4 Project development and alternatives

This chapter describes the alternatives to the project that were considered as part of the development process and explains how and why the project was selected as the preferred option. The design development of the construction and operational ancillary facilities is also discussed. Specifically, this chapter:

- Summarises the history of the existing M5 East Motorway and the development of the WestConnex program of works
- Provides an assessment of the strategic alternatives to the project considered against the project objectives
- Describes the options development process that has been undertaken for the New M5 (the project), from its early development through to the design and construct tender process
- Describes the locations considered for the St Peters interchange and provides an assessment of these locations against the interchange design and broader project objectives
- Details the design development of ancillary facilities which form part of the project.

Table 4-1 details the Secretary's Environmental Assessment Requirements (SEARs) as they relate to the development of the project and the options and alternatives considered, as well as where in the environmental impact statement (EIS) these issues have been addressed.

Table 4-1 SEARs – project development and alternatives

SEARs	Where addressed
An analysis of feasible alternatives to the carrying out of the proposal and proposal justification, including:	
• An analysis of alternatives / options considered, having regards to the proposal objectives (including an assessment of the environmental costs and benefits of the proposal relative to the alternatives and the consequences of not carrying out the proposal), and whether or not the proposal is in the public interest,	The strategic alternatives and options that were considered throughout the development of the project are discussed in **Section 4.2**. Options considered for the location and design of the motorway and St Peters interchange are discussed and assessed against the project objectives in **Section 4.3** and **Section 4.4** respectively. Public interest is addressed in **Chapter 31** (Project justification and conclusion).
• justification for the preferred proposal taking into consideration the objects of the *Environmental Planning and Assessment Act 1979*,	**Chapter 31** (Project justification and conclusion).
• Details of the ventilation options considered during the tunnel design to meet the air quality criteria for the proposal.	Ventilation options considered throughout the development of the project are discussed in **Section 4.6.1**.
• Details of the short-listed route and tunnel options from the tender process and the criteria that was considered in the selection of the preferred route and tunnel design.	The project route and tunnel options considered throughout the development of the project are discussed in **Section 4.3**.
• Staging of the proposal and the broader WestConnex scheme, and in particular access to Sydney Airport and Port Botany and improved freight efficiencies.	Staging of the project is presented in **Chapter 1** (Introduction)

The development of the project has a long history, commencing with the *M5 Transport Corridor Feasibility Study*, prepared by the NSW Roads and Traffic Authority, now Roads and Maritime Services (Roads and Maritime) in 2009 through to the recent design and construct tender process.

Figure 4-1 shows the project development process for the New M5 and the WestConnex program of works.

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Project development process

Early schemes

1971-1992

F4 Western Motorway (now M4 Motorway) between Concord and Blue Mountains opened in stages

2001

M5 East Motorway opened

2003-2004

Preferred option for extension of the M4 to City West Link at Ashfield (referred to as M4 East) developed and placed on public display

2004

Marrickville Tunnel scheme considered but never placed on public display

2009

M5 East duplication project placed on public display following M5 Transport Corridor Feasibility Study

WestConnex

2012

WestConnex identified in the State Infrastructure Strategy 2012-2032

M5 East expansion comprised doubling the number of surface and in-tunnel lanes in each direction

2013

September: WestConnex Business Case developed in late 2013, M5 East comprised doubling the number of surface and in-tunnel lanes in each direction

November: Preliminary concept design for M4 East placed on public display

November: State Significant Infrastructure application for M4 East lodged with the then Department of Planning and Infrastructure

2014

February: Preliminary concept design for M4 East public display ends

May:
- Competitive tender process to design and construct M4 East
- State Significant Infrastructure application lodged for the King Georges Road interchange upgrade project

June: Commencement of further development of WestConnex to include northern and southern extensions

August: Short-list of three construction consortia for construction of the M4 East announced

September: Invitation issued for companies to design and construct the New M5

November:
- State Significant Infrastructure application lodged for the New M5
- Short-list of three construction consortia for construction of the New M5 lodged

