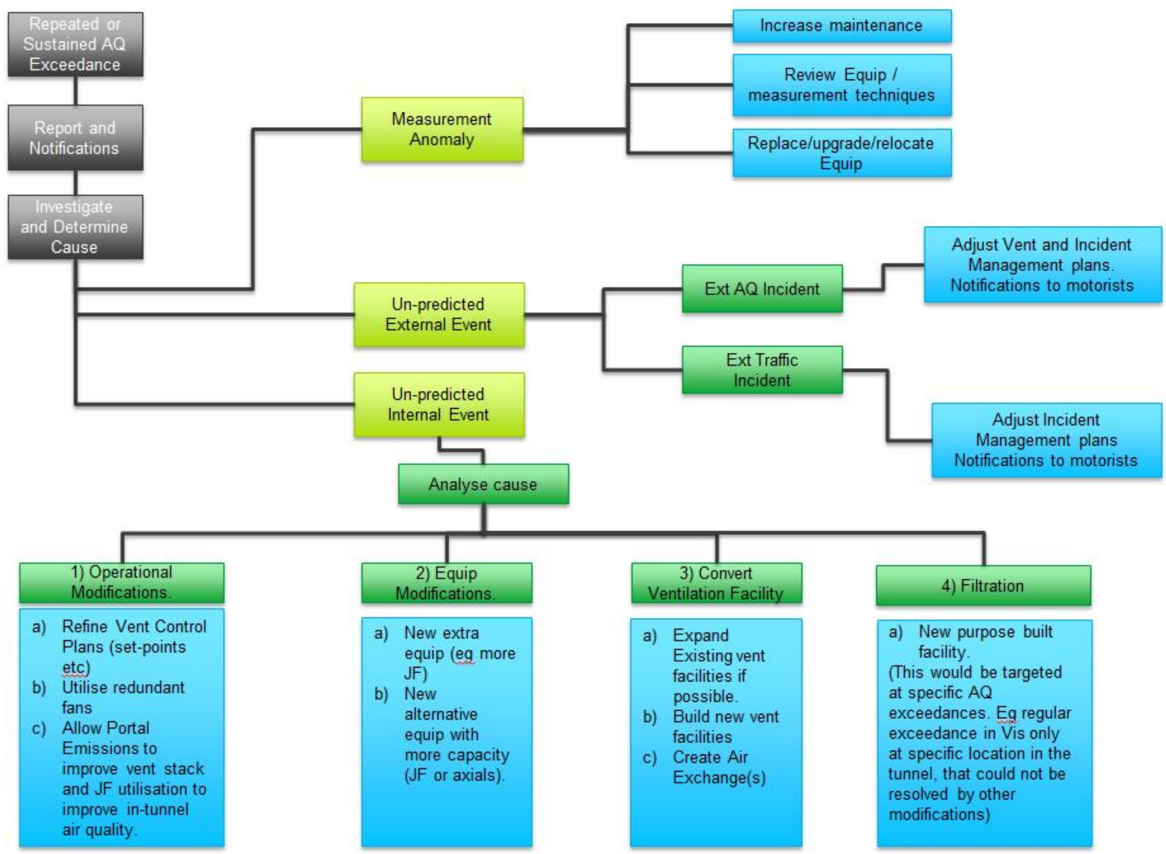
1. The proposed modification can only be implemented with a Modified Approval of the Project. It is likely there would be local community concern regarding conversion of these facilities to significantly larger and bulkier permanent buildings;
2. An assumption is that filtration system be located on the surface to facilitate regular and frequent servicing and maintenance. It is also assumed that additional property may be required, or the building volumes and heights be substantially increased to house the equipment. Note, the northern ventilation

facility is very constrained in potential locations for filtration, and is likely to be insoluble without underground excavation by tunnelling.

3. The construction capital costs would high to very high, subject to confirmation of the required alterations. In addition the operating costs of consumables, and in particular energy consumption, are very high over the life of the filtration system.
4. The current ventilation design is capable of being modified without significant alteration assuming that it utilises the existing fans at the current exhaust facilities. A timeframe to implement is likely to be between 12 months to 36 months as a minimum with environmental assessment, approval processes, detailed design, procurement, and implementation.
5. The potential modification is capable of implementation if approved as a Modification to the Project Approval

6.1.9. Prioritising Potential Modifications

A number of Potential Modifications have been identified. The selection of the appropriate Modification is dependent on the nature of the events that require the Modification. Below is a 'decision tree' to prioritise the response



Decision Tree Diagram – Potential Ventilation Modifications

Refer to the previous assessment of potential modifications.

