2.7.2 Scope of the operational air quality impact assessment

The project has been reviewed to identify potential air emissions sources during operation of the project. As part of the review, consideration has been given to the significance of the particular emissions source, and whether it may be directly or indirectly associated with the project. Emissions sources relevant to the operation of the project include:

- Emissions from the project tunnels, through the northern and southern ventilation outlets, under normal operating conditions.
- Changes in air quality associated with changes in surface traffic.
- Emissions from the project during emergency operations.

Air emissions from the project tunnels (normal operation)

The air quality impact assessments for the project have included consideration of emissions from the northern and southern ventilation outlets during normal operations. No other emissions would occur from the project tunnels.

The project has been designed to operate without portal emissions. Approval is currently not being sought to allow portal emissions, and the air quality impact assessment has therefore not included consideration of portals as an emissions source. If portal emissions are contemplated in the future, such as if vehicle emissions reduce or the number of electric or low emission vehicles increase, an appropriate air quality impact assessment would be conducted at that time.

Air emissions from surface roads

Based on a review of forecast surface traffic changes in 2019 and 2029, including the data presented in **Section 2.7.1** of this report, the extent of surface roads considered as part of the air quality impact assessment has been delineated as shown in **Figure 2-4**. The surface roads shown in **Figure 2-4** are considered to be those along which changes in traffic flows as a consequence of the project are likely to be material to the air quality impact assessment. While there is potential for changes in traffic volumes and distribution beyond this boundary, the likely effect of these changes in the context of the air quality implications of the project would be minimal and not sufficient to materially affect the outcomes of the air quality impact assessment.

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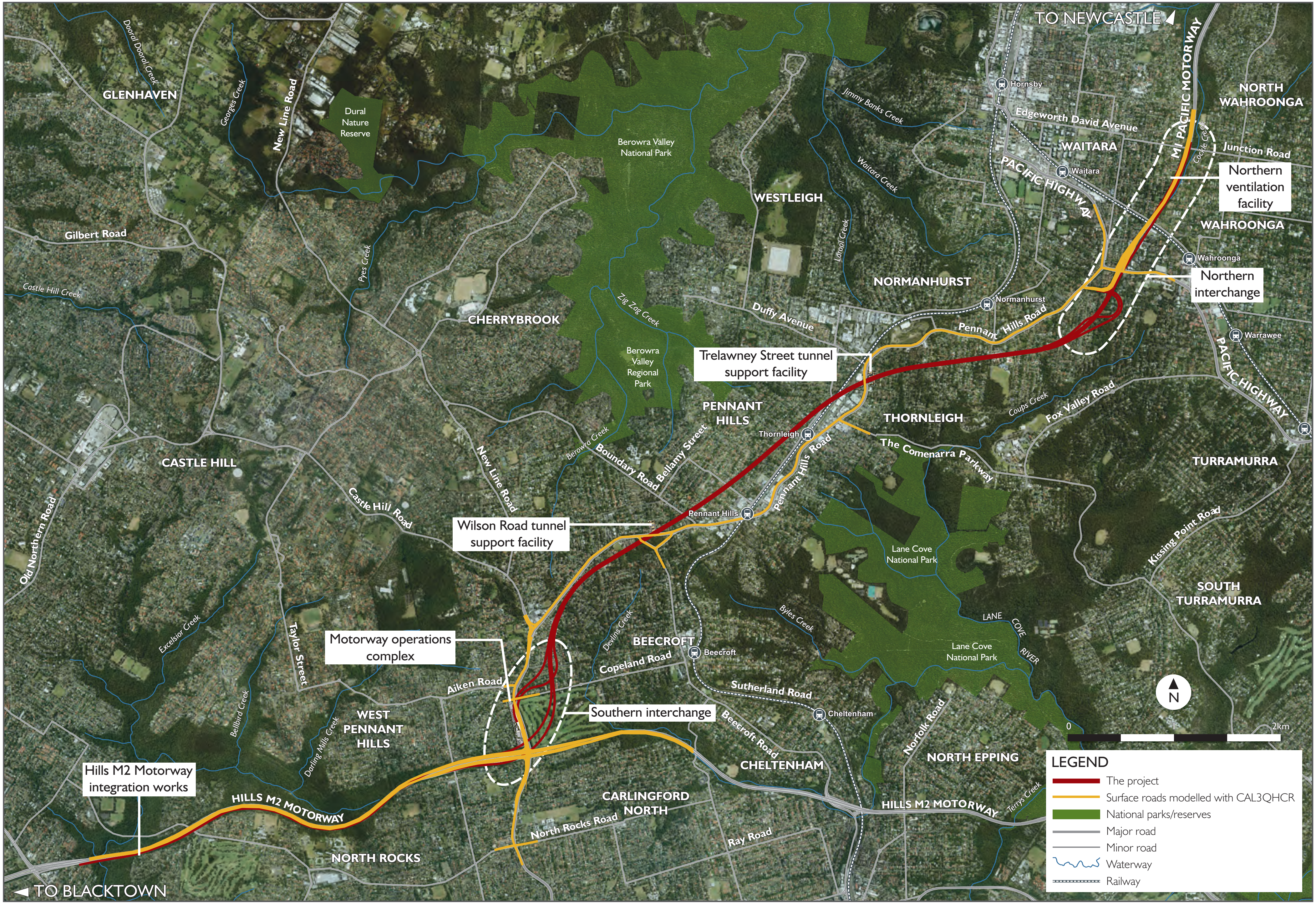

Figure 2-4 Surface roads modelled with CAL3QHCR

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Air emissions from the project tunnels (emergency operation)

The air quality impact assessment for the NorthConnex project has been conducted for a series of credible construction and operational scenarios. An appropriate level of conservatism has been applied to these scenarios to give regulatory authorities, the community and other stakeholders confidence in the veracity and robustness of the air quality impact assessment (refer to **Section 2.6**).

A detailed, quantitative assessment has not been conducted for scenarios including force majeure events, very low risk (ie very low likelihood and/ or very low consequence) incidents or other outcomes that are either not realistically or credibly foreseeable during the normal operation of the project. This is consistent with the approach taken for the assessment of other major infrastructure and developments in New South Wales, including major surface road and tunnel projects, rail infrastructure, ports and airports. These types of developments consider the risk of an emergency or unexpected event occurring (such as a major road crash, a train derailment, or an aircraft crash), but do not provide a detailed, quantified assessment of the potential environmental impacts of such an event occurring. Instead, the focus in these cases is ensuring that feasible and reasonable measures are applied to the particular development to minimise the likelihood and the consequence of emergency events.

It is also important to note that any smoke that may be generated during a tunnel fire would be controlled, contained within the tunnel and ventilated at elevated velocity using the tunnel ventilation system. Ventilation of smoke generated by a surface fire (for example on Pennant Hills Road) would not be controlled and would be emitted at ground level.

In the case of the NorthConnex project, detailed consideration has been given to the project design to ensure that feasible and reasonable design, operation and incident management measures are provided to minimise the risk of an incident and the flow-on impacts to motorists, the environment, the local community and project infrastructure. These measures have been developed in consultation with Fire and Rescue NSW, and this consultation would continue during the detailed design and implementation phases. Key aspects of the project's safety and emergency management design include:

- A unidirectional, non-contra flow design to avoid the potential for head-on collisions.
- Prohibition of dangerous goods carriage through the project tunnels.
- A higher and wider design than other domestic tunnels, to minimise the potential for vehicle strike and to provide some capacity for vehicle manoeuvrability to avoid in-tunnel incidents.
- An emergency lane and shoulder/ breakdown lane to allow emergency vehicle access or to provide a safe location for vehicle breakdowns away from the main traffic carriageway.
- Fire resistant design and project elements to minimise the risk of fire escalation and to protect project infrastructure until fire suppression and/ or emergency services bring a fire event under control.
- Automatic linear heat, smoke detection and alarm systems.
- Closed circuit television monitoring of in-tunnel conditions.
- A public address emergency warning system.

- An automatic and manually-operated deluge system capable of delivering 10 millimetres of water per minute in a minimum 60 metre length of traffic lanes with full coverage for a full kerb to kerb tunnel width.
- Dual supply fire hydrants at 60 metre intervals, with fire hydrant boosters at each tunnel portal.
- Emergency/ fire cabinet points at 60 metre intervals, including dry extinguishers, hydrants/ hoses, power outlets and emergency telephones.
- A tunnel ventilation system capable of limiting the extent of smoke zones within the tunnels, and extracting smoke and tunnel air at high temperature.
- Two vehicular cross passages near the Wilson Road and Trelawney Street sites, to allow for emergency vehicle access.
- Evacuation cross passages located at 120 metre intervals along the main alignment tunnels, and disabled persons egress capability.
- Directional sounding exit signs and illuminated egress exit signs.
- Operational measures to minimise and manage congested traffic conditions, to ensure acceptable in-tunnel air quality and to minimise the risk of congestion-related incidents.

These and other measures have been developed having regard to relevant guidelines published by the Permanent International Association of Road Congresses (PIARC), the National Fire Protection Association and Australian Standards.

There is limited data available to quantify the likelihood of an in-tunnel fire occurring other than to extrapolate from existing information which broadly indicates that the likelihood is very low. This is principally due to a number of key factors:

- There are relatively few road tunnels compared to surface road infrastructure. This has historically limited the ability to develop statistically significant datasets.
- There are relatively few regulatory authorities that actively collect and/ or share in-tunnel fire data, or which have done so over a sufficient period of time to draw meaningful conclusions from the data.
- Much of the non-Australian data that is available is not strictly transferable to an Australian context. Much of the available data, for example, relates to European road tunnels in alpine areas, or road tunnels in Europe or North America which carry dangerous goods cargoes. Much of the data also relates to tunnel incidents dating back to 1950 to 1980, and involves tunnels which have not been designed to modern standards.

A French study of 26 tunnels (PIARC, 1999) for example, identified a likelihood of one to two fires involving passenger vehicles and up to eight fires in heavy vehicles (without dangerous goods) for every 100 million vehicle kilometres. Of the fires involving heavy vehicles, only one per 100 million vehicle kilometres resulted in tunnel damage, and between 0.1 and 0.3 per 100 million vehicle kilometres were considered by French authorities to be very serious. Most of these fire incidents were minor in nature and were recorded in alpine areas, where road grades tended to increase the risk of overheating in motors and brakes.

PIARC (1999) also quotes experience from Germany and Switzerland, which suggests that as a proportion of all breakdowns and accidents in tunnels, fire events are rare. Data from Germany and Switzerland suggests that in those countries, only about one in 100 to 500 breakdowns involves a fire, and about one in 10 to 20 accidents involves a fire.

A survey undertaken by the United States Transportation Research Board published in 2011, includes in-tunnel fire incident data collected from 15 agencies worldwide, reporting on a total of 319 tunnels. Of the 29 tunnels considered in the United States, it was reported that 14 of these experienced fire incidences one to two times per year, while 11 of the tunnels reported no fires. Tunnels within the responsibility of the Port Authority of New York and New Jersey reported higher fire incident rates of two to five per year, explained by the relatively high volumes of traffic in tunnels such as the Clifford Milburn Holland Tunnel (linking Manhattan with Jersey City). Two of the agencies surveyed outside the United States reported tunnel fire frequencies of one to two per year.

A summary of available tunnel fire incident data for Australia is provided in **Table 2-11**. Australian tunnels need to be distinguished from other international tunnels because:

- Australian tunnels are typically more modern than international tunnels. They are therefore, on average, more likely to include modern traffic safety and emergency management systems than some of their international counterparts.
- Longer, more trafficked Australian tunnels ypically have deluge fire suppression systems installed. These systems have until recently not been used in European and North American road tunnels.
- The carriage of dangerous goods is prohibited in Australian tunnels.
- Australian tunnels are located in urban environments, and tunnel designs generally avoid challenging grade or geometric constraints that are encountered in other areas, such as in the alpine areas of Europe.

Based on available data, it is possible to calculate an historical tunnel fire frequency on a vehicle-kilometre basis for two of the Australian tunnels listed in **Table 2-11**:

- For the Lane Cove Tunnel, historical fire frequency has been around 0.61 fires per 100 million vehicle-kilometres (all vehicles).
- For the CityLink Tunnels, historical fire frequency has been around 0.51 fires per 100 million vehicle-kilometres (all vehicles).

Based on traffic forecasts, the NorthConnex project is anticipated to experience around 100 million vehicle kilometres in 2019 and around 130 million vehicle kilometres in 2029. Applying similar tunnel fire frequencies to forecast traffic volumes for the NorthConnex project indicates:

- An expected annual tunnel fire frequency of 0.50 to 0.60 is expected in 2019 (equivalent to one fire incident ever 1.6 to two years).
- An expected annual tunnel fire frequency of 0.67 to 0.80 is expected in 2029 (equivalent to one fire incident every 1.3 to 1.5 years).

These values are comparable to observed annual tunnel fire incident rates for other Australian tunnels presented in **Table 2-11**, which range from around 0.06 to 0.93 per year, or around 0.5 to one per 100 million vehicle kilometres.

Table 2-11 Other major roads – forecast peak hour traffic (mid block) with and without the project in 2019 and 2029

Tunnel	Length	Opened to traffic	Comments on fire incidents	Traffic volumes	Incident frequency
Sydney Harbour Tunnel	Two tunnels, each 2.7 km	August 1992	Around 10 fires since opening (around 0.45 per year). A recent heavy vehicle fire (February 2013) led to closure of the tunnel (and reopened within one hour), operation of the deluge system and fire brigade response. The fire started in the vehicle's battery.	Around 80,000 vehicles per day Around 86 million vehicle kilometres per annum	0.5 per 100 million vehicle kilometres
M5 East Motorway Tunnel	Two tunnels, each 4 km	December 2001	Around 72 fire and smoke/ fume incidents between 2002 and 2009, although this includes non-fire incidents (ie vehicle exhaust/ fume events are included in this figure. A recent heavy vehicle fire (August 2012) led to closure of the tunnel (and reopened within two hours), operation of the deluge system and fire brigade response.	Around 90,000 vehicles per day Around 130 million vehicle kilometres per annum	Insufficient data
M2 Motorway Tunnel (Norfolk Tunnel)	Two tunnels, each 0.5 km	May 1997	One heavy vehicle fire since opening (around 0.06 per year). The fire (September 2013) led to closure of the tunnel (and reopened in three hours), operation of the deluge system and fire brigade response. The fire started in the vehicle's engine compartment.	Around 50,000 vehicles per day Around nine million vehicle kilometres per annum	0.7 per 100 million vehicle kilometres
Cross City Tunnel	Two tunnels, each 2.1 km	August 2005	Two fires recorded since the tunnel was opened in 2005 (around 0.22 per year). Of these fire incidents, one required the	Around 30,000 vehicles per day Around 23 million kilometres per annum	1.0 per 100 million vehicle kilometres

Tunnel	Length	Opened to traffic	Comments on fire incidents	Traffic volumes	Incident frequency
			operation of the deluge system. The second fire was extinguished without the need for deluge.		
CityLink Tunnels (Burnley Tunnel and Domain Tunnel)	Burnley Tunnel – two tunnels each 3.4 km Domain Tunnel – two tunnels each 1.6 km	December 2000	A total of 13 fires recorded since the tunnels were opened in late 2000 (around 0.93 per year). Of these fires, seven related to vehicle fires where there vehicle was driven through and exited the tunnels without incident. Three of the fires required use of the deluge system and the remaining three fires required use of extinguishers. The most significant fire to occur was a result of a major car/ truck collision in the Burnley Tunnel in 2007. This incident resulted in three fatalities and required closure of the tunnel for four days.	Around 55,000 (Burnley) and 45,000 (Domain) vehicles per day Around 94 million vehicle kilometres per annum (combined)	0.5 per 100 million vehicle kilometres (fires within the tunnel only)
Lane Cove Tunnel	Two tunnels, each 3.6 km	March 2007	A total of three fires recorded since the tunnels were opened in 2007 (around 0.43 per year). All of these fires required use of the deluge system.	Around 66,000 vehicles per day Around 87 million vehicle kilometres per annum	0.5 per 100 million vehicle kilometres

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Not all tunnel fires will be significant in scale or consequence to the extent of requiring use of the emergency smoke extraction facilities. Based on available data from Australian tunnels, fires will in most cases be addressed through hand-held extinguishes and in some cases through the operation of tunnel deluge systems. With the exception of major in-tunnel incidents, such as was the case with the Burnley Tunnel fire in 2007, most fire incidents are rapidly brought under control with minimal or limited disruption to normal tunnel operations. A similar outcome is expected for the NorthConnex tunnels.

