WestConnex M4-M5 Link Tunnels

Potential Ventilation System Modifications - CoA E10 Report

M4-M5 LINK MAIN TUNNEL WORKS

Document No.:	M4M5-LSBJ-PRW-GEN-OP10-RPT-0001
Revision:	02
Date:	23/04/2021

Document Control

Title:	**M4-M5 LINK MAIN TUNNEL WORKS** **Potential Ventilation System Modifications - CoA E10 Report**			
Doc. No.	**M4M5-LSBJ-PRW-GEN-OP10-RPT-0001**			
Status:	**Issued for Information**			
Discipline / Department	**Mechanical and Electrical**			
	Name	**Date**	**Position**	**Signed / Approved**
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Document Revisions

Rev No	Date	Issue / Description	Approved
00	**16/12/2020**	**Issued for Information**	
01	**24/02/2021**	**Final Issue**	
02	**23/04/2021**	**Final Issue**	

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Executive Summary

The WestConnex Project is a State Significant Infrastructure project (SSI 7485) for which project approval was granted by the Minister for Planning on 17th April 2018. The approval is subject to a number of conditions, including Ministers Condition of Approval (CoA) E10, which requires the following:

> *All tunnels must be designed and constructed so as to allow for future modification of the ventilation system if required. The Proponent must submit a report to the Secretary demonstrating 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 (as a result of tunnel operation) required in the CoA. Any modifications of the ventilation system may be triggered by CoA E34.

> *Where the operation of the tunnel is identified to be a significant contributor to the recorded above-goal reading, the Report on Above-Goal Recording must include consideration of improvements to the tunnel air quality management system so as to achieve compliance with the ambient air quality goals, including but not limited to installation of the additional ventilation management facilities allowed for under Condition E10.*

This Report demonstrates that the M4-M5 Link tunnel ventilation system has been designed and constructed to allow for future modifications, if required. In doing so, it provides context by:

- discussing the requirements that were addressed in the design and how the design meets commitments made in the Environmental Impact Statement and Submissions Report;
- identifying the basic principles around the operation of the ventilation system;
- providing an overview of possible scenarios that might lead to modifications to the ventilation system being considered;
- identifying non-ventilation system features that will lead to reduced emissions; and
- discussing potential future modifications and whether they are likely to be considered feasible by the owner/operator.

Abbreviations

Abbreviation	Definition
AQCCC	Air Quality Community Consultative Committee
ASBJV	Acciona Samsung Bouygues Joint Venture
CO	Carbon Monoxide
CSSI	Critical State Significant Infrastructure
DPIE	New South Wales Department of Planning, Industry and Environment
EIS	WestConnex M4-M5 Link Environmental Impact Statement
HCV	Heavy commercial vehicle
HDV	Heavy duty vehicle, with a mass of greater than 4.5 tonnes
IMP	Incident Management Procedure
Jet fan niche	Localised increase in tunnel height where jet fans can be installed
LCV	Light commercial vehicle
M&E	Mechanical and Electrical
MCC	Motorway Control Centre
NO2	Nitrogen Dioxide
OMCS	Operations Management and Control System
PCU	Passenger Car Units
PIARC	Permanent International Association of Road Congresses
PV	Private vehicles
SVDS	Smoky Vehicle Detection System
SPIR	Submissions and Preferred Infrastructure Report (Submissions Report) – This report details aspects of the EIS that have changed since the EIS was publicly displayed, and includes refinements to the concept design of the project, in part to minimise its environmental impact, and identify and respond to issues raised and responded to in submissions.
SWTC	Scope of Works and Technical Data
TfNSW	Transport For New South Wales
TMCS	Traffic Management Control System
WRTM	WestConnex Road Traffic Model
WCX	WestConnex

1 Introduction

1.1 Background

WestConnex is one of the NSW Government's key infrastructure projects which aims to ease congestion, create jobs and connect communities. It is the largest integrated transport and urban revitalisation project in Australia. The 33-kilometre project was a key recommendation of the State Infrastructure Strategy released in October 2012. It brings together several important road projects which together form a vital link in Sydney's Orbital Network. They include a widening of the M4 east of Parramatta, a duplication of the M5 East and the M4M5 Link motorway to provide a connection between the ends of the two key corridors at Haberfield and St Peters.

Figure 1 WestConnex Project Map

Figure 1 WestConnex project map

WestConnex will support Sydney's long-term growth and boost the city's economic productivity. It will:

- Provide quicker, more reliable trips between Western Sydney and the Port Botany/Sydney Airport precinct to support Sydney's urban freight task;
- Help distribute traffic across the wider road network, removing bottlenecks and relieving congestion for local trips;
- Provide better connections along the M4 and M5 corridors to cater for the forecast growth in employment and population along these routes; and
- Allow urban revitalisation and increase opportunities for active and public transport along and across Parramatta Road.

The WestConnex project includes a number of stages:

- Stage 1a – M4 Widening
- Stage 1b – New M4
- Stage 2 – M8
- Stage 3a – M4-M5 Link
- Stage 3b – Rozelle Interchange

In August 2018 the M4-M5 Link Group awarded the Acciona (Lend Lease) Samsung Bouygues Joint Venture (ASB JV) the contract for the design and construction of Stage 3A – M4-M5 Link. Development for the purposes of the WestConnex M4-M5 Link Tunnels project being a new multi-lane road link connecting the New M4 project at Haberfield with the M8 project at St Peters comprising:

- new twin multi-lane tunnels between Wattle Street at Haberfield and the St Peters Interchange;
- construction of tunnel ventilation facilities at the Campbell Road motorway operations complex at St Peters; and
- fit out of part of the Parramatta Road ventilation facility at Haberfield (constructed under the New M4 project) for use by the M4-M5 Link.

The inclusion of the M4-M5 Link Tunnels project is part of an overall plan to connect Sydney using WestConnex to the future Rozelle Interchange, Sydney Gateway (surface road) and the F6 which is attached to the M8 at Arncliffe.

Table 1 Interim State

State	Year	M4E Stage 1B	M8 Stage 2	M4-M5 Link Stage 3A	Rozelle Stage 3B	Sydney Gateway	F6 Southern Connector
Interim State 1	2023	✓	✓	✓	×	×	×
Interim State 2	2023	✓	✓	✓	✓	×	× / ✓
Interim State 3	2033	✓	✓	✓	✓	×	×
Interim State 4	2033	✓	✓	✓	✓	✓	✓

1.2 Report Authors

This report has been prepared jointly by James Scandrett; Ventilation Systems Engineer, Tim Kelly; Design Manager, Mechanical Systems, and Andrew Hopkinson; Design Manager, Mechanical and Electrical Systems.

1.3 Purpose of this Report

The purpose of this Potential Future Modification to Tunnel Ventilation System Report (Report), is to demonstrate that the M4-M5 Link tunnel ventilation system has been designed and constructed to allow for modification in the future, if required, under SSI 7485 Infrastructure Approval Condition E10 (E10). E10 states:

All tunnels must be designed and constructed so as to allow for future modification of the ventilation system if required. The Proponent must submit a report to the Secretary demonstrating how this will be allowed for prior to finalising detailed design.

The intention of E10 can be ascertained from the Secretary of the Department of Planning, Industry and Environment's State Significant Infrastructure Assessment: WestConnex M4-M5 Link SSI 7485 (Secretary's Environmental Assessment Report) for the M4-M5 Link Tunnels project which states:

The Department has recommended Conditions of Approval requiring the implementation of an optimisation process, requiring a 5-yearly review of emissions standards and the imposition of more stringent emissions criteria if the review indicates improvements in vehicle emissions and ventilation technology and efficiency.

It has also recommended that the design of the ventilation system allows for future modification, ensuring any changes can be retrofitted with minimal disruption. The report will review:

- The tunnel ventilation design requirements,
- The possible future scenarios when modifications may be considered,
- Other designed systems influencing air quality, and
- The potential future modifications allowed for by the design and a high-level consideration of the likely feasibility of their implementation.

1.4 Summary of the EIS and SPIR Assessment – Air Quality Impact

The Sydney Motorway Corporation (formerly WestConnex Delivery Authority) authorised the preparation and submission of the following documents as part of the approval process:

- M4-M5 Link Environmental Impact Statement August 2017 (M4-M5 Link EIS); and
- M4-M5 Link Submissions and Preferred Infrastructure Report – January 2018 (SPIR). The M4-M5 Link 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 I of the EIS. The assessment was further clarified in Section C9 of the SPIR.