December:
- Western Harbour tunnel and Southern extension identified in *Rebuilding NSW: State Infrastructure Strategy Update, 2012*
- Planning approval granted for the M4 Widening project
- Tenders received for M4 East from short-listed consortia

2015

March:
- Construction of M4 Widening commenced
- Planning approval granted for the King Georges Road Interchange Upgrade project

May: Tenders received for New M5 from short-listed construction consortia

June:
- Leightons, Samsung C & T and John Holland Joint Venture announced as the preferred tenderer for the design and construction of the M4 East
- M4 East preferred design announced

July: Construction of the King Georges Road Interchange Upgrade commenced

September:
- Leightons, Dragados and Samsung C & T Joint Venture announced as the preferred tender for the design and construction of the New M5
- New M5 preferred design announced

October: WestConnex M4 East EIS placed on public exhibition

Figure 4-1 Westconnex project development process

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4.1 History of the M5 East Motorway and WestConnex

4.1.1 M5 East Motorway history

The M5 East Motorway

The M5 East Motorway was proposed in the mid-1990s to provide a motorway connection between Fairford Road, Padstow and General Holmes Drive, Mascot. The purpose of the M5 East Motorway was to improve the east-west road transportation route between south-west Sydney and the central business district (CBD), Port Botany and Sydney Airport. The M5 East Motorway was constructed to support the economic, social and environmental well-being of the Sydney region and to reduce the loss of urban amenity arising from increased heavy vehicle traffic through residential areas.

The M5 East Motorway received planning approval from the then Minister for Urban Affairs and Planning in 1997 and opened to traffic in 2001. Since its opening, the M5 East Motorway has operated at or near capacity. Currently the operation of the motorway is at or above capacity for more than 13 hours per day (Deloitte, 2012 and Sydney Motorways Project Office, 2013a). The continued congestion on the M5 East Motorway since its opening continues to impede access to and from the Sydney CBD, Port Botany and Sydney Airport, with the Australian Infrastructure Audit (Infrastructure Australia, 2015) identifying that congestion along the M5 Motorway corridor in 2011 resulted in a delay cost of around $1.19 million per lane kilometre.

M5 Transport Corridor Feasibility Study

Alternative options have been considered to alleviate congestion and improve amenity along the M5 East Motorway and the surrounding road network. This process commenced with the *M5 Transport Corridor Feasibility Study* (Roads and Traffic Authority, 2009a), which presented the outcomes of various investigations carried out as part of the development, assessment and evaluation of strategic options for improving the M5 Motorway corridor.

The *M5 Transport Corridor Feasibility Study* identified a preliminary preferred option, being the M5 East Duplication. The strategic concept for the M5 East Duplication consisted of:

- Duplicating the existing M5 East Motorway between King Georges Road, Beverly Hills and the Cooks River, Mascot
- Construction of a new connection from the M5 East Motorway at Arncliffe to Euston Road, Qantas Drive and Gardeners Road, Mascot.

The strategic concept for the M5 East Duplication was placed on public exhibition between November 2009 and March 2010 for community and stakeholder feedback. Submissions were sought from the community to assist in identifying issues and to shape further investigations that would form part of future environmental assessments. The key issues raised by the community were focused around:

- In tunnel air quality, including consideration of filtration as part of ventilation systems
- Location of ventilation outlets. Feedback from the community suggested positioning ventilation outlets within industrial areas was preferred
- Tunnel location and design, particularly tunnel gradients at portals and required property acquisitions
- Heavy vehicle access to the proposed tunnels and provision of a link road to reduce the number of vehicles using Wickham Street, West Botany Street and parallel roads to access the Princes Highway
- Increased traffic along local roads at St Peters and Mascot, such as Campbell Road, Euston Road, Mitchell Road and McEvoy Street
- The potential for loss of sensitive environments and open space, including Tempe Wetlands, Wolli Creek Regional Park, Kogarah Golf Course, as well as Tempe Reserve and playing fields
- Localised noise and air quality impacts.