Fire incidents are only likely to occur as a result of vehicle malfunction (such as motor or brake overheating) or in the event of a major collision leading to the release and ignition of fuel. The NorthConnex project has been designed to minimise the potential for both of these potential initiating events by:

- Reduced tunnel grades to minimise the potential for motor and brake overheating, and development and implementation of management measures to effectively handle congested traffic conditions to minimise the need for a stop-start or slow speed traffic scenario.
- Higher and wider tunnels to provide greater flexibility and manoeuvrability for motorists to avoid potential collisions, with provision of an emergency breakdown lane to separate broken down vehicles from the live traffic lanes. A major contributing factor to the Burnley Tunnel fire in 2007 was a broken down heavy vehicle parked in a live traffic lane (with traffic diversions into other traffic lanes around the incident) with a blown tyre. Removal of the heavy vehicle from live traffic may have assisted in avoiding or reducing the severity of the incident.

In the event that a fire is initiated, a heat detection and closed circuit television system are available to either automatically trigger or to prompt manual engagement of the tunnel's deluge system. Hand-held extinguishers, fire hose and fire reels would also be provided at regular intervals along the project tunnels.

Significant volumes of smoke are only likely to be generated during major fire incidents (involving large volumes of fuel, such as in the case of multi-vehicle accidents) and where fire management measures do not rapidly extinguish the fire. The NorthConnex project has been designed to minimise the risk of these two events simultaneously occurring. Even where a major fire occurs, and is subject to the deluge system operating but not extinguishing the fire, the operation of the deluge is likely to bring the fire under control (ie reduce the spread of the fire and reduces smoke production) and to reduce some of the in-tunnel smoke load through the wet scrubbing action of the deluge. Where this occurs, Fire and Rescue NSW would extinguish the fire through the use of the project's fire hydrant systems.

It is also relevant to compare in-tunnel fires with the potential for similar surface events to occur, for example along Pennant Hills Road. The potential for a fire in the NorthConnex tunnels is likely to be similar to, and potentially lower than, a fire on Pennant Hills Road on a vehicle-kilometre basis because:

- A vehicle malfunction (such as motor or brake overheating) is equally likely to occur in a tunnel as is it is on the surface. Potential malfunction on the surface may in fact be higher due to the congested stop-start nature of Pennant Hills Road compared with the free-flowing motorway standard NorthConnex tunnels.
- Vehicle accident rates would be lower in the free-flowing motorway standard NorthConnex tunnels compared with Pennant Hills Road, as demonstrated in Section 7.1 and Appendix E of the environmental impact statement.

The key differences between a fire on Pennant Hills Road and a fire in the NorthConnex tunnels would be:

- Smoke that may be generated during a tunnel fire would be controlled, contained within the tunnel and ventilation at elevated velocity using the tunnel ventilation system. Ventilation of smoke generated by a surface fire would not be controlled.
- A fire in the NorthConnex tunnels would be actively managed through the deluge system and hand-held extinguishers and fire hoses/ fire reels prior to attendance by emergency services. These facilities are not available on Pennant Hills Road.
- A response to a fire in the NorthConnex tunnels would be automatic in the case of the deluge system or could be manually operated if required. This level of detection and response would be more rapid than a response to a surface fire. The emergency service notification period for an incident on Pennant Hills Road is likely to be longer.
- The rapid response to an in-tunnel fire, and particularly the use of the deluge system, would act to reduce the severity of the incident and the potential generation of smoke. Smoke generated by a surface road fire would not be mitigated until fire control was initiated by emergency services (or potentially an immediate attendee in some cases).

These factors taken together highlight that the smoke generation in the unlikely event of a major incident in the NorthConnex tunnels would be minimised and ventilated in a controlled manner. The heat of the smoke/ in-tunnel air and the velocity with which it is discharged is likely to result in better dispersion and lower impacts than would be experienced during a surface road fire (under current or future conditions).

If a fire incident does occur, the emergency smoke extraction system would exhaust tunnel air vertically at high velocity. The smoke would therefore be dispersed at a high elevation over a broad area. The smoke would likely still be at an elevated temperature despite possibly being cooled by the tunnel deluge system. This elevated temperature would contribute to enhanced buoyancy of the discharge plume and improved dispersion.

The key point is that ventilation of smoke during an in-tunnel fire is managed to minimise the potential for exposure to external receivers, and therefore minimise the potential consequence for local amenity and human health. As with normal operation of the project's ventilation outlets, operation of the emergency smoke extraction facilities would eject smoke vertically at high speed which would separate the emission plume from local ground level receivers.

2.7.3 Assessment scenarios

The following scenarios have been developed and quantitatively assessed for operation of the project:

- The 'do nothing' scenario – assessment of air quality in 2019 and 2029, assuming that the project does not proceed.
- The project assuming forecast traffic volumes in 2019 and 2029.
- A breakdown scenario in the project tunnels.
- A 'worst case' air quality impact scenario (design analysis A).
- A regulatory scenario to assist regulatory authorities in their consideration of potential discharge concentration limits for the project (design analysis B).

The approach taken to calculate the emissions inventories for each of these scenarios is provided in **Section 2.8**, including discharge mass emission rates and concentrations.

The 'do nothing' scenarios (Scenario 1a and 1b)

This scenario assessed the standard 'do nothing' scenario, which predicted future pollutant concentrations from the surface roads in the event that the project is not constructed. Emissions were assessed using the CAL3QHCR model (refer to **Section 2.13**) and expected future traffic volumes for the existing road network for 2019 and 2029 (Scenarios 1a and 1b, respectively).

The predicted pollutant concentrations for this scenario were expected to be higher than those predicted for the 'with project' scenarios for sensitive receivers located along Pennant Hills Road based on:

- Continued vehicle emissions along Pennant Hills Road at ground level in proximity to receivers along the road.
- Continued traffic growth and congestion along Pennant Hills Road in the absence of the project, leading to less efficient vehicle performance and increased emissions.

Due to size constraints in the model and the reduced zone of influence associated with road emissions compared to ventilation outlet emissions, the number of sensitive receivers assessed in this scenario (and the other scenarios involving surface road modelling) were fewer than assessed in the other scenarios. All of the sensitive receivers assessed in the CAL3QHCR model, however, were assessed in CALPUFF. The set-up of these models is discussed in **Section 2.13**.

The forecast traffic volume scenarios (Scenario 2a and 2b)

This scenario assessed the forecast hourly traffic volumes expected to use the project at opening in 2019 (Scenario 2a) and ten years after opening in 2029 (Scenario 2b). The scenario used variable pollutant concentrations based on hourly traffic flows during a 24 hour period, which reflect increases and decreases in traffic volumes using the project over the course of a day. This scenario represents the most likely actual performance of the project in 2019 and 2029.

Pollutant emission concentrations and rates for hourly vehicle volumes were calculated using the PIARC emission factors for light and heavy vehicles (refer to PIARC, 2012 for details of the emission factors). This scenario took into account that the variations in flow rate throughout the day based on hourly traffic volumes, with the consequence that pollutant emissions concentrations would also vary as more or less fresh air is drawn into the tunnel (based on changing vehicle numbers and speed, and changing tunnel fan speeds).

Based on the design of the project, a minimum flow rate of 300 cubic metres per second of air was assumed to be vented through each ventilation outlet at any time, which would correspond with periods of the lowest traffic volumes in the project tunnels.

Further details of the calculation of the emissions inventory for this scenario are provided in **Section 2.8**.

The breakdown scenario

This scenario was assessed semi-quantitatively by calculating worst-case pollutant concentrations during a breakdown event in the project tunnels, and comparing those concentrations to the concentrations and modelling outcomes for with project – expected traffic flows (Scenarios 2a and 2b). Breakdowns are expected to happen infrequently.

In determining a worst-case breakdown event, two potential scenarios were considered:

Breakdown scenario A

- It was assumed that one of the tunnels was completely blocked at one exit.
- Vehicles would continue to enter the tunnel for a ten minute period, after which the tunnel would be closed to inbound traffic for the direction that was affected (that is, the northbound or southbound direction).
- The number of vehicles has taken into account an upper vehicle limit of 2,800 PCU, which would represent the indicative number of vehicles that could be accommodated within one tunnel when the average speed drops below 20 kilometres per hour.
- Vehicles within the tunnel would be idling continuously for 55 minutes. It was conservatively assumed that no vehicle engines would be turned off. In reality, the measures described above would prevent the tunnel from becoming full of vehicles and drivers would be directed to turn off their engines.
- The operation of the tunnel ventilation system was assumed to be the same as that occurring during peak traffic flows. The jet fans may be turned on, but the volumetric flow rate of emissions from the ventilation outlets would remain the same.

Breakdown scenario B

- The tunnel was assumed to be limited to one lane of traffic, with the assumption that the traffic was queuing from the start of the tunnel to the accident scene near the end of the tunnel. Vehicles were assumed to be moving very slowly past the accident at a low speed creating congestion in the tunnel.
- Vehicles would continue to enter the tunnel for a ten minute period, after which the tunnel would be closed to inbound traffic for the affected direction (that is, the northbound or southbound direction).
- Vehicles would travel at speeds of less than 20 kilometres per hour.
- The number of vehicles has taken into account an upper vehicle limit of 2,800 PCU, which would represent the indicative number of vehicles that could be accommodated within one tunnel when the average speed drops below 20 kilometres per hour.

- The operation of the tunnel ventilation system was assumed to be the same as that occurring during peak traffic flows. The jet fans may be turned on, but the volumetric flow rate of emissions from the ventilation outlets would remain the same.

Of these two scenarios, breakdown scenario A was identified as the worst case breakdown scenario as all vehicles entering the tunnel may be in the tunnel idling for up to one hour (assumed time to clear the accident). As vehicles would be exiting the tunnel with an ever decreasing overall emission rate, breakdown scenario B would be expected to have a lower overall emission rate compared with breakdown scenario A. On this basis, breakdown scenario A was considered the worst case breakdown scenario and was carried forward for more detailed assessment.

Some submissions received in response to the environmental impact statement sought further details of how the number of vehicles involved in breakdown scenario A was calculated (511 vehicles in total). Details of this calculation are provided below.

Vehicles contributing emissions during the breakdown scenario would be a combination of:

- Vehicles in the tunnel at the time of the breakdown that are prevented from leaving the tunnel due to the breakdown blockage near the tunnel exit.
- Additional vehicles that enter the tunnel in the ten minutes following the breakdown and before the tunnel is closed to additional traffic.

At the time of the breakdown, it has been assumed that average vehicle speeds drop rapidly from 80 km/h to 20 km/ h until traffic banks back to the maximum traffic throughput capacity of the main alignment tunnel at 20 km/ h. The maximum throughput capacity of a main alignment tunnel is around 2,800 passenger car units (refer to **Section 2.5.1**) at this speed. Based on the distribution of vehicle types as forecast in 2019:

- Passenger vehicles would comprise 72 per cent of vehicles in the tunnel. Passenger vehicles are one passenger car unit each.
- Heavy vehicles would comprise around 28 per cent of vehicles in the tunnel. Consistent with the assumption made in the traffic impact assessment for the project, heavy vehicles have been assumed to be 2.9 passenger car units each.

Taking this distribution of vehicles into account, 2,800 passenger car units would be around 1,316 passenger vehicles and around 512 heavy vehicles (a total of 1,828 vehicles per hour).

For a nine kilometre long tunnel, 1,828 vehicles per hour would equate to 205.7 vehicles (ie (9km)/(80 km/h) x 1,828 vph = 205.7 vehicles).

For the ten minutes following the breakdown a further 305.7 vehicles would enter the tunnel (ie (1/6) x 1,828 vph = 305.7 vehicles).

Combined, the 205.7 vehicles in the tunnel at the time of the breakdown and the 305.7 vehicles enter in the ten minutes following the breakdown, would sum to 510.4 vehicles. This figure has been rounded to 511 vehicles for the purpose of the air quality impact assessment.

The worst case scenario (design analysis A)

Consideration of 'worst case'

When considering a 'worst case' air quality scenario for the project, it is relevant to take into account two principal factors:

- The average speed of vehicles travelling through the tunnels, because lower average traffic speeds equate to more emissions. That is, traffic using the project tunnels will generate greater emissions at 40 km/ h than at 80 km/ h.
- The total volume of vehicles travelling through the tunnels, because more vehicles broadly equates to more emissions (the implications of changes in vehicle fleet and fuel mix are discussed in **Section 2.8**).

The data presented in **Section 2.5.2** of this report indicate that maximum traffic throughput capacity, traffic travelling at 40 km/ h would generate higher in-tunnel concentrations of vehicle emissions than for comparable scenarios at 60 km/h and 80 km/ h.

The project has been designed to operate with two motorway standard traffic lanes in each direction (northbound and southbound). The design capacity of a motorway standard traffic lane is 2,000 passenger car units per hour under free flowing traffic conditions (60 km/h), which is equivalent to 4,000 passenger car units per hour for each of the main alignment tunnels. As discussed in **Section 2.4.2** and shown in **Figure 2-1**, the two lane configuration of each main alignment tunnel has a design throughput capacity of vehicles (as passenger car units) at different average traffic speeds:

- A maximum of 3,480 passenger car units per hour (two lanes) at 80 km/h.
- A maximum of 4,000 passenger car units per hour (two lanes) at 60 km/h.
- A maximum of 3,698 passenger car units per hour (two lanes) at 40 km/h.

There are two potential scenarios that may lead to a decrease in average traffic speed through the main alignment tunnels:

- The patronage of the project exceeds the maximum theoretical design throughput capacity of the project tunnels (as listed above), generating congested traffic conditions and a reduction in average traffic speed.
- An incident in the tunnel(s) or downstream of the tunnel temporarily reduces the capacity of the tunnel (for example by blocking a lane, slowing traffic as a motorist reaction to the incident or causing a downstream obstruction that leads to traffic queuing).

Both of these scenarios have a low probability of occurrence based on the design and forecast performance of the project. As discussed in **Section 2.5.2**, the maximum theoretical traffic throughput of each main alignment tunnel is 4,000 passenger car units per hour. This is around 2.1 times the peak forecast traffic volumes in 2019 and around 1.6 times the peak forecast traffic volumes in 2029. This means that actual traffic volumes would need to be around 110 per cent higher than traffic forecasts in 2019 or around 60 per cent higher than traffic in forecasts in 2029. Based on traffic forecasts using the Cube strategic model, 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.