On the basis of the assumption that "any air quality issues arising through operation of the tunnel can be readily rectified" the range of potential modifications has been limited to those that would not require an additional or separate Environmental Planning and Assessment Act approval.

However there are additional modifications identified that will require an environmental assessment and approval in order to be implemented. These are:

1. Conversion of the emergency exhaust facilities at Wilson Road and Trelawney Street to ventilation outlets; and
2. Provision of filtration systems to treat in-tunnel air or ventilation outlet air.

7. Potential Modifications Identified

Several potential modifications have been identified that are capable of improving the air quality, if this is required because of systemic exceedances in the Approved air quality criteria.

Operational Modifications:

The following operational practices are suggested for consideration:

1. Increase usage of plant equipment (axial fans and tunnel jet fans). The fans are based on a tunnel vehicle capacity of 4000 pcu / hr at 60 km/h for each mainline tunnel. This far exceeds the predicted traffic volumes in the EIS;
2. Extract additional air from the ventilation outlets by using all the installed fan capacity during short peak periods; and
3. Implement traffic management measures to reduce vehicle emissions within the tunnel, such as ramp metering, lane closures, or in worst case, tunnel closure in the case of congested conditions or stopped traffic on downstream motorways (refer to CoA B7).

Additional Equipment

The following potential modifications are submitted as readily implementable, subject to detail design:

1. Modification # 1 - investigate the most effective method of increasing the tunnel air flow by increasing the number of jet fans (using a smaller diameter jet fan);
2. Modification # 2 - investigate the most effective method of increasing the tunnel air flow by increasing the capacity of the axial fans within the existing northern and / or southern ventilation outlets

All of these additional fans or increased capacity fans would require further design evaluation to assess the optimal location and the required additional power requirements.

Conversion of Existing Facilities

This Modification requires an environmental assessment, substantial tunnelling and surface civil and building works, along with potential additional land acquisition. Exact detail design would need to be developed and is dependent on the nature of the air quality issue to be rectified.

Installation of Filtration

This Modification requires an environmental assessment, substantial tunnelling and surface civil and building works, along with potential additional land acquisition. It can be installed to address specific and targeted in-tunnel air quality, or outlet air quality (potentially improving ambient air quality). Exact detail design would need to be developed and is dependent on the specific nature of the air quality issue to be rectified by a filtration system.

8. Conclusion

The tunnel ventilation system is designed to internationally recognised tunnel ventilation standards, namely PIARC for traffic density and throughput, with predicted vehicle emissions applicable to Australia, PIARC 'Road Tunnels: Vehicle Emissions and Air Demand for Ventilation' (2012R05EN).

The ventilation system design capacity is based on the theoretical; maximum throughput of a motorway lane translated to the carriageway tunnel. The design data exceeds by a considerable margin the predicted traffic volumes contained in the NorthConnex EIS.