In response to the feedback received from key stakeholders and the community, the strategic concept design for the M5 East Duplication was further refined and developed. The strategic concept for the M5 East Duplication was later used as part of the motorway options development for the current New M5 project, forming the basis of the southern alignment in the early options development undertaken by the Sydney Motorway Projects Office and industry partners in 2012 (refer to **Section 4.3.1**).

4.1.2 WestConnex program of works

Early motorway development

The M4 Motorway

The M4 Motorway is a 40 kilometre urban motorway connecting Concord with the Blue Mountains. Construction of the M4 Motorway occurred in several stages between the late 1960s and the mid-80s, opening to traffic in 1971. An additional section, between Concord and Parramatta opened in 1992.

Between 2003 and 2004 a preferred option for an eastern extension of the M4 Motorway to the Sydney CBD was developed and publicly exhibited. This option, referred to as the M4 East, proposed extending the M4 Motorway to the City West Link and Parramatta Road at Ashfield as well as widening the existing motorway. This scheme was put on hold by the NSW Government at the time.

Potential to upgrade and extend the M4 Motorway has been revisited as part of the WestConnex program for works. Planning approval for the M4 Widening project was granted on 21 December 2014. The M4 Widening project will upgrade the existing M4 Motorway to four lanes in each direction between Church Street, Parramatta and Homebush Bay Drive, Homebush. Construction work began on the M4 Widening project in March 2015.

Planning approval is currently being sought for the M4 East project, a proposed extension to the M4 Motorway from Homebush Bay Drive at Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield.

Connection between the M4 and M5 East

The Marrickville Tunnel was a scheme considered in the mid-2000s to create a direct connection between the M4 East Motorway and Mascot, to provide a direct route for traffic between Port Botany, Sydney Airport and Western Sydney. One option considered for this scheme was a truck only tunnel, recognising that the main function of this link would be to enhance freight access between Port Botany, Sydney Airport and north-western Sydney. This scheme was not progressed, and the Enfield Intermodal Terminal was developed instead to increase the volume of freight carried by rail to and from Port Botany, with distribution by road from Enfield using existing arterial roads and the M4 Motorway.

The concept of a connection between the M4 and M5 East has developed to become the future M4-M5 Link which, subject to planning approval, would form part of the WestConnex program of works. This would complete the orbital road network between Western Sydney and the eastern gateways of Port Botany and Sydney Airport, and provide a north-south bypass of the Sydney CBD.

The WestConnex program of works

The NSW State Infrastructure Strategy was released in 2012 with the aim of focusing on strategic investments and reforms that Infrastructure NSW assessed as being likely to have the most impact on the State over the next 20 years (Infrastructure NSW, 2012). The *NSW State Infrastructure Strategy Prioritisation Assessment* (Deloitte, 2012), undertaken to inform the strategy identified the WestConnex program of works as the highest priority road infrastructure project for NSW, leading to the Strategy recommending that the State Government progress the WestConnex program of works and deliver the New M5 component of the program within a decade.

The WestConnex program of works has been developed to provide an integrated and comprehensive solution which recognises that the issues currently experienced along the M4 Motorway and the M5 East Motorway cannot be resolved in isolation from each other. The holistic solution takes into account the learnings from previous unsuccessful proposals for upgrade and / or expansion works along the M4 and M5 East Motorways, as well as the former Marrickville Tunnel concept while incorporating the feedback received from the community and stakeholders as part of the historic development of these schemes.

To facilitate the delivery of the WestConnex program of works the Sydney Motorway Projects Office was established as a division of Roads and Maritime. The primary task for the Sydney Motorway Projects Office was the preparation and development of design options to inform the business case for WestConnex.

Sydney Motorway Projects Office sought early involvement from the private sector for the development of the design options for the WestConnex program of works, which would be used to demonstrate the technical and commercial viability of the project as part of the business case. Four design and construction industry consortia were selected as industry partners to assist with the review of existing designs and to develop improved design and construction solutions for specific sections of the WestConnex program of works.