The M4-M5 Link EIS identified that the air quality outcomes for the project were influenced by a number of elements, including:

- Air quality;
- Traffic predictions; and
- Tunnel ventilation design.

This section provides a summary of those system elements.

1.4.1 Air Quality

The M4-M5 Link EIS identified the following key air quality issues (M4-M5 Link EIS, Appendix I, section 3.6):

- Understanding in-tunnel air quality, and the short-term exposure of tunnel users to elevated pollutant concentrations. This relates not only to the exposure of M4-M5 Link tunnel users, but also to the cumulative exposure of users of multiple Sydney tunnels, and notably the New M4 and the M8;
- Understanding the ambient air quality impacts of tunnel ventilation outlets and changes to the surface road network. This includes:
  - Potential improvement in air quality alongside existing surface roads which will have a decrease in traffic volume;
  - Potential deterioration in air quality alongside new surface roads;
  - Potential deterioration in air quality alongside existing roads, which will have an increase in traffic volume;
  - Potential deterioration in air quality in the vicinity of tunnel ventilation outlet.
- Accurate modelling of air quality to inform tunnel ventilation design and management;

- Public understanding of air quality and the magnitude of any project impacts;
- The impacts of the construction of the project.

To manage in-tunnel air quality, the M4-M5 Link EIS noted that the tunnel ventilation system would operate in, and be responsive to, a range of traffic modes including free flowing normal traffic, congested traffic and congested traffic with a lane closure. Modelling for the M4-M5 Link EIS confirmed the tunnel ventilation system design would maintain in-tunnel air quality within operational limits (M4-M5 Link EIS_Vol.1B section 9.7.1).

During congested traffic scenarios, traffic management would be implemented e.g. through the use of variable speed signs or lane closures, and the activation of the mechanical ventilation system which would result in in-tunnel pollution levels which can be maintained at levels below the operational criteria (M4-M5 Link EIS_Vol.1B section 9.7.1).

Impacts to ambient air quality associated with the project were assessed in the M4-M5 Link EIS, including impacts from changes to surface road traffic volumes and contributions from the project ventilation outlets. The assessments found that regional impacts from project related changes to surface road traffic volumes would be negligible, and undetectable in ambient air quality measurements at background locations (M4-M5 Link EIS_Vol.1B section 9.7.2). When assessing the impacts of the project ventilation outlets, the M4-M5 Link EIS modelled impacts to carbon monoxide, nitrogen dioxide, particulate matter (both <10μm and <2.5μm) and air toxicants including benzene, polycyclic aromatic hydrocarbons, formaldehyde and 1,3-butadiene. The model found the tunnel ventilation outlets had a negligible impact to air quality in the vicinity of the project, with other non-project related sources being the predominant source (M4-M5 Link EIS_Vol.1B section 9.7.3).

The following general conclusions have been drawn from this assessment (M4-M5 Link EIS, Appendix I, section 10.2.2):

- The predicted total concentrations of all criteria pollutants at receptors were usually dominated by the existing background contribution
- For some pollutants and metrics (such as annual mean NO_2) there was also predicted to be a significant contribution from the modelled surface road traffic
- Under expected traffic conditions, the predicted contribution of tunnel ventilation outlets to pollutant concentrations was negligible for all receptors
- Any predicted changes in concentration were driven by changes in the traffic volumes on the modelled surface road network, not by the tunnel ventilation outlets
- For air quality some metrics (one hour NO2 and 24 hour PM10), exceedances of the criteria were predicted to occur both with and without the project. However, where this was the case the total numbers of receptors with exceedances decreased slightly with the project and in the cumulative scenarios
- Where increases in pollutant concentrations at receptors were predicted, these were mostly small. A very small proportion of receptors were predicted to have larger increases. However, it is likely that the predictions at these locations were overly conservative
    - o There were predicted to be marked reductions in concentration along Dobroyd Parade / and Parramatta Road to the south-east of the Parramatta Road ventilation station. In

the 2023-DM (Do Minimum) scenario, the traffic to and from the New M4 tunnel would access the tunnel using these roads. In the with-project scenarios, the M4-M5 Link tunnel connects to the New M4 tunnel, thus relieving these roads;

- There was predicted to be a substantial reduction in concentrations along the Victoria Road corridor south of Iron Cove at Rozelle, due to traffic being diverted through the Iron Cove Link tunnel
- There would also be reductions in concentration along General Holmes Drive, Prince Highway and the M5 East
- However, there would be additional traffic (and an increase in pollutant concentrations) to the north of Iron Cove Link and near Anzac Bridge as a result of the general increase in traffic due to the project
- Concentrations were also predicted to increase along Canal Road, which would be used to access St Peters interchange, and other roads associated with the Sydney Gateway project.

1.4.2 Traffic Predictions

Traffic predictions at both 2023 and after 10 years (2033) were undertaken using a screenline analysis methodology. A screenline is an imaginary line on a map, composed of one or more straight line segments. Screenline analysis provides a means of comparing the results of a traffic assignment with traffic count data. This is facilitated by comparing the directional (or bi-directional) sum of traffic count volumes across a screenline with the directional (or bi-directional) sum of the assigned traffic volumes across the same screenline and then computing the ratio of the sums, generally the assigned flow sum to the count sum.

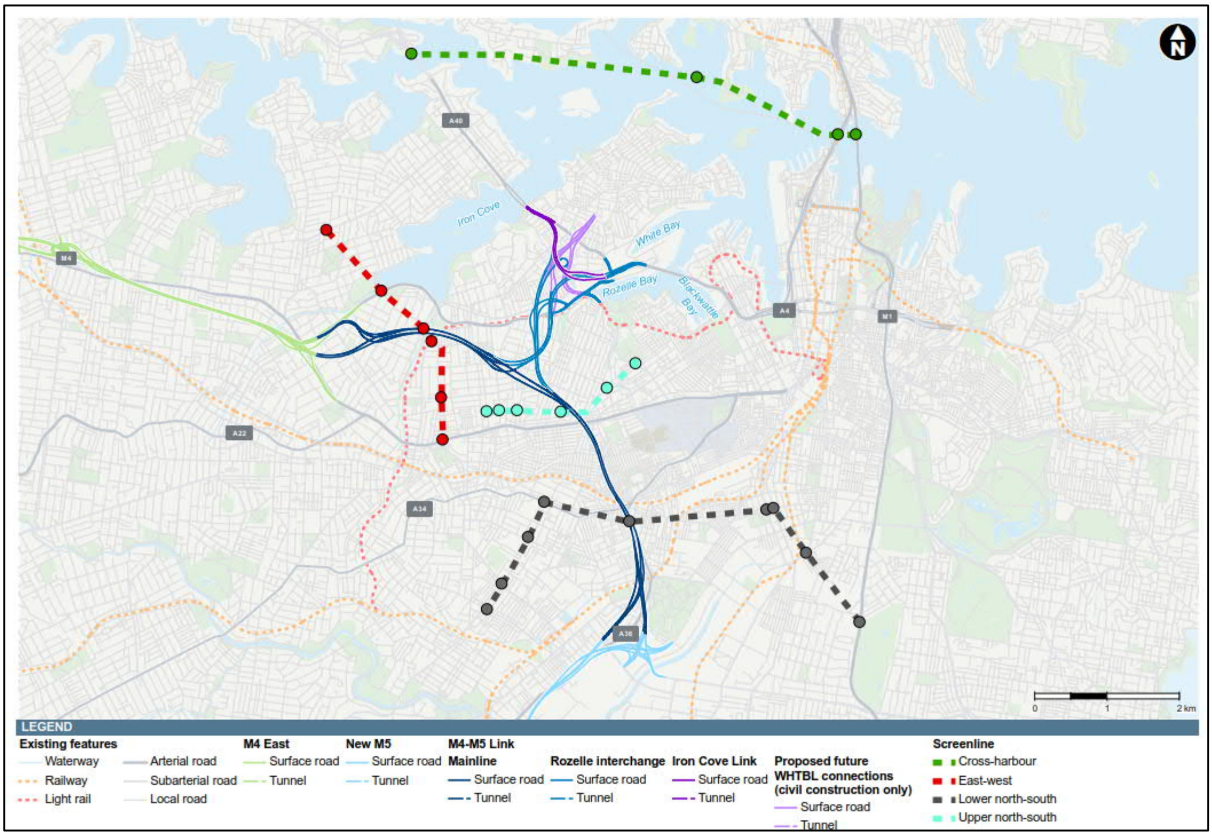
Due to the geographic scale of the project, four screenlines were selected and their locations are indicated on Figure 9-1. They were placed to collectively analyse directional and two-way traffic volume outputs from the different modelling scenarios for each common future year.