An incident in the project tunnels or downstream could involve:

- A minor incident, such as a vehicle breakdown.
- A major incident, such as a vehicle crash or fire.

Incidents in the project tunnels or downstream would be unlikely events. In the case of a major incident:

- Vehicle crashes on a motorway standard road have been estimated to occur at around 19.9 per 100 million vehicle kilometres (refer to the Technical Working Paper: Traffic and Transport in the environmental impact statement). This is equivalent to project 23 vehicle crashes in the project tunnels in 2029 (or around one every 15 days). This includes all crash types (fatal and injury).
- As discussed in **Section 2.7.2**, the frequency of fires in the project tunnels in 2029 has been estimated at 0.67 to 0.80 in 2029 (equivalent to one fire incident every 1.3 to 1.5 years).

The potential for incidents within the project tunnels would be actively monitored and managed. The project would be equipped with an automatic video incident detection (AVID) system. AVID is a close circuit television (CCTV) system but has the additional capability of detecting and actively alerting tunnel operators to incidents within the tunnel as they occur. The AVID system has the ability to detect a range of tunnel incidents including stopped vehicles, pedestrians or the presence of smoke in the project tunnels.

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

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

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

In the event of a fire incident the whole tunnel in both directions would be closed and vehicles diverted to surface roads until the incident has been dealt with.

The low frequency of incidents, the design of the project and proactive monitoring and management of incidents means that the potential for extended periods of low average traffic speeds (around 40 km/ h or less) is very low. In the event that an incident, such as a breakdown or crash occurs, management measures would be in place to rapidly move any obstruction from the operational traffic lanes into the relevant breakdown lane, and to manage the entry of additional vehicles into the project tunnels so that congested traffic conditions do not eventuate (or are not exacerbated by continued traffic entry into the tunnels).

This approach is expected to resolve most incidents within the order of an hour or less. While there may be an increase in vehicle emissions in the project tunnels during this time if average traffic speeds drop, the ventilation system would be managed to maintain acceptable in-tunnel air quality. The potential implications for ambient air quality are unlikely to be material for any more than a short duration and at a low frequency. For these reasons, it is not considered appropriate to develop a low average traffic speed scenario (around 40 km/ h) as a worst-case scenario of the air quality impact assessment.

Design analysis A

Design analysis A has assumed that the maximum theoretical design capacity of 4,000 passenger car units in a main alignment tunnel would be reached during the peak hour. It is extremely unlikely that the maximum design capacity would be experienced for an entire 24-hour period, with traffic volumes likely to ebb and flow during the day around peak periods. A realistic traffic scenario for design analysis A was therefore established by:

- Comparing the maximum theoretical design capacity of each main alignment tunnel (4,000 passenger car units) with the expected peak hour traffic volumes in 2019, which were around 1,790 passenger car units in the southbound main alignment tunnel (morning peak) and around 1,930 passenger car units in the northbound main alignment tunnel (afternoon peak).
- Noting that the theoretical design capacity was around a factor of 2.1 times the maximum forecast peak in 2019 (ie 4,000 is around 2.1 times 1,930).
- Scaling the forecast traffic flows for 2019 by a factor of 2.1 for each hour of the day, to obtain the traffic flows used for design analysis A.

An equally valid approach would have been to use forecast traffic volumes in 2029 to derive design analysis A. However, given that the relative diurnal flows of traffic would be similar in 2019 and 2029 (refer to the shape of the diurnal flow curves in Figure 5-2), and scaling would be to the same maximum (4,000 passenger car units), there would be no significant difference in outcomes if traffic forecasts for 2029 had been used instead of data from 2019.

The total daily traffic volumes for design analysis A have therefore been established at around 48,000 passenger car units in each main alignment tunnel. This is considered to be a reasonable and realistic estimate of a worst case scenario (albeit highly unlikely) for operation of the project.

Figure 2-5 shows traffic volumes for design analysis A relative to the base traffic forecasts for 2019 and the maximum traffic design capacity of the southbound and northbound main alignment tunnels. The figure shows that the peak hour traffic volumes for design analysis A could only be accommodated through the project's main alignment tunnels under free flowing traffic conditions (60 km/ h to 80 km/h). Congested traffic conditions in the project tunnels (40 km/ h or less) would require a commensurate reduction in traffic volumes below the design analysis A peak hour figures, based on the physical capacity of the project tunnel lanes.

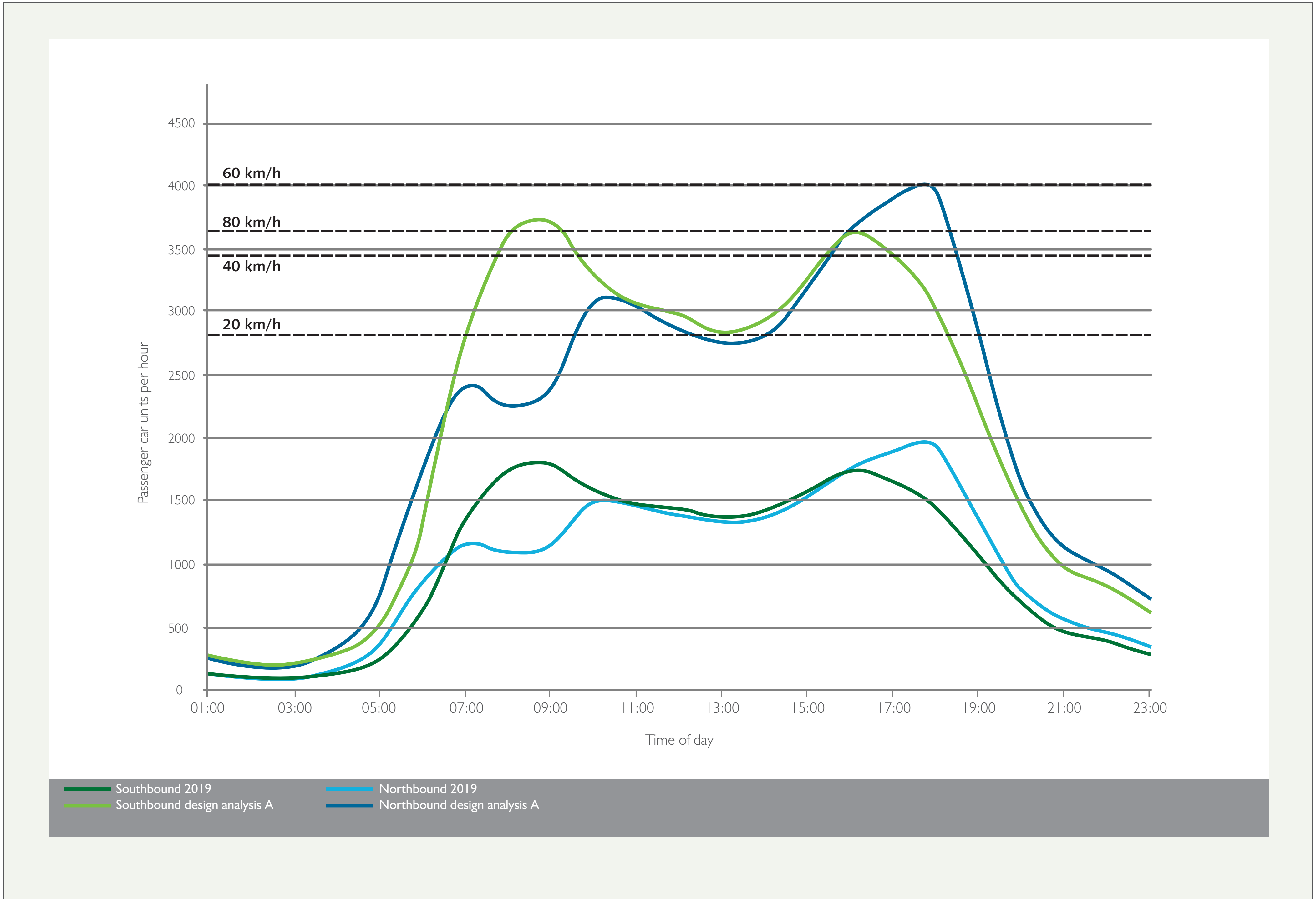

Figure 2-5 Design analysis A (PCU) relative to traffic design capacity

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The regulatory scenario (design analysis B)

Design analysis B was assessed for 2019 and 2029. The scenario was similar to Scenarios 2a and 2b, but assessed constant emission concentrations (rather than variable emission concentrations) over a 24 hour period. The design analysis is theoretical and was undertaken to assist regulatory authorities in assessing and determining potential discharge concentration limits that may be applied to the ventilation outlets through conditions of approval. Assuming that emissions concentration limits are applied to the ventilation outlets, as is common practice, the results of the design analysis will demonstrate the air quality performance of the project if it operates continuously at those emissions concentration limits. In reality, emissions concentrations would be variable (as considered in Scenarios 2a and 2b) due to changing traffic volumes and tunnel fan operation over a daily cycle.

The constant maximum pollution emissions concentrations were calculated by using the maximum hourly emission concentrations (worst case concentrations) for each pollutant for each main alignment tunnel from Scenarios 2a and 2b with the forecast hourly volumetric flow rates to back-calculate hourly emission rates. The scenarios were modelled for both 2019 (Design analysis B (2019) and 2029 (Design analysis B (2029). As the results of these scenarios are not directly applicable to the expected air quality performance of the project, they are not considered in further detail in this chapter (refer to Appendix G of the Technical Working Paper: Air Quality in the environmental impact statement for further information).

2.8 Emissions inventories

This section details how emissions inventories have been calculated as inputs into the air quality impact assessments for the project. It includes:

- Details of the emission factors used in the assessment (refer to **Section 2.8.1**).
- An explanation of how the emissions inventory for the project tunnels was calculated, including testing of the sensitivity of key assumption (refer to **Section 2.8.2**).
- An explanation of how the emissions inventory for the surface road modelling was calculated (refer to **Section 2.8.3**).

2.8.1 Emission factors

The air quality impact assessment has applied emission factors published by the Permanent International Association of Road Congresses (PIARC) (2012), and specifically those published for Australia.

The PIARC emission factors have been used to calculate emissions of particulate matter, NO_X and CO from vehicles within the tunnel and on the surface roads. As the tunnel ventilation designers used the PIARC emission factors for the design of project's ventilation system, it was considered desirable for the air quality assessment to be consistent with the tunnel design in terms of predicted emissions and transferability of ventilation and air quality information between the ventilation design and the environmental impact statement. This was considered particularly important for transparency and consistency, where it was considered more appropriate to be consistent in use of emission factors and overestimate emissions rather than to use different emission factors for the tunnel ventilation design and the air quality impact assessment. To ensure consistency of approach across all aspects of the project, PIARC emission factors were also applied to surface roads.

PIARC (2012) provides Australian-specific emissions based on fleet distribution data and emission standards relevant to Australia. As noted in Section 4.2.8.1 of the Technical Working Paper: Air Quality, the authors of the PIARC emission factors state that the factors were developed for the purpose of defining the minimum air flows required to achieve adequate air quality within road tunnels – as such, a safety margin is added to the emission factors such that, if these emission factors are used for developing emission inventories for dispersion modelling purposes, the estimated emissions are likely to be higher than would be expected in practice. The use of conservative emission factors results in higher predicted pollutant concentrations for in-tunnel and ambient receivers than would be predicted using less conservative emissions estimates.

A recent study (PEL, September 2014) comparing the PIARC emission rates to pollutant concentrations measured in the ventilation outlets of the Lane Cove Tunnel by Pacific Environment Limited (2014) determined that the PIARC emission factors overestimated emissions of CO by 1.3 to 1.7 times, emissions of NO_X by 1.6 to 1.8 times, and $PM_{2.5}$ by 2.8 to 4.4 times. While it is noted that the Lane Cove Tunnel has different dimensions and ventilation characteristics than the proposed NorthConnex project, the results of the Pacific Environment Limited study provide an indication of the potential scale of the overestimation of emissions when using the PIARC emission factors (compared to the NSW vehicle fleet using the Lane Cove Tunnel). Given these data, it could be expected that the actual contributions to pollutant concentrations at sensitive receiver locations could be 1.6 to 1.8 times lower for NO_x and 2.8 to 4.4 times lower for $PM_{2.5}$ than predicted in the air quality impact assessment for the project (based on the contribution from the project's ventilation outlets).

It should be noted that the use of PIARC emission factors in tunnel assessments has much precedence. Recent studies making use of the PIARC emission factors include the East West Link in Melbourne, where the Victorian EPA reviewed the emission factors and considered them to be appropriate, the Brisbane Northern Link Project, and the Brisbane Airport Link Project.

The PIARC emission factors have been designed to determine the minimum air requirement needed to ensure adequate in-tunnel air quality and visibility thresholds under normal operating conditions, which include high traffic loads and frequently congested traffic. The report detailing the PIARC emission factors indicates that "Vehicle speeds around 10 km/h and stopped traffic typically define the normal ventilation capacity requirements." As such, the PIARC emission factors do accommodate congested traffic conditions. While the emission factors have been specifically designed to calculate emissions in road tunnels rather than emissions from surface roads, the conservatism built into the emission factors is considered to be adequate for providing conservative estimates of emissions from surface roads, even under stop-start conditions such as experience on Pennant Hills Road. The surface road modelling conducted for the project assessed vehicle speeds between 30 and 100 kilometres per hour.

2.8.2 Project tunnel emissions inventories

This section details how the emissions inventories for the project tunnels have been calculated, including:

- Traffic fleet and fuel mix assumptions.
- Tunnel characteristics.
- Tunnel ventilation rates.
- Vehicle emission rates.
- Particulate matter and other emissions.
- Details of the calculation emissions inventories used in the air quality impact assessment.
- Analysis of the implications of air drawn into the project tunnels on the air quality impact assessment.

Traffic fleet and fuel mix assumptions

The raw outputs from the Cube strategic traffic model provided for the 2019 and 2029 forecast traffic years, and the derived 'design analysis A' were expressed in terms of total vehicles per hour for each hour of the day. Heavy vehicle numbers, as a percentage of total vehicles in each hour of the day were also provided.

In order to calculate vehicle emissions within the project tunnels, total light vehicles and heavy vehicles needed to be differentiated further based on vehicle type and fuel type. For this, data available from the Australian Bureau of Statistics was used (the Australian Bureau of Statistics – Motor Vehicle Census (31 January 2013)). These data are summarised in **Table 2-12**.

Table 2-12 Vehicle fleet composition (ABS, 2013)

Vehicle type	Petrol (total)	Diesel	Other	All
Passenger vehicles				
Passenger vehicles	11,616,025	1,029,561	354,435	13,000,021
Campervans	17,635	34.164	2,302	54,101
Motorcycles	744,518	0	214	744,732
Light duty vehicles				
Light commercial vehicles	1,300,490	1,281,381	135,802	2,717,673
Non-freight vehicles	3,159	19,338	489	22,986
Heavy vehicles				
Light rigid trucks	9,116	120,044	1,987	131,147
Heavy rigid trucks	17,172	307,340	1,486	325,998
Articulated trucks	1,332	89,416	156	90,904
Buses	17,802	71,081	4,151	93,034

Since preparing the environmental impact statement, the data in **Table 2-12** have been compared with registration records held by Roads and Maritime (as at 31 March 2014). At a vehicle category level, these two data sets are similar, as shown in **Table 2-13**. Roads and Maritime registration records show a slightly higher percentage of light duty vehicles in the fleet mix than the ABS (2013) data. For the purpose of this comparison, all Roads and Maritime registration data as at 31 March 2014 has been included with the exception of heavy and light trailers (which do not include an engine) and heavy and light plant (which are not expected to regularly uses roads as part of the New South Wales vehicle fleet, and for most of the time would be located off road).