The private sector consortia were directed to optimise the existing strategic concept design of the program of works and to reduce associated risks and costs. The involvement of private sector consortia was intended to create a market for ideas, ensuring a wide range of options were identified and considered in the development of WestConnex. An infrastructure solutions ‘challenge and review’ team was also formed within the Sydney Motorway Projects Office. This team worked alongside the private sector consortia and identified a broad range of infrastructure design options with merit for further development and potential inclusion in the project.

The options developed by the Sydney Motorway Project Office and the industry partners considered tunnel alignments, engineering structures, interchange locations and tunnel portal locations. The industry partners initially developed a wide range of options for augmentation of the M5 East corridor. These options were subject to a preliminary assessment by the ‘challenge and review’ team to identify whether the options offered greater value for money than the design proposed in the State Infrastructure Strategy. The outcome of this process was the short-listing of three alignment options. The alignment options considered as part of the development of the project are detailed in **Section 4.3**.

In June 2014, the NSW Government requested that the potential for enhancing the scope of WestConnex through the addition of Northern and Southern extensions to the scheme be assessed. The Northern extension would link to the former Rozelle Goods Yards, enabling connection to the Victoria Road corridor to the north and Anzac Bridge and the Western Distributor to the east. The Southern extension would provide a connection between the New M5 (being built as part of WestConnex) and President Avenue, Rockdale. Separate to the New M5 project, a business case for the Northern and Southern extensions is being prepared that sets out their strategic and economic rationale and indicates a path for their potential further development.

4.1.3 Tender selection process

A competitive tender process for the design and construction of the New M5 was conducted to identify an innovative, cost effective and environmentally-responsive design within the New M5 project corridor, as identified in the *New M5 SSI Application Report* (AECOM, 2015a).

Three separate tenders, including individual tender designs were received on Friday 27 March 2015. These tenders were subject to several stages of evaluation to arrive at the preferred tender design which has formed the basis of this EIS.

The tender evaluation was separated into categories, including engineering design, environmental and social performance and project cost (including upfront capital expenditure and ongoing operational expenditure). Each of these categories was further divided into a number of sub-categories to allow comparison between the three tender designs. Relevant technical specialists were involved in the tender evaluation.

Feedback received during early consultation, following the announcement of the New M5 and during the preparation of the EIS, was provided to three shortlisted consortia selected to tender for the design and construction of the project. This feedback was provided to tenderers during interactive sessions for consideration during project design (refer to **Chapter 7** (Consultation) for more information). Interactive sessions are now an industry accepted practice and are held on a commercial in confidence basis as part of the procurement process for infrastructure projects. Representatives of each tenderer met with the WestConnex Delivery Authority (WDA) on behalf of Roads and Maritime on a range of issues to assist in refining the concept design.

The evaluation of engineering design requirements involved an assessment of the tender designs against a set of mandatory functional requirements, the performance of the engineering aspects of the designs and the identification of risks within each design. This involved separate assessments for each engineering aspect such as road geometry, drainage, structural elements and ventilation systems.

The evaluation of the environmental and social factors involved assessing the performance of the three tender designs for environmental and social performance (costs and benefits) and the identification of potential environmental and social impacts and risks. Sub-categories considered as part of the evaluation of environmental and social factors included:

- Traffic and transport
- Air quality
- Human health
- Noise and vibration
- Biodiversity
- Visual impacts and urban design
- Land use and property, including acquisition
- Social and economic
- Hydrology and soils
- Contamination
- Surface water and flooding
- Heritage (Aboriginal and non-Aboriginal)
- Resource consumption and waste minimisation
- Hazards and risks.

The construction and operational phases of the project were also considered when assessing the performance of each sub-category, which was scored according to how well the minimum requirements were met or exceeded. The score for each evaluation category was then weighted to provide an overall score and ranking of each tender design.

The preferred tender design was chosen based on the outcome of the above evaluation of the three tender submissions. This process provided a balanced consideration of engineering design requirements, project cost (including upfront capital expenditure and ongoing operational expenditure), and environmental and social factors.