- The east–west screenline captures changes in east–west traffic movement and includes a location on the M4-M5 Link mainline between the Wattle Street and Rozelle interchanges, as well as on four parallel corridors (City West Link, Darley Road, Marion Street and Parramatta Road).
- This screenline also includes a location on Lyons Road, which would reflect any changes in traffic using Lyons Road to travel to and from Victoria Road
- The upper north–south screenline captures changes in vehicle travel patterns on north–south links north of Parramatta Road, including Norton Street, Balmain Road, Catherine Street, Johnston Street, Booth Street (north of Pyrmont Bridge Road) and Ross Street (north of Bridge Road). These roads are close to the Rozelle interchange and would display changes in traffic on surface roads as a result of the new road connections at the Rozelle interchange
- The lower north–south screenline includes a location on the M4-M5 Link mainline between the Rozelle interchange and the St Peters interchange, as well as locations on 10 north–south regional connector roads (Stanmore Road, Addison Road, Sydenham Road, Marrickville

Road, King Street, Wyndham Street, Botany Road, Elizabeth Street, South Dowling Street and the Southern Cross Drive)

- The cross-harbour screenline looks at changes in cross-harbour traffic flow on the Sydney Harbour Bridge, Sydney Harbour Tunnel and the Gladesville Bridge. It also includes a location on the proposed future Western Harbour Tunnel and Beaches Link in the 2023 and 2033 'cumulative' scenarios.

Figure 2 EIS Modelled Traffic Data for the M4-M5 Link based on the WestConnex Road Traffic Model Ventilation Design



The results contained in the EIS showed that the completion of the M4-M5 Link tunnels had marginal effect on the local roads (slightly reduced numbers or reduced the traffic growth), however it's not until the full extent of the project is realised where traffic is diverted off the existing harbour tunnel and harbour bridge links that the full benefit is realised.

1.4.3 Ventilation Design

The tunnel ventilation system was outlined in the M4-M5 Link EIS to meet the following criteria:

- Ensure that the air quality inside the tunnels will be maintained at a level that provides a safe environment for tunnel users during normal, maximum traffic flow and minor incident operations (as described in EIS Volume 2C Appendix I);
- The design of the ventilation system within the tunnels would cater for the interface to the M4–M5 Link;
- Ensure that air is exhausted from the tunnels and dispersed in a manner that meets the external air quality goals and limits with no portal emissions in normal operation;

- Provide a safe environment during a major incident or fire that allows all tunnel users to safely evacuate and provide for Fire & Rescue NSW intervention; and
- Ensure a suitable operational interface between the New M4, M8 and the M4–M5 Link ventilation systems.

2 Tunnel Ventilation System Design

2.1 Summary of Ventilation System

The tunnel mechanical and electrical (M&E) systems are designed to meet a minimum two-lane configuration (Stage 3A standalone) based on defined criteria of a maximum traffic volume and speed, and defined emissions data. As detailed in the M4-M5 Link EIS, Volume 2C, Appendix I, the tunnel ventilation system is designed to meet the design criteria as outlined in the EIS. 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 – for longitudinal airflow control within the tunnel;
- Axial fans – for extraction or supply of air within the ventilation station;
- Attenuators - to limit the transmission of noise within the ventilation facilities;
- Dampers – to control the flow path of air; and
- Sensors - to provide feedback to the control system.

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

Most road tunnels built in Australia in the last 20 years have been designed and operated with longitudinal ventilation systems. This type of system has been incorporated into the M4-M5 Link Project. The ventilation system is essentially made up of two components: the longitudinal ventilation system of the carriageway with extraction at a ventilation outlet near the end of each carriageway (refer to Figure 3). The design of the ventilation system incorporates a comprehensive integrated method of automatically sensing traffic flow and speed, 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 and outlet air quality.

The basic function of the tunnel ventilation system is the dilution of vehicle emissions by providing fresh air to, and removing exhaust air from, the tunnel. The movement of vehicles through a tunnel drives air flow, called the ‘piston-effect’, drawing fresh air in through the tunnel entrance, diluting the vehicle exhaust emissions. In short tunnels (up to around 500 metres long) this volume of fresh air is usually adequate to manage in-tunnel air quality. In longer tunnels, under some circumstances, additional air may need to be forced through the tunnel by fans to dilute emissions and maintain appropriate air quality. The M4-M5 Link design includes elevated ventilation outlets and air speed velocities generated by axial fans to disperse tunnel air in a way which meets air quality limits and goals set for the project (see section 3).

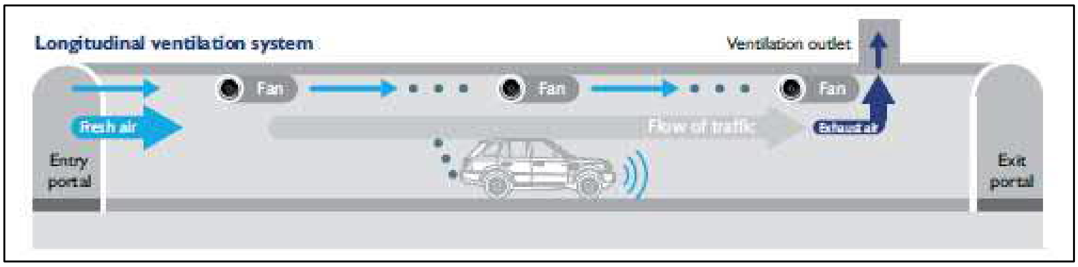
The following ventilation and emergency smoke extraction have been included in the project:

- Wattle St – The Wattle St Building (a part of the overall Parramatta Rd Ventilation Facility) is designed to extract air from the northbound tunnels and ramps; and inject air to the southbound carriageways via ventilation tunnels. The facility consists of two separate buildings, which are dedicated to the supply and exhaust of the eastbound ramps and mainline tunnels only. The exhaust and supply buildings are able to operate as an air exchange (in conjunction with the

New M4 facilities) for the north and southbound tunnels, and as a portal exhaust for the Wattle St Exit Ramp. Further details of the ventilation facilities that were of specific interest to the air quality assessment are provided in the M4-M5 Link EIS, Chapter 10.

- SPI – Campbell Road Ventilation Facility is designed to extract and inject air from and to the southbound tunnels and ramps via ventilation tunnels. The facility consists of two separate buildings, which are dedicated to the supply and exhaust of the southbound ramps and mainline tunnels only. The exhaust and supply buildings are able to operate as an air exchange for the southbound tunnel, and as a portal exhaust for the SPI Exit Ramp. Further details of the ventilation facilities that were of specific interest to the air quality assessment are provided in the M4-M5 Link EIS, Chapter 10.

Figure 3 Longitudinal Ventilation System Schematic



2.1.1 Approved Traffic Data Used

The traffic data that has been used to model air quality for the project is based on WestConnex Road Traffic Model (WRTM). The traffic volumes for the project are based on 2023 "with project" and 2033 "with project" data WRTM Version 2.3. As verified in the M4-M5 Link EIS, the WRTM is underpinned by population and employment projections which are based on the September 2014 land use data release from the Transport for NSW Bureau of Statistics and Analysis.

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' (PCU).

The PCU represents an average vehicle that can be used to determine the maximum number of vehicles that can use the tunnel at the same time. One passenger car corresponds to one PCU. For the purposes of converting a truck/bus into PCU, the heavy goods vehicle (HGV) may be assumed to occupy the space of two passenger cars in free-flowing traffic and up to three passenger cars in slow moving traffic, including uphill grades.