Table 2-13 Comparison of ABS (2013) and RMS (2014) fleet data

Vehicle category	ABS (2013)	RMS (2014)
Passenger cars	80.3%	79.8%
Light duty vehicles	16.0%	17.8%
Heavy vehicles	3.7%	2.4%

For the purpose of the environmental impact statement, ‘light vehicles’ included passenger vehicles and light duty vehicles (as distinct from heavy vehicles). When considering only light vehicles, the ABS (2013) shows contribution of 83.4 per cent from passenger vehicles and a 16.6 per cent contribution from light duty vehicles. This shows a good correlation with:

- Roads and Maritime registration records, which show a contribution of 81.8 per cent from passenger vehicles and a contribution of 18.2 per cent from light duty vehicles.
- The default values published by the Permanent International Association of Road Congresses, with include 84 per cent passenger vehicles and 16 per cent light duty vehicles.
- Data quoted in the submission received from the Environment Protection Authority, which indicate that 18 to 20 per cent of light vehicles are light duty vehicles.

Vehicles listed in the ABS (2013) data set as ‘other’ fuel were redistributed into ‘petrol’ or ‘diesel’ categories. The redistribution maintained the relative percentages of petrol and diesel fuelled vehicles for each vehicle type. For example, where petrol fuelled passenger cars were four times the number of diesel fuelled passenger cars, ‘other’ fuelled passenger cars reallocated to petrol or diesel categories to maintain this ratio. This approach is conservative, as ‘other’ fuelled vehicles include ‘cleaner’ burning fuels, such as liquefied petroleum gas.

This process yielded the breakdown in vehicle categories by fuel type summarised in **Table 2-14**. It is important to note that as part of the air quality impact assessment, all heavy vehicles were assumed to be diesel fuelled, despite the data presented in **Table 2-14**. This a conservative assumption, as it will lead to an over estimation of key pollutants include NO_x and particulate matter for these vehicles.

Table 2-14 Summary of fuel type (ABS, 2013)

Vehicle type	Petrol	Diesel
Passenger vehicles (cars)	92.1%	7.9%
Light duty vehicles	50.1%	49.9%
Heavy vehicles	7.2%	92.8%

Based on feedback received from the Environment Protection Authority, a similar process has been applied to Roads and Maritime registration data (ie re-distribution of ‘other’ fuelled vehicles). The vehicle fleet distribution as a function of fuel for Roads and Maritime registrations is summarised in **Table 2-15**. The table shows that:

- ABS (2013) and RMS (2014) fleet data are similar for passenger vehicles and light duty vehicles.
- ABS (2013) data slightly underestimates the proportion of diesel fuelled passenger vehicles relative to RMS (2014) data (7.9 per cent versus 9.9 per cent).
- ABS (2013) data slightly overestimates the proportion of diesel fuelled light duty vehicles relative to RMS (2014) data (49.9 per cent versus 46.5 per cent).
- On balance, the ABS (2013) is a reasonable representation of the New South Wales vehicle fleet fuel mix in 2013.

Table 2-15 shows a significant variance in fuel type for heavy vehicles between the ABS (2013) data and Roads and Maritime registration data. However, because all heavy vehicles were assumed to be diesel fuelled for the purpose of the air quality impact assessment in the environmental impact statement, this variance is not a relevant issue.

Table 2-15 Registered NSW vehicle fleet by fuel type (RMS, 2014)

Vehicle Type	Petrol (number)	Diesel (number)	Petrol	Diesel
Passenger vehicles (cars)	**3,816,820**	**418,906**	**90.1%**	**9.9%**
Passenger vehicles	2,801,586	94,621	96.7%	3.3%
Off-road vehicles	808,316	324,222	71.4%	28.6%
Motor cycles	191,953	61	99.9%	<0.1%
Scooters	14,964	2	99.9%	<0.1%
Light duty vehicles	**355,182**	**334,829**	**51.5%**	**48.5%**
People movers	63,801	7,592	89.4%	10.6%
Small buses	8,857	9,476	48.3%	51.7%
Mobile homes	3,367	4,502	42.8%	57.2%
Light trucks	279,037	313,256	47.1%	52.9%
Other vehicles	119	2	98.3%	1.7%
Heavy vehicles	**1,946**	**120,331**	**1.6%**	**98.4%**
Buses	232	12,744	1.8%	98.2%
Heavy trucks	1,640	88,951	1.8%	98.2%
Prime movers	74	18,636	0.4%	99.6%

Because the emission factors for Australian heavy vehicles published by the Permanent International Association of Road Congresses (2012) are based on an average mass of 23 tonnes, an analysis of heavy vehicle fleet mass has been conducted to confirm the suitability of those emission factors for use (without amendment). The calculation to estimate average heavy vehicle mass based on ABS data (2013) is presented in **Table 2-16**. Based on a broader range of heavy vehicle masses that could be expected in each heavy vehicle category, the average mass of the heavy vehicle fleet would be around nine to 25 tonnes. Based on this, the emission factors for Australian heavy vehicles published by the Permanent International Association of Road Congresses (2012) for an average 23 tonne heavy vehicle fleet are considered reasonable.

This takes into account the fact that the heavy vehicle fleet is unlikely to comprise all vehicles at their respective maximum mass. Further, it also takes into account that the average mass of heavy vehicles across Sydney in 2013, as measured at Roads and Maritime weigh-in-motion sites, was 16.6 tonnes. Taking into account that a slightly heavier fleet mix may use the NorthConnex project because of its location along a major road freight corridor, emission rates based on an average mass of 23 tonnes is reasonable.

By way of sensitivity analysis, these calculations have been tested by:

- Removing buses from the calculation. This would alter the range of average heavy vehicle mass to 7.90 tonnes to 26.49 tonnes.
- Altering the proportion of B double vehicles in the fleet mix. With no B doubles, the average heavy vehicle mass would be from 8.93 tonnes to 22.85 tonnes. With only B doubles in the articulated trucks category, the average mass would be from 11.06 tonnes to 25.4 tonnes.

Heavy vehicles as a percentage of total traffic volumes have been forecast to be around 28 per cent in 2019 and around 25 per cent in 2029.

Table 2-16 Average heavy vehicle mass (based on ABS (2013))

Heavy vehicle type	Number of vehicles (ABS, 2013)	Mass range	Mass of vehicle type
Light rigid trucks	131,147	4.5 tonnes	0.590 million tonnes
Heavy rigid trucks	325,998	4.5 tonnes to 26 tonnes	1.467 million tonnes to 8.476 million tonnes
Articulated trucks	90,904	25 tonnes to 42 tonnes 40 tonnes to 60 tonnes (B doubles)	2.272 million tonnes to 5.454 million tonnes
Buses	93,034	15 tonnes to 19 tonnes	1.396 million tonnes to 1.768 million tonnes
Total	**641,083**	**5.725 million tonnes to 16.288 million tonnes**	
Average		**8.93 tonnes to 25.4 tonnes per vehicle**	

In its submission, the Environment Protection Authority questioned the assumption in the air quality impact statement that the petrol-diesel fuel mix estimated in 2013 (based on ABS data) would remain constant into the future. Other submissions also raised questions in relation to this and related matters.

On review, it is acknowledged that this assumption was not conservative. To test the sensitivity of the air quality assessment to this assumption, the mix of fuel types derived for 2013 (refer to **Table 2-14**) has been extrapolated based on an assumed constant linear trend in fuel types between the 2008 and 2013 data published by the Australian Bureau of Statistics. For example, between 2008 and 2013, the Australian Bureau of Statistics recorded a 104 per cent increase in diesel fuelled passenger vehicles but only a six per cent increase in petrol fuelled passenger vehicles over the same period.

Extrapolating changes in fuel mix in this manner has generated the fuel mix estimates in **Table 2-17** and **Table 2-18**, for 2019 and 2029, respectively.

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%

This anticipated growth has been calculated through linear extrapolation of trends in diesel fuelled vehicles between 2008 and 2013 (based on ABS data). This extrapolation is summarised in **Table 2-19**.

Table 2-19 Extrapolated fuel mix by vehicle type (based on ABS (2008, 2013))

Vehicle type	Petrol				Diesel			
	2008	2013	2019	2029	2008	2013	2019	2029
Passenger vehicles	95.6%	92.1%	85.1%	77.1%	4.4%	7.9%	14.9%	22.9%
Light duty vehicles	63.6%	50.1%	34.4%	20.8%	36.4%	49.9%	65.6%	79.2%
Heavy vehicles	9.9%	7.2%	5.1%	2.6%	90.1%	92.8%	94.9%	97.4%

Notwithstanding the above, all air quality impact assessments conducted for the project have assumed that all heavy vehicles are diesel fuelled.

These changes in fuel mix (in 2019 and 2029) have been carried through the emissions inventory calculated for the project, and which was used as an input in the air quality impact assessment. Changes in the mass emission rate (g/s) of pollutants at the project's ventilation outlets as a consequence of these changes in fuel mix assumptions are summarised in **Table 2-20**. The table shows that with the change in fuel mix assumptions:

- Mass emission rates, and consequently ambient air quality impacts, would decrease for carbon monoxide (CO), polycyclic aromatic hydrocarbons (PAHs) and total volatile organic compounds (VOCs).
- Mass emission rates for oxides of nitrogen (NOx) and particulate matter (PM_{10} and $PM_{2.5}$) would increase marginally – around one to two per cent in 2019, and around two to four per cent in 2029. This is because NO_x and particulate matter emissions are dominated by contributions from heavy vehicles, so changes in fuel mix assumptions for passenger cars has little effect.

Table 2-20 Effect of changes in fuel mix assumptions (change in mass emission rate)

Pollutant	Change to 2019 emissions	Change to 2029 emissions
CO	-3.2% to -3.4%	-6.8% to -7.3%
NO_x	+1.1% to +1.3%	+2.9% to +3.3%
PM_{10}	+1.2% to +1.8%	+2.7% to + 3.9%
$PM_{2.5}$	+1.2% to +1.7%	+2.6% to +3.9%
PAHs	-0.4% to -0.4%	-1.0% to -1.1%
Total VOCs	-2.3% to -2.5%	-5.2% to -5.5%

These changes in mass emission rates would not significantly affect the outcomes of the air quality impact assessment presented in the environmental impact statement, and would have only a minor impact on modelled ground level concentrations of these pollutants.

Updated fuel mix assumptions have been reflected in the additional air dispersion modelling conducted for the five metre increase in ventilation outlet heights (refer to **Section 2.15** and **Section 9.2** of this report). The fuel mix has been assumed to be the extrapolated values above in 2019 and 2029.

As noted above, the percentage of heavy vehicles in the total traffic volumes using the project tunnels has been forecast to be around 28 per cent in 2019 and around 25 per cent in 2029. These traffic forecasts for the project have assumed that 95 per cent of through heavy vehicles travelling along the Pennant Hills Road corridor would be directed into the project tunnels with the implementation of regulatory measures (to require heavy vehicles to use the tunnels). There is therefore a very low potential for heavy vehicles using the project to exceed these heavy vehicle percentages.

Tunnel characteristics

Because the emission factors published by the Permanent International Association of Road Congresses (2012) are a function of road gradient, an analysis of the design of the main alignment tunnels was conducted. The analysis involved dividing each main alignment into segments between points where the road gradient changed, and calculating the gradient for that segment. Where the gradient was not an integer multiple of two (the published emission factors are available in multiples of two per cent gradient) professional judgement was used to determine an appropriately conservative gradient for the assessment. A summary of tunnel dimensions applied to the calculation of the emissions inventory is presented in **Table 2-21**.

Table 2-21 Tunnel dimensions applied to the emissions inventory

Measure	Tunnel segment					
	1	2	3	4	5	6
Northbound main alignment tunnel						
Chainage start (m)	1001.9	1230.4	2141.8	7846.8	8465.8	9776.7
Chainage end (m)	1230.4	2141.8	7846.8	8465.8	9776.7	10026.8
Length of segment (m)	228.5	911.3	5705.0	618.9	1310.9	250.2
Elevation start (m)	119.6	111.0	74.6	144.3	147.4	160.5
Elevation end (m)	111.0	74.6	144.3	147.4	160.5	170.5
Calculated gradient (%)	-3.75	-4.00	+1.22	+0.50	+1.00	+4.00
Applied gradient (%)	-4.00	-4.00	+2.00	0.00	0.00	+4.00
Southbound main alignment tunnel						
Chainage start (m)	9943.7	9576.0	8464.5	7819.8	2201.5	1148.0
Chainage end (m)	9576.0	8464.5	7819.8	2201.5	1148.0	688.2
Length of segment (m)	367.8	1111.5	644.7	5618.2	1053.6	459.8
Elevation start (m)	173.3	158.6	147.4	144.3	75.4	89.1
Elevation end (m)	158.6	147.4	144.2	75.4	89.1	107.5
Calculated gradient (%)	-4.00	-1.01	-0.49	-1.23	+1.30	+4.00
Applied gradient (%)	-4.00	0.00	0.00	-2.00	+2.00	+4.00

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Ventilation rates

The ventilation system for the project has been designed to achieve specified in-tunnel air quality criteria based on the maximum traffic throughput capacity of the main alignment tunnels at various average traffic speeds. These design criteria and the process applied to design the ventilation system and to ensure sufficient ventilation capacity are discussed in **Section 2.4.2**.

The project's ventilation system has a maximum capacity of 700 m^3/s (per ventilation outlet), and is anticipated to operate at around 300 m^3/s under low traffic volume conditions. The ventilation flow rate through the main alignment tunnels would be managed to ensure acceptable in-tunnel air quality, and would operationally be considered a function of total traffic volumes and the composition of traffic within the tunnels (particularly heavy vehicles).

Although ventilation would be directly managed to ensure acceptable in-tunnel air quality, ventilation flows would be indirectly a function of traffic volumes at any particular time, and the percentage of heavy vehicles in the traffic flows. The ventilation flow rates applied to the air quality impact assessment, based on the design of the project's ventilation system, as summarised in **Table 2-22**. The ventilation flow rates are based on an average traffic speed of 80 km/ h for the forecast traffic scenarios in 2019 and 2029.

In the case of 'design analysis A', traffic volumes are based on the design throughput capacity of two motorway lanes travelling at different speeds. Since there is more traffic throughput at 60km/ h in the case of 'design analysis A', requiring more ventilation than traffic at 80km/h, the ventilation flow rates during these peak hours are based on an average traffic speed of 60 km/h rather than 80km/h. Further discussion of the traffic throughput capacity of motorway lanes at different speeds is provided in **Section 2.4.2**.

Table 2-22 Applied ventilation flow rates

Time of day	Ventilation flow rate (m^3/s)		
	Forecast traffic 2019	Forecast traffic 2019	Design analysis A
01:00	300	300	380
02:00	300	300	380
03:00	300	300	380
04:00	300	300	380
05:00	380	380	460
06:00	460	460	540
07:00	540	620	700
08:00	620	620	620
09:00	620	620	620
10:00	620	620	620
11:00	540	620	700
12:00	540	620	700
13:00	540	620	700
14:00	540	620	700
15:00	540	620	620
16:00	620	620	620
17:00	620	620	620
18:00	540	620	700
19:00	540	540	620
20:00	460	460	620
21:00	380	460	540
22:00	380	460	460
23:00	380	380	460
00:00	380	380	380

Emission rates

Emission rates published by the Permanent International Association of Road Congresses (PIARC) have been applied in the calculation of the project's emissions inventory. The emissions rates that were used are specific to Australia, and take into account vehicle type (passenger car, light duty vehicle or heavy vehicle), fuel (petrol or diesel) and road gradient.