4.2 Strategic alternatives

The merits of the project were considered in the context of a range of other alternatives, based on the extent to which they could meet the project objectives and how well they performed with reference to other transport, environmental, engineering, social and economic factors.

The following alternatives to the project were considered:

- Alternative 1 – The base case or ‘do nothing / do minimum’
- Alternative 2 – Optimising the performance of existing infrastructure
- Alternative 3 – Investment only in public transport and rail freight improvements
- Alternative 4 – Demand management
- Alternative 5 – Construction of the New M5 as part of the WestConnex program of works.

These options have been considered and assessed against the project objectives (refer to **Section 3.5**) and are discussed in **Section 4.2.1** to **Section 4.2.4**.

4.2.1 Alternative 1 - Base case or ‘do nothing / do minimum’

A theoretical base case or ‘do-nothing’ alternative was considered, defined as the minimum possible upgrade to the existing M5 East Motorway. This alternative would see the M5 East Motorway retain its existing arrangement with only minor improvements provided over time to improve capacity and ongoing maintenance activities.

Over the next 10 to 20 years, population growth is expected to be greatest in Sydney’s west while workforce and employment demands will continue to remain greater in Sydney’s east. As a result, east-west traffic movements would continue to increase and the M5 East Motorway will be placed under additional strain and will be subject to further congestion than what is already experienced from the current road transportation demand. Further, predicted increases in the volume of freight through Sydney Airport and Port Botany as well as land use changes such as the development of the South West Growth Centre, the planned construction of the Western Sydney Airport, development of the Western Sydney Employment Area and the proposed intermodal terminal at Moorebank will result in additional freight movements along the M5 East Motorway.

The current road network does not support a growing population that needs to efficiently and reliably access dispersed employment areas and services. Traffic modelling under the ‘do nothing / do minimum’ scenario indicates morning peak travel times on the M5 East Motorway in the eastbound direction would increase from around 15 minutes to around 26 minutes between King Georges Road and Foreshore Road in 2031, refer to **Chapter 9** (Traffic and transport) for further details.

Without the project, congestion along the M5 East Motorway corridor will continue to have a negative impact on local roads and amenity, productivity levels and the growth of the NSW economy.

Summary

Given the forecast growth in population across the Sydney greater metropolitan area, continued expansion and development of employment areas in Sydney’s West, the increased road freight task along the M5 East Motorway and the limited capacity of the existing road network, a ‘do nothing / do minimum’ alternative would not meet any of the project objectives.

Further, in the context of Sydney’s transport challenges, a ‘do nothing / do minimum’ option is considered unrealistic and would not address the key strategic actions and goals of the State Infrastructure Strategy outlined in **Chapter 3** (Strategic context and project need).

4.2.2 Alternative 2 - Optimising the performance of existing infrastructure

Maximising the performance of existing infrastructure could potentially include undertaking improvements to the existing arterial network and to the existing M5 East Motorway.

The introduction of variable tolling, road pricing and congestion tolling is considered as part of Alternative 4 - Demand Management (**Section 4.2.3**).

Improvements to the existing arterial road network

The existing arterial road network around the M5 East Motorway services a mixture of land uses, predominantly established commercial and residential development. Continued development along this network has resulted in limited capacity for widening and / or upgrades to these roads. The limited road reservations would mean any future improvements to the road network would not be able to proceed without considerable constructability, social and environmental impacts.

Improvements to the surrounding arterial road network would potentially partially relieve road congestion in the short term. However, undertaking these improvements as an alternative to the project would not satisfy the other project objectives. For example, improving the arterial road network would not improve motorway access and connections between Sydney Airport and Port Botany with Western Sydney, and the speed and reliability of the M5 Motorway corridor would not be considerably improved. Improvements to the existing surrounding arterial network are considered complementary to the project.

Improvements to the existing M5 East Motorway

Improvements to the M5 East Motorway could be achieved through widening the surface sections of the motorway and / or providing additional capacity within the existing tunnels.