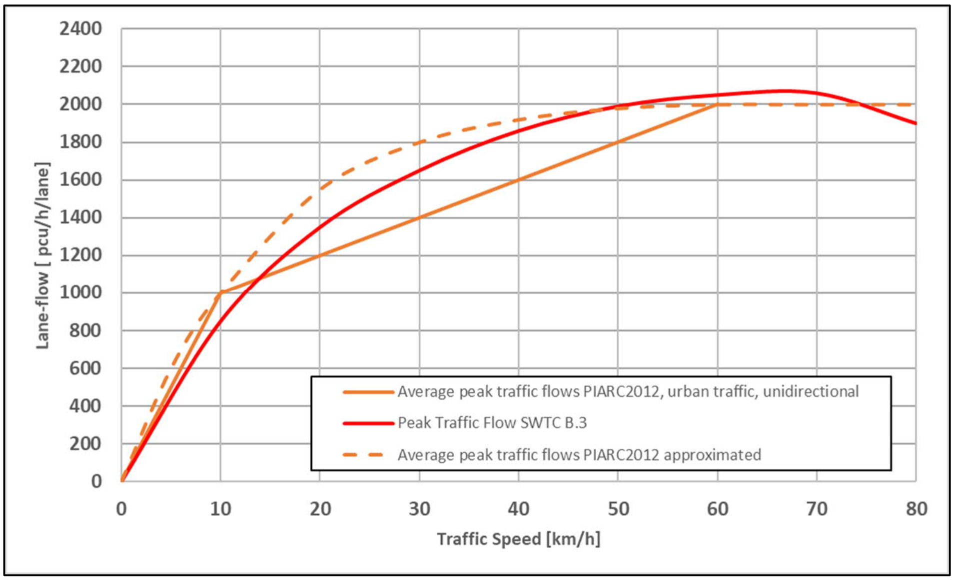
The model was reviewed on behalf of the Roads and Maritime Services by a Peer Review Committee that included representatives from transport planning specialists and academia. The reviewers approved the use of the WRTM for application in the Government's planning and design investigations for WestConnex.

The traffic predictions used for the tunnel are outlined in the M4-M5 Link EIS in Volume 2B, Appendix H Traffic and Transport. Section 4 of this Appendix details the modelling used to derive future year traffic demand for road and intersection locations within the Project Area.

This relationship between the theoretical motorway lane ‘throughput capacity’ and average traffic speed is illustrated in Figure 4. The figure shows that:

- A maximum motorway lane capacity of 2,060 passenger car units per lane per hour is achievable at an average traffic speed of 70km/h. This means that 2,060 passenger car units could pass a fixed monitoring point on a motorway lane every hour if traffic is travelling at 70km/h.
- 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 1860 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 1350 passenger car units per hour. WestConnex Stage 3A mainline tunnels are a minimum of two lanes wide (before Rozelle Interchange is connected), therefore the theoretical capacity of the mainline tunnel is doubled to 4,120 passenger car units per hour.

Figure 4 Relationship between the theoretical motorway the ‘throughput capacity’ and average traffic speed



2.2 Ventilation Design Requirements

The ventilation has been designed in accordance with the Permanent International Association of Road Congresses (PIARC) standard for traffic density adopted throughout, with predicted vehicle emissions and air demand for ventilation (2012R05EN). Australian Standards (AS) referenced in Table 2 have also been included in the design.

Table 2 Australian Standards References in Tunnel Design

Abbreviation	Definition
AS 1668.1	The use of ventilation and air conditioning in buildings, Part 1: Fire and smoke control in multi-compartment buildings
AS 1682	Fire, smoke and air dampers – Specification
AS 1851	Routine service of fire protection systems and equipment
AS/NZS 3580.1.1:2007	Methods for sampling and analysis of ambient air – Guide to siting air monitoring equipment
AS 4100	Steel structures

The tunnel ventilation has been designed to release emissions from the ventilation outlets only, and to avoid emissions from the portals, except for emergency smoke management purposes in the event of a fire in the tunnel and periodic testing or maintenance of the system.

The requirements for tunnel ventilation are determined by the limits of pollutant levels set by regulatory authorities. Pollutant levels are managed by ensuring that the volume of fresh air coming into the tunnel adequately dilutes the pollutants. The air quality limits approved for the project are listed in Annexure A. The tunnel ventilation system is required to ensure that the tunnel will operate with acceptable air quality during differing types of operations. The operating conditions can be divided into the following categories:

- Normal operation – traffic is free flowing;
- Congested operation – traffic is slow moving due to vehicle build up;
- Incident operation – traffic is slow moving or stopped (due to an accident / breakdown or similar) in or beyond the tunnel; and
- Fire operations – these are operations that require the intervention of the Fire Services (e.g. a vehicle fire).

The system is designed to be controlled automatically by the Operations Management and Control System (OMCS) or with a manual override, allowing the operator to intervene and directly control the ventilation system if required.

Key determinates of the ventilation system design were:

1. The predicted number of vehicles and the sensitivity of the predicted numbers;
2. The predicted fleet mix, particularly the fuel type and the proportion of HGV;
3. Predicted air quality in the tunnel and in the outlets prior to dispersion; and
4. The ambient air quality outside the tunnels. First as the source of ‘fresh air’, and secondly as the environment for dispersion of the tunnel air from the ventilation outlets.

2.2.1 Jet Fan Usage

A total of 195 jet fans (98 jet fans southbound, 97 jet fans northbound) are required in the M4-M5 Link tunnel to cope with the design scenarios of from Interim Stage 1 to Interim Stage 4.

As the subsequent stages of WestConnex are added to the network, the requirements on jet fans reduce. This is shown by the modelling analysis performed during detailed design. The following table outlines the predicted maximum percentages of jet fans required to maintain air quality and facilitate safe egress during a fire scenario.

Table 3 Jet Fan Requirements Summary

Interim State	Traffic Case				
	Case 1 Capacity Metered Traffic	Case 2 Design Metered Traffic	Case 3 Capacity Traffic	Case 4 Design Traffic	Case 5 Fire Scenarios
1	27%	1%	82%	56%	24%
2	33%	0%	89%	28%	0%
3	0%	0%	0%	33%	0%
4	32%	0%	86%	42%	14%

The worst-case jet fan requirements correspond to Capacity case traffic scenarios at 20km/h. However the data shows that traffic metering and other traffic controls have the greatest effect on jet fan requirements and subsequently pollution and smoke control. This will be discussed in Chapter 5, Potential Modifications.

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 SWTC maximum traffic throughput of 2060 pcu/hr/lane at 70km/h which the speed is providing the maximum throughput of vehicles per hour. That is, each tunnel mainline carriageway is designed for a minimum of 4120 PCU / hr in Interim Stage 1 configuration.

Based on the traffic mix specified (cars and heavy goods vehicles), this equates to approximately 3400 vehicles per hour per 2-lane tunnel. Note: EIS predicted traffic volumes at 2033 are significantly less than this, in the order of 50%.

On these predicted traffic volumes:

- Under normal free flowing conditions, no jet fans are required to be operated as the traffic induced piston effect provides sufficient ventilation to dilute pollutants.

- Under fully congested conditions the number of jet fans required in the northbopund and southbound tunnels is approximately 170 out of the 196 jet fans installed (89% of the installed capacity during interim state 1).
- The number of jet fans required on subsequent interim states reduces as the induction of fresh air to the M4-M5 link tunnels improves with extra tunnel entry portals being added to the system.

2.2.2 Axial Fan Usage (Exhaust Stations)

Each of the smoke extraction ventilation stations at Wattle St and St Peters used for extraction of smoke or other pollutants in an emergency have axial fans designed in a “n” duty plus one standby configuration. In an emergency, extraction rates will be controlled to maintain tenable conditions within the incident tunnel.

2.2.3 Axial Fan Usage (supply Stations)

Fresh air supply stations Wattle St and St Peters (which are attached to the exhaust stations) perform an exchange function after vitiated air has been removed from the tunnel. The supply vent stations perform normal operation duties as well as an air supply function during emergencies.

2.2.4 Axial Fan Usage (Generally)

Similar to the jet fan usage described above, the installed capacity of the axial fan system is based on the following considerations:

- The PIARC maximum traffic throughput through the tunnels;
- PIARC maximum pollution generated in the tunnels;
- Smoke exhaust requirements through the tunnel;
- SWTC Requirements; and
- Civil Aviation Safety Authority (CASA) limitations for each of the exhaust ventilation stations.