To account for improvements in vehicle and fuel efficiency over time, the emission factors are published for a base year (2010) with future emission factors then applied to determine emission rates for future years. Future emission factors have been published up to 2020. For the purpose of the air quality impact assessment, emission factors were scaled to 2019 for the 2019 forecast traffic scenario, but only to 2020 for the 2029 forecast traffic scenario. This is a conservative assumption, as it makes no allowance for around nine years of potential improvements in vehicle and fuel efficiencies for the 2029 forecast traffic scenario.

Emission rates for 'design analysis A' were taken as the 2019 emissions factors. This is also a conservative assumption because the traffic volumes contemplated by this scenario are very unlikely to occur when the project is anticipated to open in 2019, and vehicle and fuel efficiencies would improve beyond that date.

Base emission rates (2010) relevant to the project for a range of vehicle speeds are provided in **Table 2-23** (for passenger cars), **Table 2-24** (for light duty vehicles) and **Table 2-25** (for heavy vehicles). Full emission factors are provided in Road Tunnels: Vehicle Emissions and Air Demand for Ventilation (PIARC, 2012).

Table 2-23 Base emission rates for passenger cars (2010)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – petrol					
20 km/h	58.2 g/h	66 g/h	73.7 g/h	84.8 g/h	97.3 g/h
40 km/h	64.4 g/h	81.8 g/h	106.1 g/h	136.1 g/h	177.3 g/h
60 km/h	66.5 g/h	93.9 g/h	132.8 g/h	191.4 g/h	274.1 g/h
80 km/h	65.9 g/h	99.7 g/h	161 g/h	262.8 g/h	408.1 g/h
Carbon monoxide – diesel					
20 km/h	9.6 g/h	9.8 g/h	11 g/h	11.9 g/h	11.2 g/h
40 km/h	9.6 g/h	10.1 g/h	12 g/h	12.4 g/h	13.3 g/h
60 km/h	9.6 g/h	10.2 g/h	11.2 g/h	13.2 g/h	8.8 g/h
80 km/h	9.6 g/h	11.4 g/h	12.2 g/h	8.8 g/h	7.9 g/h
Oxides of nitrogen – petrol					
20 km/h	6.3 g/h	6.5 g/h	10.4 g/h	12.4 g/h	17.6 g/h
40 km/h	6.3 g/h	8.4 g/h	13.4 g/h	23.9 g/h	30.2 g/h
60 km/h	6.3 g/h	9.6 g/h	20.3 g/h	31 g/h	37.2 g/h
80 km/h	6.3 g/h	13.3 g/h	30 g/h	38.1 g/h	53.7 g/h
Oxides of nitrogen – diesel					
20 km/h	8 g/h	9.1 g/h	19.1 g/h	25.8 g/h	31.5 g/h
40 km/h	8 g/h	12.2 g/h	26.7 g/h	38.9 g/h	55.9 g/h
60 km/h	8 g/h	13 g/h	31.9 g/h	56.3 g/h	84.2 g/h
80 km/h	8 g/h	22.1 g/h	48.4 g/h	84.2 g/h	124 g/h
Opacity – diesel					
20 km/h	2.3 m^2/h	2.8 m^2/h	8.2 m^2/h	12.6 m^2/h	16.8 m^2/h
40 km/h	2.3 m^2/h	4.3 m^2/h	13.3 m^2/h	20.6 m^2/h	28.7 m^2/h
60 km/h	2.3 m^2/h	4.7 m^2/h	17 m^2/h	28.8 m^2/h	40.5 m^2/h
80 km/h	2.3 m^2/h	10.1 m^2/h	25.3 m^2/h	40.5 m^2/h	55.2 m^2/h

Table 2-24 Base emission rates for light duty vehicles (2010)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – petrol/ diesel					
20 km/h	34.8 g/h	53.3 g/h	108.4 g/h	96.9 g/h	53.9 g/h
40 km/h	34.8 g/h	85.9 g/h	72.8 g/h	66.2 g/h	148.6 g/h
60 km/h	34.8 g/h	115 g/h	56.5 g/h	179.4 g/h	393.2 g/h
80 km/h	34.8 g/h	130 g/h	181.4 g/h	474.8 g/h	758.9 g/h
Oxides of nitrogen – petrol/ diesel					
20 km/h	9.3 g/h	14.1 g/h	32.2 g/h	35.3 g/h	37 g/h
40 km/h	9.3 g/h	24.1 g/h	30.8 g/h	33.6 g/h	55.9 g/h
60 km/h	9.3 g/h	34.8 g/h	30.2 g/h	63.6 g/h	103.3 g/h
80 km/h	9.3 g/h	35.7 g/h	64 g/h	87.1 g/h	169.5 g/h
Opacity – diesel					
20 km/h	1.2 m^2/h	2.2 m^2/h	5.6 m^2/h	8.4 m^2/h	11.2 m^2/h
40 km/h	1.2 m^2/h	4.1 m^2/h	9.6 m^2/h	14.5 m^2/h	19.7 m^2/h
60 km/h	1.2 m^2/h	6 m^2/h	13.6 m^2/h	21.3 m^2/h	28.8 m^2/h
80 km/h	1.2 m^2/h	11.4 m^2/h	21.4 m^2/h	31.3 m^2/h	41.2 m^2/h

Table 2-25 Base emission rates for heavy vehicles (2010)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – diesel					
20 km/h	31.4 g/h	55 g/h	67.6 g/h	76 g/h	90.2 g/h
40 km/h	29.6 g/h	62.1 g/h	75.4 g/h	97.9 g/h	129.4 g/h
60 km/h	23.5 g/h	56.2 g/h	82.1 g/h	127 g/h	167.4 g/h
80 km/h	20.3 g/h	56.9 g/h	98.9 g/h	156.3 g/h	212.2 g/h
Oxides of nitrogen – diesel					
20 km/h	52.8 g/h	151.1 g/h	217.2 g/h	305.3 g/h	432.3 g/h
40 km/h	48.8 g/h	183.3 g/h	295.1 g/h	493.2 g/h	751.3 g/h
60 km/h	33.3 g/h	154.6 g/h	357.7 g/h	727.7 g/h	1079.6 g/h
80 km/h	28 g/h	163.5 g/h	499.4 g/h	987.2 g/h	1445.3 g/h
Opacity – diesel					
20 km/h	25.9 m^2/h	36.4 m^2/h	49.5 m^2/h	61.1 m^2/h	73.5 m^2/h
40 km/h	24.4 m^2/h	45.7 m^2/h	59.9 m^2/h	80.1 m^2/h	109.9 m^2/h
60 km/h	20.6 m^2/h	42.9 m^2/h	66.6 m^2/h	107.4 m^2/h	147.4 m^2/h
80 km/h	16.7 m^2/h	42.9 m^2/h	80.7 m^2/h	136.6 m^2/h	190.6 m^2/h

Future emission factors published by the Permanent International Association of Road Congresses (2012) are available for the years 2015 and 2020. For 2019, a linear interpolation has been applied to the published factors. Future emission factors applied in calculation of the emissions inventory for the project are summarised in **Table 2-26**.

These future emission factors have been applied to the base emission rates (2010) in the tables above to generate:

- Future emission rates in 2019 (refer to **Table 2-27** to **Table 2-29**).
- Future emission rates in 2029 (refer to **Table 2-30** to **Table 2-32**).

Table 2-26 Future emission factors

Year	CO		NO_x		Opacity
	Petrol	Diesel	Petrol	Diesel	Diesel
Passenger cars					
2010	1	1	1	1	1
2015	0.59	0.67	0.55	0.84	0.64
2019	0.45	0.48	0.36	0.66	0.42
2020	0.42	0.43	0.31	0.61	0.37
Light duty vehicles					
2010	1		1		1
2015	0.69		0.72		0.64
2019	0.55		0.53		0.46
2020	0.51		0.48		0.41
Heavy vehicles					
2010	-	1	-	1	1
2015	-	0.73	-	0.74	0.73
2019	-	0.55	-	0.56	0.54
2020	-	0.50	-	0.52	0.49

Table 2-27 Future emission rates for passenger cars (2019)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – petrol					
20 km/h	26.4 g/h	30.0 g/h	33.5 g/h	38.5 g/h	44.2 g/h
40 km/h	29.2 g/h	37.1 g/h	48.2 g/h	61.8 g/h	80.5 g/h
60 km/h	30.2 g/h	42.6 g/h	60.3 g/h	86.9 g/h	124.4 g/h
80 km/h	29.9 g/h	45.3 g/h	73.1 g/h	119.3 g/h	185.3 g/h
Carbon monoxide – diesel					
20 km/h	4.59 g/h	4.68 g/h	5.26 g/h	5.69 g/h	5.35 g/h
40 km/h	4.59 g/h	4.83 g/h	5.74 g/h	5.93 g/h	6.36 g/h
60 km/h	4.59 g/h	4.88 g/h	5.35 g/h	6.31 g/h	4.21 g/h
80 km/h	4.59 g/h	5.45 g/h	5.83 g/h	4.21 g/h	3.78 g/h
Oxides of nitrogen – petrol					
20 km/h	2.26 g/h	2.33 g/h	3.72 g/h	4.44 g/h	6.30 g/h
40 km/h	2.26 g/h	3.01 g/h	4.80 g/h	8.56 g/h	10.81 g/h
60 km/h	2.26 g/h	3.44 g/h	7.27 g/h	11.10 g/h	13.32 g/h
80 km/h	2.26 g/h	4.76 g/h	10.74 g/h	13.64 g/h	19.22 g/h
Oxides of nitrogen – diesel					
20 km/h	5.25 g/h	5.97 g/h	12.53 g/h	16.92 g/h	20.66 g/h
40 km/h	5.25 g/h	8.00 g/h	17.52 g/h	25.52 g/h	36.67 g/h
60 km/h	5.25 g/h	8.53 g/h	20.93 g/h	36.93 g/h	55.24 g/h
80 km/h	5.25 g/h	14.50 g/h	31.75 g/h	55.24 g/h	81.34 g/h
Opacity – diesel					
20 km/h	0.98 m^2/h	1.19 m^2/h	3.48 m^2/h	5.34 m^2/h	7.12 m^2/h
40 km/h	0.98 m^2/h	1.82 m^2/h	5.64 m^2/h	8.73 m^2/h	12.170 m^2/h
60 km/h	0.98 m^2/h	2.00 m^2/h	7.21 m^2/h	12.21 m^2/h	17.17 m^2/h
80 km/h	0.98 m^2/h	4.28 m^2/h	10.73 m^2/h	17.17 m^2/h	23.41 m^2/h

Table 2-28 Future emission rates for light duty vehicles (2019)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – petrol/ diesel					
20 km/h	19.0 g/h	29.1 g/h	59.2 g/h	52.9 g/h	29.4 g/h
40 km/h	19.0 g/h	46.9 g/h	39.7 g/h	36.1 g/h	81.1 g/h
60 km/h	19.0 g/h	62.8 g/h	30.8 g/h	98.0 g/h	214.7 g/h
80 km/h	19.0 g/h	71.0 g/h	99.0 g/h	259.2 g/h	414.4 g/h
Oxides of nitrogen – petrol/ diesel					
20 km/h	4.9 g/h	7.4 g/h	17.0 g/h	18.6 g/h	19.5 g/h
40 km/h	4.9 g/h	12.7 g/h	16.3 g/h	17.7 g/h	29.5 g/h
60 km/h	4.9 g/h	18.4 g/h	15.9 g/h	33.6 g/h	54.5 g/h
80 km/h	4.9 g/h	18.8 g/h	33.8 g/h	46.0 g/h	89.5 g/h
Opacity – diesel					
20 km/h	0.5 m^2/h	1.0 m^2/h	2.6 m^2/h	3.8 m^2/h	5.1 m^2/h
40 km/h	0.5 m^2/h	1.9 m^2/h	4.4 m^2/h	6.6 m^2/h	9.0 m^2/h
60 km/h	0.5 m^2/h	2.7 m^2/h	6.2 m^2/h	9.7 m^2/h	13.1 m^2/h
80 km/h	0.5 m^2/h	5.2 m^2/h	9.8 m^2/h	14.3 m^2/h	18.8 m^2/h

Table 2-29 Future emission rates for heavy vehicles (2019)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – diesel					
20 km/h	17.14 g/h	30.03 g/h	36.91 g/h	41.50 g/h	49.25 g/h
40 km/h	16.16 g/h	33.91 g/h	41.17 g/h	53.45 g/h	70.65 g/h
60 km/h	12.83 g/h	30.69 g/h	44.83 g/h	69.34 g/h	91.40 g/h
80 km/h	11.08 g/h	31.07 g/h	54.00 g/h	85.34 g/h	115.86 g/h
Oxides of nitrogen – diesel					
20 km/h	29.8 g/h	85.2 g/h	122.5 g/h	172.2 g/h	243.8 g/h
40 km/h	27.5 g/h	103.4 g/h	166.4 g/h	278.2 g/h	423.7 g/h
60 km/h	18.8 g/h	87.2 g/h	201.7 g/h	410.4 g/h	608.9 g/h
80 km/h	15.8 g/h	92.2 g/h	281.7 g/h	556.8 g/h	815.1 g/h
Opacity – diesel					
20 km/h	13.9 m^2/h	19.6 m^2/h	26.6 m^2/h	32.9 m^2/h	39.5 m^2/h
40 km/h	13.1 m^2/h	24.6 m^2/h	32.2 m^2/h	43.1 m^2/h	59.1 m^2/h
60 km/h	11.1 m^2/h	23.1 m^2/h	35.8 m^2/h	57.8 m^2/h	79.3 m^2/h
80 km/h	9.0 m^2/h	23.1 m^2/h	43.4 m^2/h	73.5 m^2/h	102.5 m^2/h

Table 2-30 Future emission rates for passenger cars (2029)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – petrol					
20 km/h	24.4 g/h	27.7 g/h	31.0 g/h	35.6 g/h	40.9 g/h
40 km/h	27.0 g/h	34.4 g/h	44.6 g/h	57.2 g/h	74.5 g/h
60 km/h	27.9 g/h	39.4 g/h	55.8 g/h	80.4 g/h	115.1 g/h
80 km/h	27.7 g/h	41.9 g/h	67.6 g/h	110.4 g/h	171.4 g/h
Carbon monoxide – diesel					
20 km/h	4.13 g/h	4.21 g/h	4.73 g/h	5.12 g/h	4.82 g/h
40 km/h	4.13 g/h	4.34 g/h	5.16 g/h	5.33 g/h	5.72 g/h
60 km/h	4.13 g/h	4.39 g/h	4.82 g/h	5.68 g/h	3.78 g/h
80 km/h	4.13 g/h	4.90 g/h	5.25 g/h	3.78 g/h	3.40 g/h
Oxides of nitrogen – petrol					
20 km/h	1.95 g/h	2.02 g/h	3.22 g/h	3.84 g/h	5.46 g/h
40 km/h	1.95 g/h	2.60 g/h	4.15 g/h	7.41 g/h	9.36 g/h
60 km/h	1.95 g/h	2.98 g/h	6.29 g/h	9.61 g/h	11.53 g/h
80 km/h	1.95 g/h	4.12 g/h	9.30 g/h	11.81 g/h	16.65 g/h
Oxides of nitrogen – diesel					
20 km/h	4.88 g/h	5.55 g/h	11.65 g/h	15.74 g/h	19.22 g/h
40 km/h	4.88 g/h	7.44 g/h	16.29 g/h	23.73 g/h	34.10 g/h
60 km/h	4.88 g/h	7.93 g/h	19.46 g/h	34.34 g/h	51.36 g/h
80 km/h	4.88 g/h	13.48 g/h	29.52 g/h	51.36 g/h	75.64 g/h
Opacity – diesel					
20 km/h	0.85 m^2/h	1.04 m^2/h	3.03 m^2/h	4.66 m^2/h	6.22 m^2/h
40 km/h	0.85 m^2/h	1.59 m^2/h	4.92 m^2/h	7.62 m^2/h	10.62 m^2/h
60 km/h	0.85 m^2/h	1.74 m^2/h	6.29 m^2/h	10.66 m^2/h	14.99 m^2/h
80 km/h	0.85 m^2/h	3.74 m^2/h	9.36 m^2/h	14.99 m^2/h	20.42 m^2/h