It is feasible to widen the existing motorway to provide additional capacity along the M5 East Motorway by widening the surface road section of the Motorway between King Georges Road and Bexley Road with minimal impact on surrounding land use. In contrast, widening the M5 East Motorway between Marsh Street and General Holmes Drive would considerably encroach into the wetlands at Marsh Street and Eve Street, Arncliffe. Also any increase to the capacity of this section of the motorway would increase the demand on adjacent sections of the road network such as the airport tunnel which is already operating at or near capacity during peak periods and has limited capacity to cater for additional traffic.

Enhancing the capacity of the existing M5 East Motorway tunnels by widening the outer sides of the tunnels to provide an additional lane or by excavating the existing tunnel ceilings to provide a 'double-decker' arrangement was considered. However, this arrangement would make connection to the surrounding network difficult as the arrangement of the tunnel would be at a different vertical alignment to the existing established road network.

Increasing the capacity of the tunnels would reduce existing congestion within the tunnels and would provide some capacity within the tunnels to cater for the future growth in transport demand. Widening the existing tunnels would reduce the requirement for merging and diverging of traffic in the tunnel and would generally provide additional capacity. These improvements to the existing M5 East Motorway tunnels would be costly and highly disruptive to existing traffic during construction.

Summary

Improvements to the arterial road network are an inadequate response to the significant transport challenges along the M5 Motorway corridor and would potentially result in significant constructability, social and environmental impacts to existing residential and commercial development along these roads. Localised road corridor improvements would only provide a relatively small incremental change to the network, rather than additional capacity. For alternatives to be worthy of consideration, they must be broadly capable of accommodating the identified transport task and challenges being addressed by the WestConnex program of works. These can only be met by major arterial road improvements that will have significant construction impacts or require the construction of new infrastructure. Arterial road improvement options would therefore not meet the project objectives.

Improvements to the existing M5 East Motorway through widening of the surface sections of the motorway and / or providing additional capacity within the existing tunnels were considered. Although improvements to the M5 East Motorway were deemed as possible, the improvements would be costly and highly disruptive to existing traffic during construction. Alternative 3 - Investment only in public transport and rail freight improvements

As discussed in **Chapter 3** (Strategic context and project need), the WestConnex program of works is a key component of the Transport Master Plan, the State Infrastructure Strategy and A Growing Sydney. As part of a broader integrated transport solution, the project supports a coordinated approach to the management of freight and passenger movements, as well as all modes of transport including road, rail, bus, ferries, light rail, cycling and walking. There is, however, recognition that Sydney's freight, commercial and services tasks require distribution of goods and services across the Sydney basin, which relies on more diverse and dispersed point-to-point transport connections that can only be provided by the road network.

Public transport improvements

The State Infrastructure Strategy states that, based on the economic and demographic forecasts, public transport is expected to experience strong growth particularly around the Sydney CBD and other business centres. The Strategy also notes that the key challenges facing urban public transport relate to:

- The ability of the existing public transport network to serve a growing population while providing the mobility and connectivity requirements to sustain economic growth and productivity
- Improving access to the Sydney CBD
- Supporting growth in Sydney's emerging centres
- Optimising the performance of the existing public transport network
- Building future network capacity that keeps pace with demand and meets the needs of businesses and households.

Public transport in Sydney is predominantly via passenger trains (44 per cent) and buses (28 per cent), and improvements to public transport in Sydney are focused on these two services.

Improvements to passenger rail services

The passenger rail system is often congested and services can be slow and unreliable, with demand for rail services forecast to increase by 37 per cent over the next 20 years (Infrastructure NSW, 2012). The East Hills and Airport line runs largely parallel to the M5 East Motorway. Sydney's Rail Future (Transport for NSW, 2012b) indicates that by 2031, this line will experience passenger displacement (additional passengers are unable to board the train) on much of the line between Revesby and Green Square. The Kingsgrove to Revesby Quadruplication project along the East Hills and Airport line was completed in 2013. The Quadruplication involved the construction of a second pair of tracks and associated bridge and station works to allow a physical separation of local and express services operating along the railway line.