2.3 Tunnel Alignment Design

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

The tunnel connects the existing M8 Tunnel at St Peters to the Existing M4E Tunnel at Haberfield. The tunnel provides free flow mainline to mainline connections to both precincts and future connection to M4E, M8 and Sydney Gateway.

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

- Topographical level difference between the St Peters Interchange connection to the Haberfield connection at the New M4 end;
- Connection of the exit ramps at St Peters and Wattle St; and
- Placing the tunnels below rock fissures reducing the impact to tunnel lining and support.

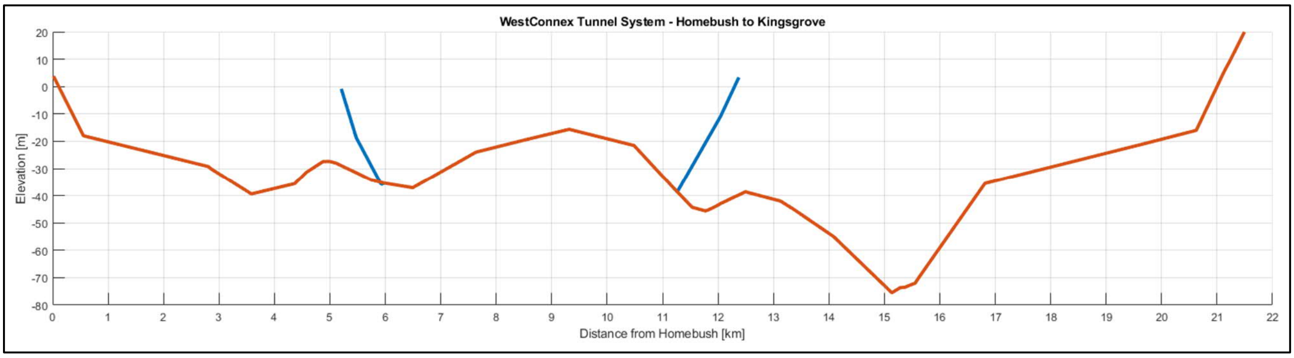
The effect of the tunnel gradient on the vehicle emissions did not dominate jet fan design. Additional jet fans are required in the westbound tunnel to draw air down the entry ramps at St Peters and Haberfield which are up to a 7% gradient.

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 HGV;
3. Air quality in the tunnel, and in the outlets prior to dispersion;
4. The heat release rate and location of potential worst-case fires in the tunnel;
5. 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 HGV to the remaining vehicles. The tunnel ventilation design adopts the PIARC recommendation of a maximum theoretical throughput 2060 PCU/hr at 70 km/h for each carriageway eastbound and westbound.

Figure 5 Relationship between the tunnel height and tunnel length (Homebush to Kingsgrove)



3 Potential Above-Goal Reading or Exceedance Events

The tunnel ventilation system has been designed to achieve compliance with in-tunnel, ambient and ventilation outlet air quality limits and goals identified in the Minsters Condition of Approval (CoA). These are set out in conditions E3, E4, E5, E6, E2A. While it is not anticipated that there will be exceedances of these limits and goals (caused by the tunnel), there are two types of variables that might cause exceedances:

1. Events / incidents which lead to short term exceedances, or
2. Inaccuracies in the models upon which the design is based which might lead to regular and ongoing exceedances because the design was based on incorrect modelling data.

It should be noted that the data and modelling undertaken for the EIS has been conservative, extremely rigorous and has involved multiple independent and expert reviews. It is considered highly unlikely that the potential modelling inaccuracies identified will materialise. The Secretary of the Department of Planning, Industry & 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 M4-M5 Link. The Final Review Report was provided to the Secretary on 29 January 2016.

The advice concluded that the M4-M5 Link EIS:

"constitutes a thorough review of high quality. It covers all of the major issues and areas that an EIS of this scale should. The information presented is of suitable detail and logical in order. The choices made regarding data used and methods followed have been logical and reasonable and it is our view that the benefit of exploring alternative approaches would be questionable or marginal."

Events (including natural events) or incidents that might cause short term exceedances could include:

- Severe traffic congestion within the tunnel or downstream of motorway / tunnel in holidays or other periods;
- Major traffic incidents, either within the tunnel or external to the tunnel, blocking lanes and causing prolonged congestion and slowing of traffic;
- Bushfires;
- Dust storms; and
- Adverse weather patterns (thermal inversions that may affect air dispersion).

Inaccuracies in the models, upon which the design is based, and which might lead to regular and ongoing exceedances, are considered highly unlikely however could potentially include:

- Vehicle emissions being substantially different from the design assumptions, either from changes in the fleet mix, changes in assumed heavy vehicle volumes or fuel types;
- Tunnel traffic volumes being different from the ventilation design assumptions;

- Incorrect inputs in the air quality modelling undertaken during the EIS or in accordance with condition E41.

A summary of potential causes of exceedances, in accordance with E6 and E2A, and impacts for the project because of the cause are outlined in Table 4 Potential Impacts Summary

Table 4 Potential Impacts Summary

Potential cause of exceedances	Potential Impact Summary	Comments
Severe traffic congestion within the tunnel or downstream of motorway / tunnel in holidays or other periods.	Congestion and slower traffic speeds lead to sub-optimal operation of the piston effect, and therefore reduced air quality.	The current tunnel ventilation system design is capable of managing this type of event.
Major traffic incidents, either within the tunnel or external to the tunnel, blocking lanes and causing prolonged congestion and slowing of traffic	Congestion and slower traffic speeds lead to sub-optimal operation of the piston effect, and therefore reduced air quality.	The current tunnel ventilation system design is capable of managing this type of event.
Bushfires	Quality of ambient air and air entering the tunnel is poorer.	Bushfires are an external event which may impact on the operation of the tunnel. There are no design implications other than potential tunnel closure for safety reasons if too much bushfire smoke enters the tunnel.
Dust storms/events	Quality of ambient air and air entering the tunnel is poorer.	Dust storms/events are an external event which may impact on the operation of the tunnel. There are no design implications other than potential tunnel closure for such a scenario.
Adverse weather patterns (thermal inversions that may affect air dispersion)	Not achieving the predicted dispersion from ventilation outlets.	Dispersion modelling considered an extensive range of meteorological conditions including adverse weather patterns. The results of the modelling indicated that ambient air quality criteria would be met.
Vehicle emissions being substantially different from the design assumptions, either from changes in the fleet mix, changes in assumed heavy vehicle volumes or fuel types	Higher than predicted inputs of pollutants, placing greater demand on the ventilation system than modelled.	The only likely impact in this case would be in-tunnel air quality. The ventilation outlets have been designed and shown to adequately disperse emissions at levels much greater than the predicted emissions levels form vehicles using the tunnels
Tunnel traffic volumes being different from the ventilation design assumptions	Higher than predicted inputs of pollutants, placing greater demand on the ventilation system than modelled.	The only likely impact in this case would be in-tunnel air quality. The ventilation outlets have been designed and shown to adequately disperse emissions at levels much greater than the predicted emission levels from vehicles using the tunnels.

Potential cause of exceedances	Potential Impact Summary	Comments
Incorrect inputs in the air quality modelling undertaken during the EIS or in accordance with condition B3	Not achieving the predicted dispersion from ventilation outlets.	The ventilation outlets have been designed and based not only on modelling but also on practical experience and shown to adequately disperse emissions.

3.1 Monitoring and Reporting of Exceedances

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 Conditions E29A and E31.

Similar monitoring, notification and reporting are required for the ventilation outlets as detailed in Conditions E19A and E34. Note, Condition E37 requires engagement of a person independent from the design and construction of the CSSI, to audit the air quality monitoring (in-tunnel and ambient) for the CSSI at six (6) monthly intervals following commencement of operation of the CSSI, or at any longer interval if approved by the Secretary.

Ambient air quality goals are detailed in Condition E6, with notification and reporting requirements detailed in Condition E32.