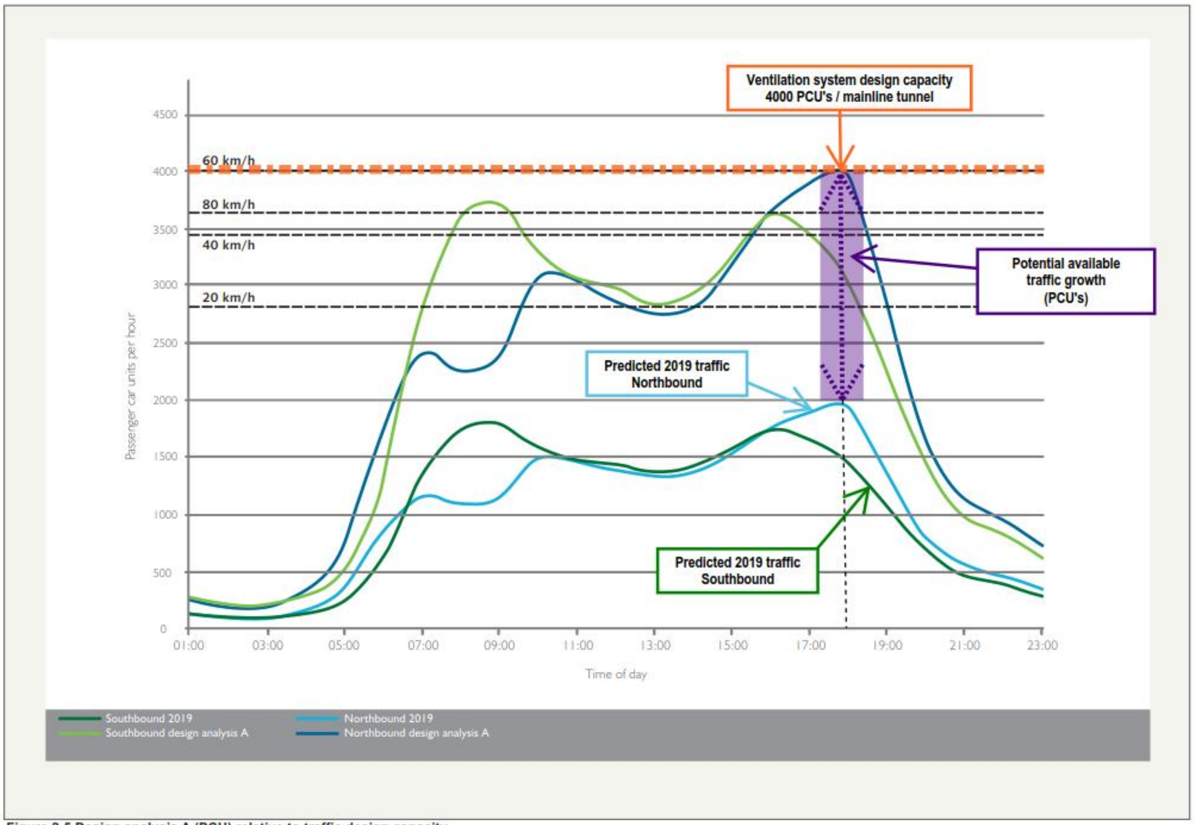


Figure 2-5 Design analysis A (PCU) relative to traffic design capacity

The likelihood of traffic volumes exceeding the theoretical design capacity of the motorway tunnels is very low. As noted in the SPIR:

"… the triggers that may lead to this level of variance in traffic volumes (demography, land use, major additions to the road network, traffic generating developments) are not expected within the timeframes considered as part of the assessment of the project."

It is unlikely that the design criteria adopted for the tunnel ventilation system will be exceeded during tunnel operations. However, in the unlikely event that the in-tunnel air quality or outlet air quality is systemically exceeded, larger capacity or additional jet fans in the tunnel carriageways, could be installed. This may require larger capacity axial fans installed at the outlets to provide better air quality.

In-tunnel air quality could be further improved by conversion of the emergency smoke outlets at Wilson Road and Trelawney Street to tunnel ventilation outlets, thereby providing a capability to extract air and simultaneously supplying fresh ambient air to the tunnel. This modification would be subject to a further Environmental Approval.

Alternatively, if these measures are unable to address specific pollutants, such as particulate matter causing exceedances of the visibility criteria, or NO_2 concentrations leading to exceedances, then consideration could be given to provision of in-tunnel filtration, or provision of outlet filtration depending on the specific pollutants to be addressed. It should be noted that conversion of the intermediate facilities from emergency smoke extracts to permanent ventilation outlets or the provision of additional infrastructure for filtration of tunnel would require a modification to the current Project Approval.

The ventilation system, as designed for the approved Project, does not preclude any of the potential modification options identified in this Report.

Appendix 1: Approved Air Quality Criteria

A1 Project Approval Air Quality Requirements:

In-Tunnel Air Quality — Limits

E2 The tunnel ventilation system must be designed and operated so that the average concentration of CO and NO_2, calculated along the length of the tunnel, does not exceed the concentration limit specified for that pollutant in **Table 5**.

Table 5 – In-tunnel average limits along length of tunnel

Pollutant	Concentration Limit	Units of measurement	Averaging period
CO	87	ppm	Rolling 15-minute
CO	50	ppm	Rolling 30–minute
NO_2	0.5	ppm	Rolling 15-minute

E3 The tunnel ventilation system must be designed and operated so that the concentration of CO as measured at any single point in the tunnel must not exceed the concentration limit specified for that pollutant in **Table 6** under all conditions (including congested conditions).

Table 6 – In-tunnel single point exposure limits

Pollutant	Concentration Limit	Units of measurement	Averaging period
CO	200	ppm	Rolling 3–minute

E4 The tunnel ventilation system must be designed and operated so that the visibility in the tunnel does not exceed the level specified in **Table 7**.