Table 2-31 Future emission rates for light duty vehicles (2029)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – petrol/ diesel					
20 km/h	17.7 g/h	27.2 g/h	55.3 g/h	49.4 g/h	27.5 g/h
40 km/h	17.7 g/h	43.8 g/h	37.1 g/h	33.8 g/h	75.8 g/h
60 km/h	17.7 g/h	58.7 g/h	28.8 g/h	91.5 g/h	200.5 g/h
80 km/h	17.7 g/h	66.3 g/h	92.5 g/h	242.1 g/h	387.0 g/h
Oxides of nitrogen – petrol/ diesel					
20 km/h	4.5 g/h	6.8 g/h	15.5 g/h	16.9 g/h	17.8 g/h
40 km/h	4.5 g/h	11.6 g/h	14.8 g/h	16.1 g/h	26.8 g/h
60 km/h	4.5 g/h	16.7 g/h	14.5 g/h	30.5 g/h	49.6 g/h
80 km/h	4.5 g/h	17.1 g/h	30.7 g/h	41.8 g/h	81.4 g/h
Opacity – diesel					
20 km/h	0.5 m^2/h	0.9 m^2/h	2.3 m^2/h	3.4 m^2/h	4.6 m^2/h
40 km/h	0.5 m^2/h	1.7 m^2/h	3.9 m^2/h	5.9 m^2/h	8.1 m^2/h
60 km/h	0.5 m^2/h	2.5 m^2/h	5.6 m^2/h	8.7 m^2/h	11.8 m^2/h
80 km/h	0.5 m^2/h	4.7 m^2/h	8.8 m^2/h	12.8 m^2/h	16.9 m^2/h

Table 2-32 Future emission rates for heavy vehicles (2029)

Speed	Gradient				
	-4%	-2%	0%	+2%	+4%
Carbon monoxide – diesel					
20 km/h	15.7 g/h	27.5 g/h	33.8 g/h	38.0 g/h	45.1 g/h
40 km/h	14.8 g/h	31.1 g/h	37.7 g/h	49.0 g/h	64.7 g/h
60 km/h	11.8 g/h	28.1 g/h	41.1 g/h	63.5 g/h	83.7 g/h
80 km/h	10.2 g/h	28.5 g/h	49.5 g/h	78.2 g/h	106.1 g/h
Oxides of nitrogen – diesel					
20 km/h	27.5 g/h	78.6 g/h	112.9 g/h	158.8 g/h	224.8 g/h
40 km/h	25.4 g/h	95.3 g/h	153.5 g/h	256.5 g/h	390.7 g/h
60 km/h	17.3 g/h	80.4 g/h	186.0 g/h	378.4 g/h	561.4 g/h
80 km/h	14.6 g/h	85.0 g/h	259.7 g/h	513.3 g/h	751.6 g/h
Opacity – diesel					
20 km/h	12.7 m^2/h	17.8 m^2/h	24.3 m^2/h	29.9 m^2/h	36.0 m^2/h
40 km/h	12.0 m^2/h	22.4 m^2/h	29.4 m^2/h	39.2 m^2/h	53.9 m^2/h
60 km/h	10.1 m^2/h	21.0 m^2/h	32.6 m^2/h	52.6 m^2/h	72.2 m^2/h
80 km/h	8.2 m^2/h	21.0 m^2/h	39.5 m^2/h	66.9 m^2/h	93.4 m^2/h

Particulate matter emissions

Emissions of particulate matter come from two sources:

- Exhaust emissions generated by the combustion of fuel in vehicles.
- Non-exhaust emissions, generated by brake and tyre wear, and re-entrainment of particulate matter from the road surface.

In the case of exhaust emissions, the opacity emission rates listed in **Table 2-27** to **Table 2-32** of this report have been converted to particulate matter (PM_{10}) emissions based on the correlations published by the Permanent International Association of Road Congresses (2012).

Opacity in m^2/h has been converted to an equivalent vehicle mass emission rate for PM_{10} based on:

1 g/h = 4.7 m^2/h (PIARC, 2012)

It should be noted that the Permanent International Association of Road Congresses deals with particulate matter in terms of opacity (extinction coefficients). At the time of preparing the air quality impact assessment, it was unclear from the PIARC publications (2012) whether opacity factors were based on PM_{10} or $PM_{2.5}$. For the purpose of the air quality impact assessment, it was assumed that opacity as referred to by PIARC included the full PM_{10} fraction.

As part of preparing this report, it has been clarified with a contributor to the PIARC document that opacity is in fact based on the $PM_{2.5}$ fraction. This clarification if carried through the air quality impact assessment for the project will result in around a five per cent variance in $PM_{2.5}$ and PM_{10} mass emission rates from the project (ventilation outlet and surface road assessments). Given the low predicted impacts of the project, and conservatism in other areas of the assessment, a variance of five percent in particulate matter mass emission rates is considered minor and would not affect the outcomes of the air quality impact assessment (in terms of compliance with applicable air quality standards).

The $PM_{2.5}$ fraction has been determined through comparison of PM_{10} and $PM_{2.5}$ emission rates from the National Pollutant Inventory (NPI) for combustion engines (2008). The ratio of $PM_{2.5}$ to PM_{10} in exhaust emissions applied to the emissions inventory is summarised in **Table 2-33**. Note that the NPI emission factors are expressed in kilograms per cubic metre (kg/m^3) of fuel consumed. Because they are only used below to calculate $PM_{2.5}$:PM_{10} ratios, there is no need to convert these emission factors into a grams per hour (g/h) basis (as has been used elsewhere in this report and the environmental impact statement).

In the case of heavy vehicles, the ratio of $PM_{2.5}$ to PM_{10} has been calculated with National Pollutant Inventory data for different categories of heavy vehicles, and then calculated as a weighted average for the whole heavy vehicle group. Weightings have been applied based on the relative proportion of each heavy vehicle category based on ABS (2013) data, as summarised in **Table 2-34**.

These emission ratios have been applied to calculated exhaust emissions of PM_{10} to determine exhaust emissions of $PM_{2.5}$.

Table 2-33 Ratio of $PM_{2.5}$ to PM_{10} for passenger cars and light duty vehicles

Particulate matter fraction	Emission factor (kg/m^3 fuel)	Ratio ($PM_{2.5}$:PM_{10})
Passenger cars – petrol		
PM_{10}	0.067 kg/m^3	0.9254
$PM_{2.5}$	0.062 kg/m^3	
Passenger cars – diesel		
PM_{10}	2.1 kg/m^3	0.9524
$PM_{2.5}$	2 kg/m^3	
Light duty vehicles – petrol		
PM_{10}	0.072 kg/m^3	0.9306
$PM_{2.5}$	0.067 kg/m^3	
Light duty vehicles - diesel		
PM_{10}	2.4 kg/m^3	0.9583
$PM_{2.5}$	2.3 kg/m^3	

Table 2-34 Ratio of $PM_{2.5}$ to PM_{10} for heavy vehicles

Particulate matter fraction	Emission factor (kg/m^3 fuel)	Ratio ($PM_{2.5}$:PM_{10}) for heavy vehicle category	Percentage of total heavy vehicles	Ratio ($PM_{2.5}$:PM_{10}) for all heavy vehicles
Medium goods vehicle				0.9510
PM_{10}	2.3 kg/m^3	0.9565	20.46%	
$PM_{2.5}$	2.2 kg/m^3			
Heavy goods vehicle				
PM_{10}	1.8 kg/m^3	0.9444	50.85%	
$PM_{2.5}$	1.7 kg/m^3			
Very heavy goods vehicle				
PM_{10}	1.2 kg/m^3	0.9167	14.18%	
$PM_{2.5}$	1.1 kg/m^3			
Buses				
PM_{10}	2.1 kg/m^3	1.000	14.51%	
$PM_{2.5}$	2.1 kg/m^3			

Note that while it may appear from the table above that heavy vehicles emit less particulate matter than passenger cars (compare, for example, a PM_{10} emission factor for a diesel fuelled car at 2.1 kg/m^3 compared with the same figure for a very heavy goods vehicle of only 1.2 kg/m^3), the emission factors presented above are expressed in terms of total mass of particulate matter per cubic metre of fuel consumed. Heavy vehicles use more fuel per kilometre than passenger cars, so while they may emit less mass of particulate matter per cubic metre of fuel, they emit a greater total amount of particulate matter because of a much higher amount of fuel used per kilometre than passenger cars.

The Permanent International Association of Road Congresses (2012) provides emission factors for non-exhaust $PM_{2.5}$, as summarised in **Table 2-35**. These emission factors have been added to the emission factors for exhaust emissions to determine a total $PM_{2.5}$ emission factor for the purpose of calculating the project's emissions inventory. Unlike exhaust emissions, non-exhaust emission factors have been applied consistently over time with no assumed improvement in the future. To determine non-exhaust PM_{10} emissions, the same $PM_{2.5}$:PM_{10} ratios as outlined above have been applied.

Table 2-35 Non-exhaust $PM_{2.5}$ emission factors

Speed	Non-exhaust emission factors ($PM_{2.5}$)	
	Passenger cars/ light duty vehicles	Heavy vehicles
20 km/h	0.56 g/h	2.08 g/h
40 km/h	1.12 g/h	4.16 g/h
60 km/h	1.68 g/h	6.24 g/h
80 km/h	2.24 g/h	8.32 g/h

Other emissions

Data from the National Pollutant Inventory (NPI) for combustion engines (2008) has been used to determine the emission factors for other hydrocarbon pollutants. These other pollutants have been calculated based on their ration relative to the emission factor for carbon monoxide, as summarised in **Table 2-36** for passenger and light duty vehicles, and **Table 2-37** for heavy vehicles.

Table 2-36 Ratio of hydrocarbons to CO for passenger cars and light duty vehicles

Pollutant	Emission factor	Ratio of pollutant: CO
Passenger cars – petrol		
CO	37 kg/m^3	-
Polycyclic aromatic hydrocarbons (PAHs)	5.2 x 10^{-6} kg/m^3	1.41 x 10^{-7}
Total volatile organic compounds (VOCs)	2.5 kg/m^3	0.0676
Passenger cars – diesel		
CO	10 kg/m^3	-
Polycyclic aromatic hydrocarbons (PAHs)	3.2 x 10^{-4} kg/m^3	3.2 x 10^{-5}
Total volatile organic compounds (VOCs)	0.82	0.082
Light duty vehicles – petrol		
CO	87 kg/m^3	-
Polycyclic aromatic hydrocarbons (PAHs)	1.8 x 10^{-5} kg/m^3	2.07 x 10^{-7}
Total volatile organic compounds (VOCs)	8.5 kg/m^3	0.0977
Light duty vehicles - diesel		
CO	19 kg/m^3	-
Polycyclic aromatic hydrocarbons (PAHs)	1.6 x 10^{-4} kg/m^3	8.42 x 10^{-6}
Total volatile organic compounds (VOCs)	0.42 kg/m^3	0.0221

Table 2-37 Ratio of hydrocarbons to CO for heavy vehicles

Pollutant	Emission factor	Ratio of pollutant: CO for heavy vehicle category	Percentage of total heavy vehicles	Ratio of pollutant: CO for all heavy vehicles
Medium goods vehicle				PAHs: 8.143×10^{-5} VOCs: 0.21
CO	12 kg/m^3	-	20.46%	
Polycyclic aromatic hydrocarbons	8.4×10^{-4} kg/m^3	7.0×10^{-5}		
Total volatile organic compounds	2.1 kg/m^3	0.175		
Heavy goods vehicle				
CO	6.8 kg/m^3	-	50.85%	
Polycyclic aromatic hydrocarbons	7.1×10^{-4} kg/m^3	1.04×10^{-4}		
Total volatile organic compounds	1.8 kg/m^3	0.2647		
Very heavy goods vehicle				
CO	8.5 kg/m^3	-	14.18%	
Polycyclic aromatic hydrocarbons	4.0×10^{-4} kg/m^3	4.71×10^{-5}		
Total volatile organic compounds	1.0 kg/m^3	0.1176		
Buses				
CO	9.1 kg/m^3	-	14.51%	
Polycyclic aromatic hydrocarbons	4.6×10^{-4} kg/m^3	5.05×10^{-5}		
Total volatile organic compounds	1.2 kg/m^3	0.1318		

Calculated emissions inventories

This section includes:

- Updated emissions inventories used in the air quality impact assessment presented in this report (to reflect an increase in ventilation outlet heights by five metres). As discussed in **Section 2.3**, some amendments have been made to assumptions and inputs used in the air quality impact assessment for the project since public exhibition of the environmental impact statement. One of these amendments (future fuel mix) has altered the emissions inventories for the project, as detailed below.
- Clarification of the emissions inventory presented in the environmental impact statement for forecast traffic flow scenarios in 2019 and 2029 (scenario 2a and scenario 2b).

Updated emissions inventories

As discussed in **Section 2.3** and detailed in the relevant sections in this chapter, four amendments have been made to the assumptions and inputs into the air quality impact assessment for the project:

- Increasing the resolution of the receiver grid applied around each ventilation outlet (ie reduced receiver spacing) (refer to **Section 2.13.1**).
- Applying higher resolution topographic data (refer to **Section 2.12**).
- Revising future projections of vehicle fleet fuel mix, to reflect an increased use of diesel fuel in the future) (refer to **Section 2.7**).
- Amending the ozone limiting method equation to take into account a NO_2:NO_x ratio of 16 per cent, as recommended by the Environment Protection Authority (refer to **Section 2.14**).

Of these amendments, the revision of future projections of vehicle fuel mix has affected the emissions inventories for the air quality impact assessment scenarios. The updated emissions inventories are provided in this section. With the exception of the clarification in the following section of this report, the emissions inventories applied to the air quality impact assessment presented in the environmental impact statement have not been reproduced in this report because those emissions inventories have now been superseded by the inventories provided in this report.

Emission inventories for the air quality impact assessment scenarios are provided in the following tables. Flow rates and pollutant concentrations have been expressed in terms of normal cubic metres per second (Nm^3/s) at 0^oC, one atmosphere of pressure and dry conditions.