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

1. The nature of the event, including details relating to the cause;
2. The duration of the event;
3. The extent and severity of the event;
4. The measures employed to minimise the concentration levels or to improve the visibility levels in the event that visibility levels were above the specified limit; and
5. The frequency of the event, including whether an event with the same or similar circumstances has occurred previously.

Based on an assessment of the circumstances, the Secretary may request a Tunnel Air Quality Management Systems Effectiveness Report, in accordance with E31. This ‘Systems Effectiveness’ Report is to detail:

- Overall performance and concentration levels in the tunnel for the preceding six-month period (or since commencement of operation, where the SSI has operated for under six-months), including average and maximum levels and the respective time periods;
- Details of any instances throughout operation of the SSI where pollutant concentration levels in the tunnel have exceeded the limits specified in conditions E3, E4, E5; and
- Consideration of improvements to the tunnel air quality management system.

4 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:

- NSW Cleaner Vehicles and Fuels Strategy (Department of Environment and Climate Change, 2008) including vapour recovery at service station, stricter emissions levels, alternative fuels and the Diesel Retrofit Program;
- Smoky Vehicle Detection Program – an initiative under the NSW Cleaner Vehicles and Fuel Strategy which aims to reduce vehicle emissions by ensuring that owners properly maintain their vehicles. A smoky vehicle is regarded as any motor vehicle that emits visible smoke continuously for over 10 seconds. Under NSW environmental legislation, it is an offence for a vehicle to emit visible air impurities for more than 10 seconds.
  - The WestConnex tunnels include provisions for the implementation of the Smoky Vehicle Detection System (SVDS). The SVDS uses a number of photo electronic devices and sophisticated software to trigger the detection and subsequent photographing and identification of medium to heavy diesel-powered vehicles emitting visible particulates in their exhaust gases (smoky vehicles). The detection system is restricted to identifying those with a gross vehicle mass of 4.5 tonnes or greater, all of which are required by law in NSW to have vertical exhaust stacks. The system is designed to reduce emissions from the in-service fleet, and is a source of emissions design control program;
- Adoption of Australian Design Rules governing on-road motor vehicle emission limits which have been progressively tightened based on United States and European standards, this includes 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.
  - The Traffic Management Control System (TMCS) is part of the Operations Management and Control Systems (OMCS) and is the system responsible for all traffic related control and monitoring. The TMCS devices are designed to be operated manually and / or automatically and can be used to manage traffic in a way which controls air quality. The TMCS will be used in accordance with the Tunnel Ventilation Incident Response and Traffic Management System Integration Protocol.

5 Modification Concepts

5.1 Summary of Main Ventilation Requirements

There are three main ventilation requirements:

- Maintain air quality below certain limits during normal operation;
- Ensure no net portal emissions during normal operation; and
- Ensure “critical velocity” during fire operation.

In the current ventilation design, the main ventilation requirements are being achieved as following:

- Air quality
  The air quality is being kept below defined limits by ensuring minimal air speeds in the tunnel to the extraction points. The minimum airspeeds are achieved by longitudinal ventilation via jet fans.
- No net portal emissions
  No net portal emissions are ensured by extracting all the air from the carriageway through the ventilation outlets with air being drawn in to the tunnel through the exit portals.
- Critical velocity
  Critical velocity is achieved by sufficiently accelerating the air by means of jet fans and smoke extraction facilities.

5.2 Considerations for Ventilation Modifications

Notwithstanding the robust design of the ventilation system, the intent of E10 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.

A classification of the potential future modification is therefore useful. Generally, the rule applies that a more cost-intensive solution also provides a better outcome on the ventilation requirements. 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.

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.

5.3 Constraints on Potential Modifications

The constraints associated with the civil and associated services design would also need to be considered. Several of these are either not feasible 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 at the entry portals St Peters and Haberfield;
- 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. No allowances have been made in the maximum demand for any future modifications to the ventilation system
- Capacity of switchgear and control gear, transformers, busducts and cables to be assessed prior to any modifications
- HV system studies including load flow, voltage regulation, fault analysis and power quality analysis must be carried out prior to any modifications
- Available floor space in switchrooms, pits and conduits for any additional equipment
- Limits on the spacing of longitudinal jet fans due to in-tunnel noise limitations (for audibility and intelligibility) and proximity to existing tunnel devices.

5.4 Assessment Methodology of the Potential Modifications

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

- Can the proposed modification be readily implemented;
- 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;
- A broad qualitative ranking of costs. This has been assessed only as low, medium, or high with potential timeframes and additional approvals that may be required;
- Can the current ventilation system design be modified or augmented in the future and outline in what form; and
- A qualitative assessment on the capability to implement the potential modification.

This broad assessment has been provided with each potential modification described.

6 Potential Modifications

A number of potential modifications have been identified that are capable of improving the air quality, in the event that systemic exceedances in the air quality criteria occurs due to the operation of the tunnel. These include:

- Installation and operation of higher capacity or additional jet fans;
- Additional Capacity of Outlet Axial Fans;
- Tunnel Air Filtration; and
- Modification of Air Quality Goals

The Secretary's Environmental Assessment Report recommended that the design of the ventilation system allow for future potential modification if required that can be retrofitted with minimal disruption (State Significant Infrastructure Assessment: M4-M5 Link Environmental Assessment Report, pg. 63).

Each of these potential modifications are described below and have been deemed feasible on the basis that they could be retrofitted and/or applied with minimal disruption. The following factors have been considered in the analysis of their feasibility:

1. Effectiveness (estimated) on tunnel ventilation;
2. Impact to (tunnel) operation;
3. Technical constraints and limitations (feasibility); and
4. Cost.

The analyses in the below section is high level and indicative only. A full analysis of all relevant factors would need to be undertaken by the parties that are contemplating making modifications to the ventilation system.

6.1 Potential Modification #1 – Higher Capacity or Additional Jet Fans

This potential modification would require the provision of additional jet fans, or jet fans with increased capacity, within the tunnels to improve longitudinal air flow control.

Additional 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 per hour increases beyond the design assumptions (based on the nominated fleet mix).

The following modifications to jet fans within the tunnel may be implemented for the M4-M5 Link Tunnels project:

a) Increasing the size of the jet fans:

With the application of a new jet fan size, the longitudinal ventilation capacity (thrust) can be increased. This will marginally reduce the concentration of pollution in the tunnel, however it will require extensive cabling and coordination works to locate the larger units on site.

b) New jet fan niches:

Additional jet fan niches can be constructed, where further jet fans can be installed (e.g. cut and cover structures, merges and diverges). This offers the benefit of a localised increase of longitudinal vent capacity (increasing the flow rate and reducing concentration). This option is limited to certain areas of the tunnel, since some tunnel sections do not offer enough space to provide additional niches due to other already existing M&E equipment.

6.1.1 Assessment – Upgrade of jet fan size

Upgrade of the jet fan type involves installing a larger unit into the tunnel to increase the thrust. The existing jet fan is a 1250mm diameter unit. Theoretically in some locations where the soffit height is larger, a 1400mm diameter banana jet fan may be installed. Where a larger capacity jet fan can be installed, this may result in a 25% improvement in the individual thrust of the jet fan.

An upgrade to the electrical switch room and cables from the circuit breaker would be required due to the extra power demand for the 1400mm diameter jet fan/s. Subject to design, power from a substation (above ground or within the tunnel) would be required, and longer lengths of cable from the surface to within the tunnel, with an increased cable size.

Estimated effect: medium

Impact to operations: high

Feasibility: medium

Cost: medium

6.1.2 Assessment – New jet fan niches utilising localised enlargements

Jet fans may also be installed in localised enlargements where no or minimal civil works are required. General areas where this may be achieved are the four-lane sections of tunnel between the Rozelle Interchange large caverns and the Caverns at St Peters and Haberfield. Jet fans installed in these sections would be able to provide thrust for the mainline and ramp connections of the Stage 3A tunnel system.

The installation of new Jet fan niches is however very inefficient as the quantity of jet fans required to increase the in-tunnel velocity by 10% is in the order of 30% more than the existing quantity of fans.

Additional jet fan niches can be constructed, where further jet fans can be installed. However, this option is limited to certain areas of the tunnel, since some tunnel sections do not offer enough space to provide additional niches due to other already existing M&E equipment.