Table 7 — In-tunnel visibility limits along length of tunnel

Parameter	Average extinction co-efficient Limit	Units of measurement	Averaging period
Visibility	0.005	m^{-1}	Rolling 15–minute

Ambient Air Quality — Goals

E8 Should ambient monitoring of air pollutants exceed the following goals, the provisions of Condition E9 shall apply:

(a) CO – 8 hour rolling average of 9.0 ppm (NEPM);
(b) NO_2 – One hour average of 0.12 ppm (245 µg/m3) (NEPM);
(c) PM_{10} – 24 hour average of 50 µg/m^3 (NEPM); and
(d) $PM_{2.5}$ – 24 hour average of 25 µg/m^3 (proposed NEPM).

Table 10 —— Ventilation Outlet Mass Pollutant Concentrations

Pollutant	100 percentile limit	Units of measurement	Averaging period	Reference conditions
Solid particles	1.1	mg/m^3	1 hour, or the minimum sampling period specified in the relevant test method, whichever is the greater	Dry, 273K, 101.3kPa
NO_2 or NO or both, as NO_2 equivalent	20	mg/m^3	1 hour block	Dry, 273K, 101.3kPa
NO_2	2.0	mg/m^3	1 hour block	Dry, 273K, 101.3kPa
CO	40	mg/m^3	1 hour rolling	Dry, 273K, 101.3kPa
VOC (as propane)	1.0	mg/m^3	1 hour rolling	Dry, 273K, 101.3kPa

Appendix 2: Tunnel Ventilation Design Criteria

A2 Tunnel Ventilation Design Requirements

The tunnel M&E Systems are designed to meet a two lane configuration.

A2.1 Design Criteria

A2.1.1 Normal Operation Requirements

During normal operation, the tunnel ventilation system shall maintain:

- In-tunnel air quality; and
- External air quality (via dispersion and net portal inflow).

The operation of the ventilation system during normal mode will be controlled automatically by the tunnel ventilation control system, based on traffic, time of day information and feedback from air monitoring sensors.

A2.1.2 Congested Operation Requirements

During congested operation (below 20kmph), operational measures to restrict traffic entering the affected tunnel shall be implemented in addition to the tunnel ventilation system to maintain:

- In-tunnel air quality; and
- External air quality (via dispersion and net portal inflow).

A2.1.3 Emergency Operation Requirements

During emergency operation, the tunnel ventilation system shall be:

- Capable of performing smoke control by providing a longitudinal air velocity, in line with the critical velocity as determined using the process set out in NFPA 502; and
- Controlled automatically, based on the location of the incident as detected by the fire and control systems).

Emergency Operations, such as smoke control, are designed to provide tenable conditions for emergency egress of tunnel occupants, and also for firefighting personnel (possibly with breathing apparatus) in conducting an emergency response.

This operational mode is not required to meet the Tunnel Air Quality criteria.

A2.1.4 Traffic Density/Fleet Mix

The in tunnel air quality requirements to be achieved (as specified in the Environmental Documents) are to be based upon a peak capacity of 4000 PCU/hr at 60 km/hr. The peak traffic data, traffic densities and fleet mix required for the control of in tunnel air quality is identified in Exhibit A SWTC Appendix 18, Section 1.6(b)(i).

A2.1.5 In-Tunnel Air Quality Limits

In-tunnel air quality limits are identified in the NorthConnex Planning Approval Conditions (January 2015), Tables 5, 6 and 7 (Refer Appendix A)

A2.1.6 Ventilation Outlet Limits

Ventilation outlet limits are identified in the NorthConnex Planning Approval Conditions (January 2015), Table 10. (Refer Appendix A)

A2.1.7 Vehicle Emissions

Vehicle emissions used in the design of the ventilation system are based upon PIARC Road Tunnels Vehicle Emissions and Air Demand for Ventilation (2012R05EN).

A2.1.8 Emission Conversion Factors

NO_2:NOx Ratio

The NO_2 emissions are determined based on a 10% ratio to the PIARC NOx emissions in accordance with Exhibit A SWTC Appendix 18, Section 1.6(b)(iii).

A2.1.9 Visibility to Solid Particle Conversion

The amounts of solid particles present in the tunnel are determined based on an inverse relationship to the PIARC Visibility emissions in accordance with Exhibit A SWTC Appendix 18, Section 1.6(b)(iv).

A2.1.10 VOC:CO Ratio

The amount of VOCs present in the tunnel is determined based on a 10% ratio to the PIARC CO emissions in accordance with Exhibit A SWTC Appendix 18, Section 1.6(b)(v).