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Table 2-38 Emissions inventory – forecast traffic volumes 2019 (scenario 2a)

Time of day	Flowrate (Nm^3/s)	CO g/s	CO mg/m^3	NO_x g/s	NO_x mg/m^3	PM_{10} g/s	PM_{10} mg/m^3	$PM_{2.5}$ g/s	$PM_{2.5}$ mg/m^3	PAHs g/s	PAHs mg/m^3	VOCs g/s	VOCs mg/m^3
Southbound													
01:00	300	0.171	0.570	0.197	0.655	0.018	0.061	0.017	0.057	0.000003	0.000011	0.0172	0.0572
02:00	300	0.134	0.447	0.155	0.518	0.014	0.048	0.014	0.045	0.000003	0.000008	0.0135	0.0450
03:00	300	0.129	0.431	0.148	0.492	0.014	0.046	0.013	0.043	0.000002	0.000008	0.0129	0.0431
04:00	300	0.181	0.603	0.212	0.707	0.020	0.065	0.019	0.062	0.000003	0.000012	0.0183	0.0610
05:00	380	0.307	0.807	0.359	0.945	0.033	0.087	0.031	0.082	0.000006	0.000016	0.0310	0.0815
06:00	460	0.786	1.709	0.915	1.990	0.085	0.184	0.080	0.174	0.000015	0.000033	0.0793	0.1723
07:00	540	1.659	3.073	1.929	3.572	0.178	0.331	0.169	0.312	0.000032	0.000059	0.1672	0.3097
08:00	620	2.176	3.509	2.526	4.075	0.234	0.377	0.221	0.356	0.000041	0.000067	0.2192	0.3535
09:00	620	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369	0.000043	0.000069	0.2270	0.3661
10:00	620	1.995	3.217	2.321	3.743	0.215	0.346	0.203	0.327	0.000038	0.000061	0.2011	0.3243
11:00	540	1.857	3.439	2.158	3.996	0.200	0.370	0.189	0.349	0.000035	0.000066	0.1871	0.3466
12:00	540	1.809	3.349	2.101	3.891	0.194	0.360	0.184	0.340	0.000034	0.000064	0.1822	0.3375
13:00	540	1.721	3.188	2.002	3.708	0.185	0.343	0.175	0.324	0.000033	0.000061	0.1735	0.3213
14:00	540	1.778	3.293	2.068	3.829	0.191	0.354	0.181	0.335	0.000034	0.000063	0.1792	0.3319
15:00	540	1.954	3.619	2.272	4.208	0.210	0.389	0.199	0.368	0.000037	0.000069	0.1970	0.3648
16:00	620	2.196	3.542	2.551	4.114	0.236	0.381	0.223	0.360	0.000042	0.000067	0.2212	0.3568
17:00	620	2.097	3.382	2.436	3.929	0.225	0.364	0.213	0.344	0.000040	0.000064	0.2113	0.3408
18:00	540	1.855	3.436	2.158	3.996	0.200	0.370	0.189	0.349	0.000035	0.000066	0.1870	0.3463
19:00	540	1.378	2.551	1.602	2.967	0.148	0.274	0.140	0.259	0.000026	0.000049	0.1389	0.2572
20:00	460	0.895	1.946	1.039	2.258	0.096	0.209	0.091	0.197	0.000017	0.000037	0.0902	0.1960
21:00	380	0.605	1.592	0.703	1.850	0.065	0.171	0.061	0.162	0.000012	0.000030	0.0610	0.1605
22:00	380	0.515	1.354	0.597	1.571	0.055	0.145	0.052	0.137	0.000010	0.000026	0.0518	0.1364
23:00	380	0.389	1.024	0.450	1.184	0.042	0.110	0.039	0.104	0.000007	0.000019	0.0391	0.1030
24:00	380	0.260	0.684	0.302	0.796	0.028	0.074	0.026	0.070	0.000005	0.000013	0.0262	0.0689
Northbound													
01:00	300	0.240	0.800	0.348	1.161	0.020	0.068	0.019	0.064	0.000005	0.000015	0.0241	0.0803
02:00	300	0.184	0.614	0.269	0.897	0.016	0.053	0.015	0.050	0.000003	0.000012	0.0185	0.0618
03:00	300	0.187	0.623	0.269	0.898	0.016	0.053	0.015	0.050	0.000003	0.000012	0.0187	0.0624
04:00	300	0.306	1.019	0.443	1.478	0.026	0.087	0.025	0.082	0.000006	0.000019	0.0307	0.1022
05:00	380	0.697	1.835	0.999	2.630	0.059	0.155	0.056	0.146	0.000013	0.000034	0.0697	0.1834
06:00	460	1.642	3.570	2.362	5.136	0.139	0.302	0.131	0.286	0.000031	0.000067	0.1643	0.3572

07:00	540	2.261	4.187	3.251	6.020	0.191	0.354	0.181	0.335	0.000042	0.000078	0.2262	0.4189
08:00	620	2.117	3.920	3.044	5.638	0.179	0.332	0.169	0.314	0.000039	0.000073	0.2118	0.3922
09:00	620	2.215	4.103	3.187	5.902	0.188	0.347	0.177	0.328	0.000041	0.000077	0.2217	0.4105
10:00	620	2.895	5.362	4.156	7.696	0.245	0.453	0.231	0.428	0.000054	0.000100	0.2895	0.5361
11:00	540	2.857	5.291	4.107	7.606	0.242	0.448	0.229	0.423	0.000053	0.000099	0.2858	0.5293
12:00	540	2.696	4.992	3.870	7.167	0.228	0.422	0.215	0.399	0.000050	0.000093	0.2696	0.4992
13:00	540	2.602	4.819	3.742	6.930	0.220	0.408	0.208	0.386	0.000049	0.000090	0.2603	0.4821
14:00	540	2.635	4.879	3.790	7.018	0.223	0.413	0.211	0.390	0.000049	0.000091	0.2636	0.4882
15:00	540	2.976	5.511	4.281	7.928	0.252	0.466	0.238	0.441	0.000055	0.000103	0.2978	0.5514
16:00	620	3.421	5.517	4.916	7.929	0.289	0.467	0.274	0.441	0.000064	0.000103	0.3422	0.5519
17:00	620	3.646	5.880	5.234	8.442	0.308	0.497	0.291	0.470	0.000068	0.000109	0.3646	0.5880
18:00	540	3.774	6.088	5.424	8.748	0.319	0.515	0.302	0.487	0.000070	0.000113	0.3775	0.6089
19:00	540	2.701	5.001	3.885	7.194	0.229	0.423	0.216	0.400	0.000050	0.000093	0.2702	0.5004
20:00	460	1.592	3.460	2.284	4.965	0.134	0.292	0.127	0.276	0.000030	0.000064	0.1591	0.3460
21:00	380	1.104	2.400	1.586	3.448	0.093	0.203	0.088	0.192	0.000021	0.000045	0.1104	0.2400
22:00	380	0.917	2.413	1.316	3.464	0.078	0.204	0.073	0.193	0.000017	0.000045	0.0917	0.2413
23:00	380	0.692	1.821	0.998	2.628	0.059	0.155	0.056	0.146	0.000013	0.000034	0.0693	0.1824
24:00	380	0.404	1.063	0.586	1.542	0.034	0.091	0.033	0.086	0.000008	0.000020	0.0405	0.1067

Table 2-39 Emissions inventory – forecast traffic volumes 2029 (scenario 2b)

Time of day	Flowrate (Nm^3/s)	CO		NO_x		PM_{10}		$PM_{2.5}$		PAHs		VOCs	
		g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3
Southbound													
01:00	300	0.204	0.680	0.220	0.734	0.022	0.074	0.021	0.069	0.000004	0.000012	0.0199	0.0664
02:00	300	0.160	0.533	0.174	0.580	0.017	0.058	0.016	0.055	0.000003	0.000009	0.0156	0.0521
03:00	300	0.154	0.514	0.165	0.552	0.017	0.055	0.016	0.052	0.000003	0.000009	0.0150	0.0500
04:00	300	0.216	0.719	0.237	0.792	0.024	0.079	0.022	0.074	0.000004	0.000013	0.0212	0.0706
05:00	380	0.366	0.962	0.402	1.058	0.040	0.105	0.038	0.100	0.000006	0.000017	0.0359	0.0944
06:00	460	0.937	2.037	1.025	2.228	0.102	0.222	0.097	0.210	0.000016	0.000035	0.0918	0.1996
07:00	620	1.979	3.191	2.160	3.484	0.216	0.348	0.204	0.328	0.000034	0.000055	0.1937	0.3125
08:00	620	2.594	4.184	2.829	4.563	0.283	0.456	0.267	0.430	0.000045	0.000073	0.2539	0.4096
09:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
10:00	620	2.378	3.836	2.599	4.192	0.260	0.419	0.245	0.395	0.000041	0.000067	0.2329	0.3757
11:00	620	2.214	3.572	2.417	3.898	0.241	0.389	0.228	0.367	0.000038	0.000062	0.2168	0.3497
12:00	620	2.156	3.478	2.353	3.795	0.235	0.379	0.222	0.358	0.000037	0.000060	0.2111	0.3405
13:00	620	2.052	3.310	2.242	3.616	0.224	0.361	0.211	0.341	0.000036	0.000058	0.2010	0.3242
14:00	620	2.120	3.420	2.316	3.735	0.231	0.373	0.218	0.352	0.000037	0.000059	0.2076	0.3349
15:00	620	2.330	3.758	2.544	4.104	0.254	0.410	0.240	0.387	0.000041	0.000065	0.2282	0.3680
16:00	620	2.618	4.223	2.856	4.607	0.285	0.460	0.269	0.434	0.000045	0.000073	0.2563	0.4134
17:00	620	2.500	4.033	2.728	4.400	0.273	0.440	0.257	0.415	0.000043	0.000070	0.2448	0.3948
18:00	620	2.212	3.568	2.416	3.897	0.241	0.389	0.228	0.367	0.000038	0.000062	0.2166	0.3494
19:00	540	1.643	3.042	1.794	3.322	0.179	0.332	0.169	0.313	0.000029	0.000053	0.1609	0.2979
20:00	460	1.067	2.320	1.163	2.528	0.116	0.253	0.110	0.238	0.000019	0.000040	0.1044	0.2271
21:00	460	0.721	1.568	0.787	1.711	0.079	0.171	0.074	0.161	0.000013	0.000027	0.0706	0.1536
22:00	460	0.614	1.334	0.669	1.453	0.067	0.145	0.063	0.137	0.000011	0.000023	0.0600	0.1305
23:00	380	0.464	1.221	0.504	1.326	0.050	0.133	0.048	0.125	0.000008	0.000021	0.0453	0.1193
24:00	380	0.310	0.815	0.339	0.891	0.034	0.089	0.032	0.084	0.000005	0.000014	0.0303	0.0798
Northbound													
01:00	300	0.286	0.954	0.384	1.279	0.024	0.081	0.023	0.076	0.000005	0.000016	0.0278	0.0928
02:00	300	0.220	0.733	0.296	0.987	0.019	0.062	0.018	0.059	0.000004	0.000013	0.0214	0.0714
03:00	300	0.223	0.744	0.297	0.990	0.019	0.063	0.018	0.059	0.000004	0.000013	0.0216	0.0722
04:00	380	0.365	0.960	0.488	1.285	0.031	0.081	0.029	0.077	0.000006	0.000016	0.0354	0.0933
05:00	380	0.833	2.191	1.102	2.899	0.070	0.184	0.066	0.173	0.000014	0.000037	0.0806	0.2122

06:00	540	1.960	3.630	2.603	4.821	0.165	0.305	0.156	0.288	0.000033	0.000061	0.1901	0.3519
07:00	540	2.699	4.999	3.582	6.634	0.227	0.420	0.214	0.397	0.000045	0.000084	0.2616	0.4845
08:00	540	2.527	4.680	3.355	6.213	0.212	0.393	0.201	0.371	0.000042	0.000079	0.2450	0.4537
09:00	540	2.645	4.898	3.512	6.504	0.222	0.412	0.210	0.389	0.000044	0.000082	0.2564	0.4748
10:00	620	3.457	5.575	4.580	7.387	0.290	0.468	0.274	0.442	0.000058	0.000093	0.3349	0.5402
11:00	620	3.411	5.502	4.526	7.300	0.287	0.462	0.271	0.436	0.000057	0.000092	0.3306	0.5333
12:00	620	3.218	5.191	4.265	6.879	0.270	0.436	0.255	0.411	0.000054	0.000087	0.3118	0.5029
13:00	620	3.106	5.010	4.124	6.651	0.261	0.421	0.246	0.398	0.000052	0.000084	0.3011	0.4857
14:00	620	3.146	5.073	4.176	6.736	0.264	0.426	0.250	0.403	0.000053	0.000085	0.3049	0.4918
15:00	620	3.553	5.730	4.718	7.609	0.299	0.482	0.282	0.455	0.000060	0.000096	0.3444	0.5555
16:00	620	4.084	6.587	5.417	8.738	0.343	0.553	0.324	0.522	0.000069	0.000111	0.3958	0.6384
17:00	620	4.352	7.020	5.768	9.304	0.365	0.589	0.345	0.556	0.000073	0.000118	0.4217	0.6802
18:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
19:00	620	3.224	5.200	4.281	6.904	0.271	0.437	0.256	0.413	0.000054	0.000087	0.3126	0.5041
20:00	540	1.900	3.519	2.517	4.662	0.159	0.295	0.151	0.279	0.000032	0.000059	0.1841	0.3409
21:00	460	1.318	2.865	1.748	3.799	0.111	0.241	0.104	0.227	0.000022	0.000048	0.1277	0.2777
22:00	460	1.095	2.380	1.451	3.154	0.092	0.200	0.087	0.189	0.000018	0.000040	0.1061	0.2306
23:00	380	0.826	2.174	1.100	2.895	0.070	0.183	0.066	0.173	0.000014	0.000037	0.0802	0.2110
24:00	380	0.482	1.269	0.645	1.699	0.041	0.107	0.038	0.101	0.000008	0.000022	0.0469	0.1233

Table 2-40 Emissions inventory – worst case scenario (design analysis A)