Estimated effect:	medium
Impact to operations:	high
Feasibility:	medium
Cost:	medium

6.2 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. This would be required if the fleet mix increases the vehicle emissions, or the number of vehicles per hour increases beyond the design assumptions (based on the nominated fleet mix).A higher airflow rate would then be required 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 9.0% heavy vehicles per day from 2012 to 2021. The daily fleet mix is expected to vary from hour to hour with the worst-case fleet mix for ventilation occurring during the respective AM and PM peaks.

The following operational modifications can be implemented:

a) Utilisation of redundant fan:

All the ventilation facilities are equipped with a redundant fan, which could be used, if available (design of power supply allows for approx. 20% additional power). This option can only be considered as a temporary solution and cannot be relied upon for a permanent state of operation, since it cannot be guaranteed that the redundant fan is available at any time.

b) Operate ventilation equipment (fans) beyond nominal speed:

The ventilation equipment can be operated beyond the nominal speed (design of power supply allows for approx. 20% additional power). This option should only be considered as a temporary solution and cannot be relied upon for a permanent state of operation, since the design life of the equipment may be shortened.

6.2.1 Assessment – Upgrade axial fans

Retrofitting new motors or larger axial fans may be feasible subject to spatial conditions. The following points ordered in ease of implementation outline the options that may be undertaken:

- retrofitting higher capacity fans at Wattle St exhaust building;
- supplying an additional fan at Wattle St supply building;
- retrofitting larger and higher capacity fans at St Peters exhaust building;
- retrofitting larger and higher capacity fans at St Peters supply building;

As described in Section 2, the design of a tunnel ventilation system requires an extensive process involving several critical processes. As modification of the asset involves changes that are outside the scope of the Scope of Works and Technical Requirements (SWTC) and Ministers Conditions, a modification to the EIS is required and CASA will have to be notified of changes to the nature of the ventilation outlets.

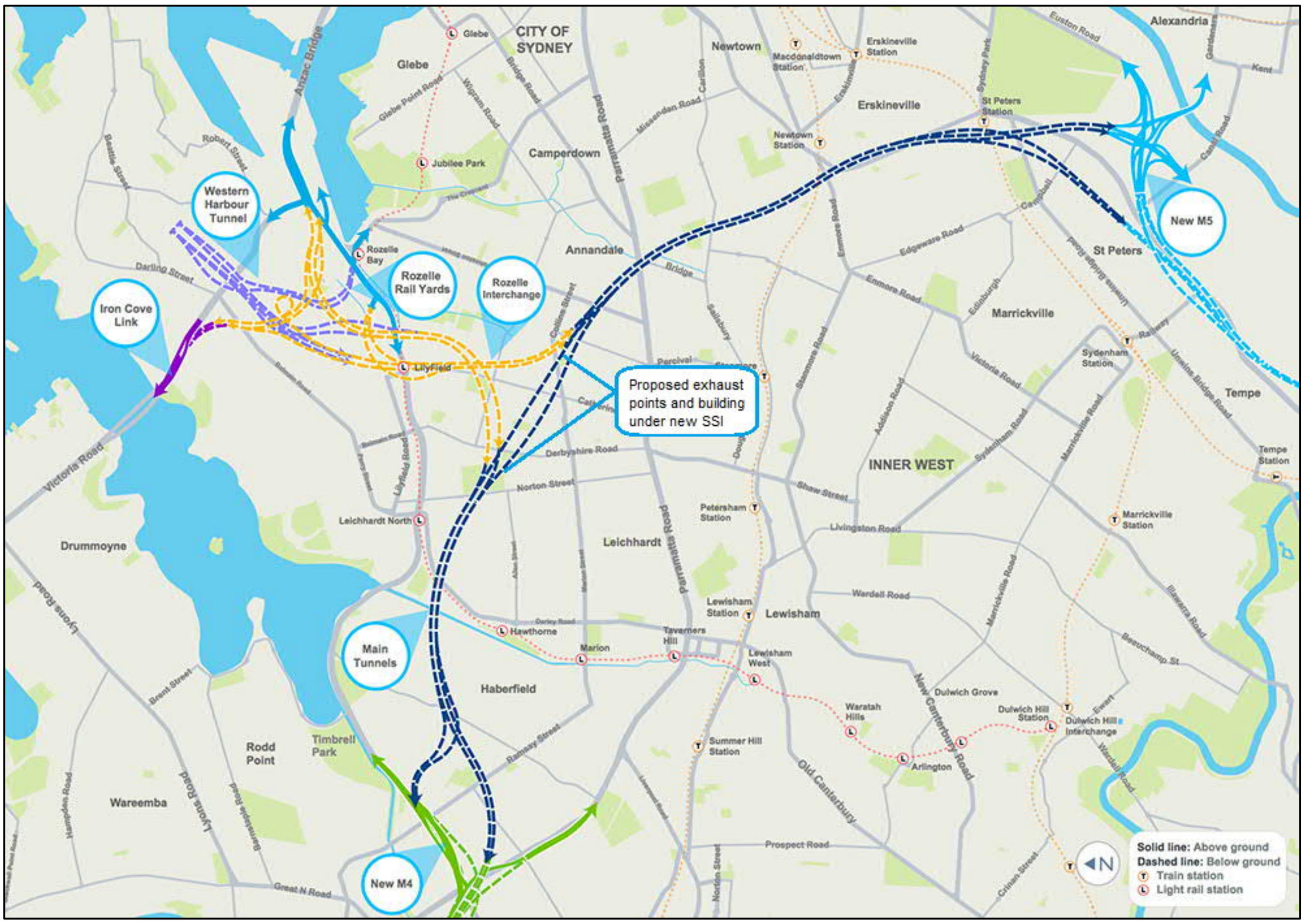
Estimated effect:	medium-high
Impact to operations:	medium
Feasibility:	medium-high

Costs: very-low

6.3 Potential Modification #3 – Installation of additional facilities at Annandale

Where the air quality goals may change due to new legislation, a possible solution to meet compliance would be to add an exhaust facility at the Rozelle Interchange ramps within the M4-M5 Link mainline tunnels. This option involves extracting air just prior to the two merge points in the northbound and southbound tunnels and relying on the connections at Rozelle to draw in extra fresh air down the relatively short entry ramps.

Figure 6 Potential Future Modification – Installation of Mid Tunnel Exhaust Points



Placement of the ventilation building would also have its own limitations, with public space available in the Annandale area at a minimum and a significant amount of public disruption. The installation of a new exhaust building would also be under a new State Significant Infrastructure application.

Estimated effect: High

Impact to operations: Medium

Feasibility: Medium

Costs: High

6.4 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 another Sydney tunnel project (NorthConnex Submissions and Preferred Infrastructure Report), these filtration types have mixed success, with electrostatic precipitation used to address issues with visibility in road tunnels. The limitations to filtration systems are that they target specific pollutants, however are not able to remove all or the full range of road tunnel pollutants. It may address specific localised air quality issues, however, it is not a complete treatment.

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 points 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 NO_X treatment downstream;
- If located below ground, a large cavern would be required to house the equipment, both for electrostatic precipitation, and a downstream NO_X treatment (for assessment purposes, assumed to be an activated carbon filter 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 Bexley and Arncliffe.

The WestConnex 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 Bexley and Arncliffe. This would need to be combined with managed tunnel closures to implement the interface works, the upgrade of power supplies, system controls, and cabling.

6.4.1 Assessment of modification – Tunnel Air Filtration

The technical benefit and feasibility of implementing filtration for the ventilation system was reviewed in the EIS in Appendix H and determined that:

The provision of a tunnel filtration system does not represent a feasible and reasonable mitigation measure and is not being proposed. The reasons for this are as follows:

- The project's in-tunnel air pollutant levels, which are comparable to best practice and accepted elsewhere in Australia and throughout the world, would be achieved without filtration
- Emissions from the ventilation outlets of the project tunnel will have a negligible impact on existing ambient pollutant concentrations
- Of the systems that have been installed, the majority have subsequently been switched off or are currently being operated infrequently
- Incorporating filtration to the ventilation outlets would require a significant increase in the size of the tunnel facilities to accommodate the equipment. It would result in increased project size, community footprint, and capital cost. The energy usage would be substantial and does not represent a sustainable approach.

If in-tunnel air quality levels cannot be achieved with the proposed ventilation system, the most effective solution would be the introduction of additional ventilation outlets and additional air supply locations. This is a proven solution and more sustainable and reliable than tunnel filtration systems.

The Secretary's Environmental Assessment Report also found that:

A number of community and local government council submissions requested that the proposal be modified to include filtration. Based on the predicted air quality outcomes and low risks to human health, the Department is satisfied that the proposed ventilation management system would provide for appropriate local air quality outcomes. In addition, the Department considers that there are alternate cost-effective government initiatives to filtration that would help manage emissions from the proposal and also go towards addressing surface road emissions including:

- NSW Cleaner Vehicles and Fuels Strategy (Department of Environment and Climate Change, 2008) including vapour recovery at service stations, stricter emission levels and the Diesel Retrofit Program;
- Smoky Vehicle Enforcement Project is an initiative under the NSW Cleaner Vehicles and Fuels Strategy comprising fines for operators of smoky vehicles; and
- Adoption of Australian Design Rules governing on-road motor vehicle emission limits which have been progressively tightened based on United States and European standards

Filtration would incur a high financial cost to implement and require an increase in the project size, community footprint and capital costs. Additional energy would be required to operate the additional filtration equipment, increasing the projects greenhouse gas emissions. It would require modifications to the existing planning approval and disrupt tunnel users during its installation, as well as disrupting residents surrounding the current ventilation facilities as they were upgraded to allow for the extra equipment.

Estimated effect:	Low
Impact to operations:	Medium
Feasibility:	Medium
Costs:	High

6.5 Potential Modification #5 – Modification of Air Quality Goals

The tunnel air quality limits (reproduced in Appendix 1) are limits prescribed by the minister in consultation with the EPA during the approval of the SSI. Ventilation goals are put in place to prevent the limits from being exceeded. During design of the tunnel ventilation system, the goals are set to minimise the pollution in the tunnel and are programmed into the control system.

The following modifications can be implemented to reduce power consumption:

- Optimisation of ventilation goals with corresponding set-points and limits,
- Allow for portal emissions or increase the air-quality thresholds to optimise power consumption based on actual traffic and emissions, once the tunnel is under operation.

6.5.1 Assessment – Modification of Air Quality Goals

Optimisation of the ventilation system normally occurs during commissioning; however major gains can be made after the tunnel is opened for traffic and the operator has become comfortable with the operation of the ventilation system.

The most gains can be made with the allowance for partial or complete portal emissions. This requires approval from the Secretary and evidence of a substantial decrease in overall emissions that may be possible with a change in vehicle fleet.

Estimated effect:	High
Impact to operations:	Very-low
Feasibility:	Medium
Costs:	Very-low

7 Potential Modifications Summary

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

7.1 Potential Modifications

7.1.1 Network Modifications

The following network modifications are suggested for consideration:

a) Include the Rozelle Interchange Carriageways into the existing WestConnex network at the earliest possible date. The addition of exit and entry ramps facilitates extra fresh air exchanges which reduce the normal operational requirements on jet fans.
b) Provide a mid-point exhaust facility to remove vitiated air from the M4-M5 Link mainline tunnels prior to the tunnel merge points.

7.1.2 Operational Modifications

The following operational practices are suggested for consideration:

a) Increase usage of plant equipment (axial fans and tunnel jet fans). The fans are based on a tunnel vehicle capacity of 4120 PCU / hr at 70 km/h for each mainline tunnel. This far exceeds the predicted traffic volumes in the EIS;
b) Extract additional air from the ventilation outlets by using all the installed fans during short peak periods; and
c) 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.

7.1.3 Additional Equipment

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

a) 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);
b) Modification # 2 - investigate the most effective method of increasing the tunnel air flow by increasing the capacity of the axial fans within the existing ventilation outlets. Install an additional Supply axial fan in the Wattle St Facility.

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.

7.1.4 Conversion of Existing Facilities

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

7.1.5 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). Detailed 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.

7.2 Summary of Modifications

A summary of the ways in which each modification may be used to address air quality exceedances is summarised in Table 5.

Table 5 Potential modification to ventilation system if the operation of the tunnel is identified as a significant contributor

	Potential Impact Summary				
Air Quality Exceedance Type	**Installation and operation of higher capacity or additional jet fans**	**Additional Capacity of Outlet Axial Fans**	**Construction of new exhaust facility at Annandale**	**Tunnel Air Filtration**	**Modification of Air Quality Goals**
In-tunnel	✓	✓	✓	✓	✓
Ventilation Outlet	✓	✓	✓	✓	✓
Ambient	✓	✓	✓	✓	

The feasibility of each potential modification has been discussed above, and a high-level summary of the impacts assessed for each modification has been summarised in Table 6.

Table 6 Ranking of modifications

Potential Future Modification	**Effectiveness**	**Impact to Operations**	**Feasibility**	**Cost**	**Rank**
#1 – Higher Capacity or Additional Jet Fans	Medium	High	Medium	Medium	2
#2 – Additional Capacity of Outlet Axial Fans	Med-High	Medium	Med-high	Low	1
#3 – Construction of exhaust air facility at Annandale	High	Medium	Medium	High	3
#4 – Tunnel Air Filtration	Low	Medium	Medium	High	5
#5 – Modification of Air Quality Goals	High	Very-low	Medium	Very-low	4

8 Conclusion

The M4-M5 Link tunnel ventilation system has been designed in accordance with the SWTC and internationally recognised tunnel ventilation standards, namely the PIARC for traffic density and throughput, with predicted vehicle emissions applicable to Australia, PIARC 'Road Tunnels: Vehicle Emissions and Air Demand for Ventilation' (2012R05EN), in order to meet strict air quality goals and limits set out in the Conditions of Approval. The predicted traffic volumes used to model the requirements of the ventilation system have been prepared by the State Government and have been peer reviewed and found by that review to be appropriate for use in the design and planning of the M4-M5 Link Project.

A number of modifications to the M4-M5 Link tunnel ventilation system have been considered and assessed. This Report therefore demonstrates that the tunnel ventilation system has been designed and constructed to allow for future modification, if required. The modifications within Section 5 and 6 could be implemented in the future in the unlikely event that the Project is found to be a significant contributor to exceedances of in-tunnel, ventilation outlet or ambient air quality goals and/or limits.

The modifications identified within Section 6 would require design and modelling, and would cause disruption if implemented, but have not been excluded by the design and construction of the Project.

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

Appendices

Appendix A

Approved Air Quality Limits for WestConnex M4-M5 Link Project

Appendix A - Approved Air Quality Limits for WestConnex M4-M5 Link Project

A.1. In Tunnel Air Quality – Limits

E3 The tunnel ventilation system must be designed and operated so that the average concentrations of CO and NO2, calculated along the length of the tunnel, do not exceed the concentration limit specified for that pollutant in Table 7.

Table 7 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
NO2	0.5	ppm	Rolling 15-minute

A.2. In Tunnel single Point Exposure Limits

E4 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 8under all traffic scenarios.

Table 8 In-tunnel single point exposure limits

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

A.3. In Tunnel Visibility Limits

E5 The tunnel ventilation system must be designed and operated so that the visibility in the tunnel does not exceed the level specified in Table 9.

Table 9 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

A.4. Ambient Air Quality Goals

E6 Should ambient monitoring of air pollutants exceed the following goals, the provisions of Conditions E32, E33 and E34 will apply:

a) CO – 8 hour rolling average of 9.0 ppm (NEPM);
b) NO2 – One hour average of 0.12 ppm (245 µg/m3) (NEPM);

c) PM10 – 24 hour average of 50 µg/m3 (NEPM);
d) PM2.5 – 24 hour average of 25 µg/m3 (NEPM);
e) PM10 – annual average of 25 µg/m3 (NEPM); and
f) PM2.5 – annual average of 8 µg/m3 (NEPM).

A.5. Ventilation Outlet Mass Pollutant Concentrations

E2A The concentration of a pollutant discharged from the ventilation outlets must not exceed the respective limits specified for that pollutant in

Table 10 Ventilation Outlet Mass Pollutant Concentrations

Pollutant	10 Percentile limit	Units of measurements	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)	4.0	mg/m^3	1 hour rolling	Dry, 273K, 101.3kPa