Time of day	Flowrate (Nm^3/s)	CO		NO_x		PM_{10}		$PM_{2.5}$		PAHs		VOCs	
		g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3	g/s	mg/m^3
Southbound													
01:00	380	0.383	1.009	0.441	1.160	0.041	0.108	0.039	0.102	0.000007	0.000019	0.0385	0.1013
02:00	380	0.301	0.791	0.348	0.917	0.032	0.085	0.030	0.080	0.000006	0.000015	0.0303	0.0797
03:00	380	0.290	0.762	0.331	0.871	0.031	0.081	0.029	0.076	0.000005	0.000014	0.0290	0.0764
04:00	380	0.406	1.068	0.476	1.252	0.044	0.116	0.041	0.109	0.000008	0.000021	0.0410	0.1079
05:00	460	0.687	1.494	0.805	1.750	0.074	0.162	0.070	0.153	0.000013	0.000029	0.0695	0.1510
06:00	540	1.762	3.263	2.052	3.799	0.190	0.351	0.179	0.332	0.000034	0.000062	0.1777	0.3291
07:00	700	3.720	5.314	4.324	6.178	0.400	0.572	0.378	0.540	0.000071	0.000101	0.3749	0.5356
08:00	620	5.139	8.289	5.889	9.498	0.550	0.887	0.520	0.838	0.000109	0.000175	0.5361	0.8646
09:00	620	5.321	8.582	6.098	9.836	0.569	0.918	0.538	0.868	0.000113	0.000182	0.5551	0.8953
10:00	620	4.711	7.599	5.410	8.726	0.505	0.814	0.477	0.770	0.000100	0.000161	0.4919	0.7933
11:00	700	4.163	5.948	4.838	6.911	0.448	0.640	0.423	0.604	0.000079	0.000113	0.4195	0.5994
12:00	700	4.055	5.792	4.710	6.729	0.436	0.623	0.412	0.588	0.000077	0.000110	0.4085	0.5836
13:00	700	3.859	5.513	4.489	6.413	0.415	0.593	0.392	0.560	0.000074	0.000105	0.3890	0.5557
14:00	700	3.987	5.695	4.636	6.622	0.429	0.613	0.405	0.579	0.000076	0.000109	0.4018	0.5740
15:00	620	4.616	7.446	5.297	8.543	0.494	0.797	0.467	0.754	0.000098	0.000158	0.4818	0.7771
16:00	620	5.187	8.365	5.946	9.590	0.555	0.895	0.525	0.846	0.000110	0.000177	0.5411	0.8728
17:00	620	4.953	7.989	5.679	9.159	0.530	0.855	0.501	0.808	0.000105	0.000169	0.5168	0.8335
18:00	700	4.160	5.942	4.837	6.910	0.448	0.639	0.423	0.604	0.000079	0.000113	0.4193	0.5989
19:00	620	3.089	4.982	3.591	5.793	0.332	0.536	0.314	0.506	0.000059	0.000095	0.3113	0.5021
20:00	620	2.007	3.237	2.328	3.755	0.216	0.348	0.204	0.328	0.000038	0.000062	0.2021	0.3260
21:00	540	1.357	2.512	1.576	2.919	0.146	0.270	0.138	0.255	0.000026	0.000048	0.1367	0.2531
22:00	460	1.154	2.508	1.338	2.909	0.124	0.269	0.117	0.254	0.000022	0.000048	0.1162	0.2526
23:00	460	0.872	1.896	1.009	2.193	0.093	0.203	0.088	0.192	0.000017	0.000036	0.0877	0.1907
24:00	380	0.582	1.533	0.678	1.784	0.063	0.165	0.059	0.156	0.000011	0.000029	0.0587	0.1545
Northbound													
01:00	380	0.497	1.308	0.722	1.899	0.042	0.112	0.040	0.105	0.000009	0.000025	0.0499	0.1313
02:00	380	0.382	1.005	0.557	1.466	0.033	0.086	0.031	0.081	0.000007	0.000019	0.0384	0.1010
03:00	380	0.387	1.019	0.558	1.469	0.033	0.086	0.031	0.082	0.000007	0.000019	0.0388	0.1020
04:00	380	0.633	1.666	0.919	2.417	0.054	0.142	0.051	0.134	0.000012	0.000031	0.0635	0.1672
05:00	460	1.445	3.141	2.071	4.502	0.122	0.265	0.115	0.251	0.000027	0.000058	0.1444	0.3139
06:00	620	3.402	5.487	4.895	7.895	0.288	0.465	0.272	0.439	0.000063	0.000102	0.3404	0.5491

07:00	620	4.684	7.556	6.735	10.863	0.396	0.639	0.375	0.604	0.000087	0.000141	0.4687	0.7559
08:00	620	4.386	7.074	6.308	10.174	0.371	0.599	0.351	0.566	0.000082	0.000132	0.4388	0.7078
09:00	620	4.590	7.404	6.603	10.650	0.389	0.627	0.367	0.592	0.000086	0.000138	0.4593	0.7408
10:00	700	5.999	8.569	8.610	12.300	0.507	0.724	0.479	0.685	0.000112	0.000159	0.5998	0.8569
11:00	700	5.920	8.457	8.509	12.156	0.501	0.715	0.473	0.676	0.000110	0.000158	0.5922	0.8460
12:00	700	5.585	7.979	8.018	11.455	0.472	0.674	0.446	0.638	0.000104	0.000148	0.5585	0.7978
13:00	700	5.391	7.701	7.753	11.076	0.456	0.652	0.431	0.616	0.000100	0.000144	0.5394	0.7706
14:00	700	5.459	7.799	7.852	11.217	0.462	0.660	0.437	0.624	0.000102	0.000145	0.5462	0.7803
15:00	700	6.166	8.808	8.870	12.671	0.522	0.746	0.493	0.705	0.000115	0.000164	0.6169	0.8813
16:00	620	6.346	10.236	9.982	16.100	0.614	0.990	0.580	0.936	0.000141	0.000228	0.6737	1.0866
17:00	700	6.763	9.662	10.627	15.182	0.654	0.934	0.618	0.883	0.000150	0.000215	0.7177	1.0253
18:00	700	7.002	10.003	11.012	15.732	0.677	0.967	0.640	0.915	0.000156	0.000223	0.7433	1.0619
19:00	700	5.595	7.993	8.049	11.498	0.474	0.677	0.448	0.640	0.000104	0.000149	0.5598	0.7998
20:00	620	3.298	5.319	4.732	7.633	0.279	0.449	0.263	0.425	0.000061	0.000099	0.3297	0.5318
21:00	540	2.287	4.236	3.286	6.085	0.193	0.358	0.183	0.339	0.000043	0.000079	0.2288	0.4237
22:00	460	1.900	4.131	2.728	5.929	0.161	0.349	0.152	0.330	0.000035	0.000077	0.1900	0.4130
23:00	460	1.434	3.117	2.069	4.497	0.122	0.264	0.115	0.250	0.000027	0.000058	0.1436	0.3122
24:00	380	0.837	2.203	1.214	3.195	0.071	0.188	0.067	0.177	0.000016	0.000041	0.0840	0.2210

Table 2-41 Emissions inventory – regulatory scenario 2019 (design analysis B 2019)

Time of day	Flowrate (Nm^3/s)	CO g/s	CO mg/m^3	NO_x g/s	NO_x mg/m^3	PM_{10} g/s	PM_{10} mg/m^3	$PM_{2.5}$ g/s	$PM_{2.5}$ mg/m^3	PAHs g/s	PAHs mg/m^3	VOCs g/s	VOCs mg/m^3
Southbound													
01:00	300	1.090	3.634	1.266	4.220	0.117	0.391	0.111	0.369	0.000021	0.000069	0.1098	0.3661
02:00	300	1.090	3.634	1.266	4.220	0.117	0.391	0.111	0.369	0.000021	0.000069	0.1098	0.3661
03:00	300	1.090	3.634	1.266	4.220	0.117	0.391	0.111	0.369	0.000021	0.000069	0.1098	0.3661
04:00	300	1.090	3.634	1.266	4.220	0.117	0.391	0.111	0.369	0.000021	0.000069	0.1098	0.3661
05:00	380	1.381	3.634	1.603	4.220	0.148	0.391	0.140	0.369	0.000026	0.000069	0.1391	0.3661
06:00	460	1.671	3.634	1.941	4.220	0.180	0.391	0.170	0.369	0.000032	0.000069	0.1684	0.3661
07:00	540	1.962	3.634	2.279	4.220	0.211	0.391	0.199	0.369	0.000037	0.000069	0.1977	0.3661
08:00	620	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369	0.000043	0.000069	0.2270	0.3661
09:00	620	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369	0.000043	0.000069	0.2270	0.3661
10:00	620	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369	0.000043	0.000069	0.2270	0.3661
11:00	540	1.962	3.634	2.279	4.220	0.211	0.391	0.199	0.369	0.000037	0.000069	0.1977	0.3661
12:00	540	1.962	3.634	2.279	4.220	0.211	0.391	0.199	0.369	0.000037	0.000069	0.1977	0.3661
13:00	540	1.962	3.634	2.279	4.220	0.211	0.391	0.199	0.369	0.000037	0.000069	0.1977	0.3661
14:00	540	1.962	3.634	2.279	4.220	0.211	0.391	0.199	0.369	0.000037	0.000069	0.1977	0.3661
15:00	540	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369	0.000043	0.000069	0.2270	0.3661
16:00	620	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369	0.000043	0.000069	0.2270	0.3661
17:00	620	2.253	3.634	2.616	4.220	0.242	0.391	0.229	0.369	0.000043	0.000069	0.2270	0.3661
18:00	540	1.962	3.634	2.279	4.220	0.211	0.391	0.199	0.369	0.000037	0.000069	0.1977	0.3661
19:00	540	1.962	3.634	2.279	4.220	0.211	0.391	0.199	0.369	0.000037	0.000069	0.1977	0.3661
20:00	460	1.671	3.634	1.941	4.220	0.180	0.391	0.170	0.369	0.000032	0.000069	0.1684	0.3661
21:00	380	1.671	3.634	1.941	4.220	0.180	0.391	0.170	0.369	0.000032	0.000069	0.1684	0.3661
22:00	380	1.381	3.634	1.603	4.220	0.148	0.391	0.140	0.369	0.000026	0.000069	0.1391	0.3661
23:00	380	1.381	3.634	1.603	4.220	0.148	0.391	0.140	0.369	0.000026	0.000069	0.1391	0.3661
24:00	380	1.381	3.634	1.603	4.220	0.148	0.391	0.140	0.369	0.000026	0.000069	0.1391	0.3661
Northbound													
01:00	300	1.826	6.088	2.624	8.748	0.154	0.515	0.146	0.487	0.000034	0.000113	0.1827	0.6089
02:00	300	1.826	6.088	2.624	8.748	0.154	0.515	0.146	0.487	0.000034	0.000113	0.1827	0.6089
03:00	300	1.826	6.088	2.624	8.748	0.154	0.515	0.146	0.487	0.000034	0.000113	0.1827	0.6089
04:00	300	1.826	6.088	2.624	8.748	0.154	0.515	0.146	0.487	0.000034	0.000113	0.1827	0.6089
05:00	380	2.313	6.088	3.324	8.748	0.196	0.515	0.185	0.487	0.000043	0.000113	0.2314	0.6089
06:00	460	2.800	6.088	4.024	8.748	0.237	0.515	0.224	0.487	0.000052	0.000113	0.2801	0.6089

07:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
08:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
09:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
10:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
11:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
12:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
13:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
14:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
15:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
16:00	620	3.774	6.088	5.424	8.748	0.319	0.515	0.302	0.487	0.000070	0.000113	0.3775	0.6089
17:00	620	3.774	6.088	5.424	8.748	0.319	0.515	0.302	0.487	0.000070	0.000113	0.3775	0.6089
18:00	620	3.774	6.088	5.424	8.748	0.319	0.515	0.302	0.487	0.000070	0.000113	0.3775	0.6089
19:00	540	3.287	6.088	4.724	8.748	0.278	0.515	0.263	0.487	0.000061	0.000113	0.3288	0.6089
20:00	460	2.800	6.088	4.024	8.748	0.237	0.515	0.224	0.487	0.000052	0.000113	0.2801	0.6089
21:00	460	2.800	6.088	4.024	8.748	0.237	0.515	0.224	0.487	0.000052	0.000113	0.2801	0.6089
22:00	380	2.313	6.088	3.324	8.748	0.196	0.515	0.185	0.487	0.000043	0.000113	0.2314	0.6089
23:00	380	2.313	6.088	3.324	8.748	0.196	0.515	0.185	0.487	0.000043	0.000113	0.2314	0.6089
24:00	380	2.313	6.088	3.324	8.748	0.196	0.515	0.185	0.487	0.000043	0.000113	0.2314	0.6089

Table 2-42 Emissions inventory – regulatory scenario 2029 (design analysis B 2029)

Time of day	Flowrate (Nm^3/s)	CO g/s	CO mg/m^3	NO_x g/s	NO_x mg/m^3	PM_{10} g/s	PM_{10} mg/m^3	$PM_{2.5}$ g/s	$PM_{2.5}$ mg/m^3	PAHs g/s	PAHs mg/m^3	VOCs g/s	VOCs mg/m^3
Southbound													
01:00	300	1.300	4.333	1.418	4.725	0.142	0.472	0.134	0.446	0.000023	0.000075	0.1272	0.4241
02:00	300	1.300	4.333	1.418	4.725	0.142	0.472	0.134	0.446	0.000023	0.000075	0.1272	0.4241
03:00	300	1.300	4.333	1.418	4.725	0.142	0.472	0.134	0.446	0.000023	0.000075	0.1272	0.4241
04:00	300	1.300	4.333	1.418	4.725	0.142	0.472	0.134	0.446	0.000023	0.000075	0.1272	0.4241
05:00	380	1.646	4.333	1.796	4.725	0.179	0.472	0.169	0.446	0.000029	0.000075	0.1612	0.4241
06:00	460	1.993	4.333	2.174	4.725	0.217	0.472	0.205	0.446	0.000035	0.000075	0.1951	0.4241
07:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
08:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
09:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
10:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
11:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
12:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
13:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
14:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
15:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
16:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
17:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
18:00	620	2.686	4.333	2.930	4.725	0.293	0.472	0.276	0.446	0.000047	0.000075	0.2629	0.4241
19:00	540	2.340	4.333	2.552	4.725	0.255	0.472	0.241	0.446	0.000041	0.000075	0.2290	0.4241
20:00	460	1.993	4.333	2.174	4.725	0.217	0.472	0.205	0.446	0.000035	0.000075	0.1951	0.4241
21:00	460	1.993	4.333	2.174	4.725	0.217	0.472	0.205	0.446	0.000035	0.000075	0.1951	0.4241
22:00	460	1.993	4.333	2.174	4.725	0.217	0.472	0.205	0.446	0.000035	0.000075	0.1951	0.4241
23:00	380	1.646	4.333	1.796	4.725	0.179	0.472	0.169	0.446	0.000029	0.000075	0.1612	0.4241
24:00	380	1.646	4.333	1.796	4.725	0.179	0.472	0.169	0.446	0.000029	0.000075	0.1612	0.4241
Northbound													
01:00	300	2.180	7.268	2.892	9.640	0.183	0.610	0.173	0.576	0.000037	0.000122	0.2113	0.7044
02:00	300	2.180	7.268	2.892	9.640	0.183	0.610	0.173	0.576	0.000037	0.000122	0.2113	0.7044
03:00	300	2.180	7.268	2.892	9.640	0.183	0.610	0.173	0.576	0.000037	0.000122	0.2113	0.7044
04:00	380	2.762	7.268	3.663	9.640	0.232	0.610	0.219	0.576	0.000046	0.000122	0.2677	0.7044
05:00	380	2.762	7.268	3.663	9.640	0.232	0.610	0.219	0.576	0.000046	0.000122	0.2677	0.7044

06:00	540	3.925	7.268	5.206	9.640	0.330	0.610	0.311	0.576	0.000066	0.000122	0.3804	0.7044
07:00	540	3.925	7.268	5.206	9.640	0.330	0.610	0.311	0.576	0.000066	0.000122	0.3804	0.7044
08:00	540	3.925	7.268	5.206	9.640	0.330	0.610	0.311	0.576	0.000066	0.000122	0.3804	0.7044
09:00	540	3.925	7.268	5.206	9.640	0.330	0.610	0.311	0.576	0.000066	0.000122	0.3804	0.7044
10:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
11:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
12:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
13:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
14:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
15:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
16:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
17:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
18:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
19:00	620	4.506	7.268	5.977	9.640	0.378	0.610	0.357	0.576	0.000076	0.000122	0.4367	0.7044
20:00	540	3.925	7.268	5.206	9.640	0.330	0.610	0.311	0.576	0.000066	0.000122	0.3804	0.7044
21:00	460	3.343	7.268	4.434	9.640	0.281	0.610	0.265	0.576	0.000056	0.000122	0.3240	0.7044
22:00	460	3.343	7.268	4.434	9.640	0.281	0.610	0.265	0.576	0.000056	0.000122	0.3240	0.7044
23:00	380	2.762	7.268	3.663	9.640	0.232	0.610	0.219	0.576	0.000046	0.000122	0.2677	0.7044
24:00	380	2.762	7.268	3.663	9.640	0.232	0.610	0.219	0.576	0.000046	0.000122	0.2677	0.7044