Nonetheless, demand for rail in the Sydney metropolitan area is forecast to grow faster than operational transport demand over the next two decades (Infrastructure NSW, 2014). The State Infrastructure Strategy update recognises that capital investment will be required to tackle projected overcrowding and maintain service reliability on key railway lines. It is acknowledged however, that passenger rail services along the East Hills and Airport railway line largely serves the movement of people to and from the Sydney CBD, which is only one route in a widely dispersed transport task.

Key public passenger rail opportunities identified in the State Infrastructure Strategy and the State Infrastructure Strategy Update, include:

- Progressing stage 2 of Sydney's Rail Future, including the introduction of simpler timetables across the metropolitan rail network and automatic train operations, the transition to dedicated fleet types for some lines, enhancing track infrastructure, re-design of platforms and completion of the South West Rail Link, station upgrades and the Rail Clearways Program to generate network efficiencies
- Progressing the planning and development of the Sydney rapid transit network (now Sydney Metro).

Improvements to the Sydney bus network

Buses are a fundamental part of Sydney's public transport system. They can be put into service more quickly, cheaply and to more places than any other type of public transport. Sydney's bus network currently includes more than 600 routes and for more than 90 per cent of residents within Sydney, local bus routes are within 400 metres of home and offer connections to neighbourhood shops and services, major centres and the wider public transport system (Transport for NSW, 2013a). In response to changing passenger needs and an increase in demand, additional services have been added to the bus network. However, without measures to improve journey times, the addition of more buses to the network contributes to congestion and bus services become less effective at meeting customer needs. Sydney's Bus Future acknowledges that improvements to the bus network are essential to meet changing customer needs, including access to major centres outside of the Sydney CBD. The Transport Master Plan aims to connect seamlessly to other transport modes to deliver the right mix of services.

Sydney's Bus Future proposes to redesign the Sydney bus network to meet current and future demands by providing rapid service routes to connect major centres along transport routes with mass transit demand. Suburban and local service routes would build on the foundation of the rapid routes to improve access to local, neighbourhood destinations. Sydney's Bus Future specifically states that new bus connections would take advantage of WestConnex to improve access across the Princes Highway to the Inner West and to south-east suburbs. These changes would provide better public transport for workers and airport users.

A number of key bus-related infrastructure opportunities are identified in the State Infrastructure Strategy. The key initiative relevant to the project is the Bus Priority Infrastructure Program as part of Sydney's Bus Future. The program is a rolling program of infrastructure and traffic management works to improve bus network reliability and travel speeds in Sydney.

Public transport constraints

Public transport is critical to urban productivity, expanding labour market catchments, reducing congestion and increasing economic and social mobility (Infrastructure NSW, 2014). Even though the use of public transport is expected to grow with the implementation of key public transport initiatives, most growth in transport demand over the next 20 years will be met by roads.

Public transport is best suited to serving concentrated, high volume flows of people to and from established centres. It is less suited to serving disposed cross-city or local trips. Even with significant investment and high levels of patronage growth forecasts for Sydney's public transport network, 72 per cent of journeys in 2031 will be made on the road network each weekday by vehicle, equal to an additional 4.3 million new trips compared to current traffic movements (Infrastructure NSW, 2014).

With about 60 per cent of employment dispersed across the Sydney Metropolitan Area, public transport alone cannot viably serve most of these locations. Along the M5 East Motorway about 40 per cent of users during business hours are on work related business. Even under the most ambitious scenarios for land use change and growth in public transport, the absolute number of car journeys will continue to increase. The demand for passenger road travel is forecast to account for 73 per cent of total trip growth. While public transport is an important means for transport, cars will continue to remain an important practical option for many daily travel requirements.

As it is forecast that the demand for passenger road travel by private vehicles will continue to grow, public transport initiatives would only partially contribute to relieving congestion on arterial roads adjacent to the M5 East Motorway. The provision of additional public transport services would create opportunities for improved liveability; however implementing these initiatives alone would not considerably enhance the productivity of commercial and freight generating land uses.

Active transport improvements

Sydney's Cycling Future aims to make cycling a safe, convenient and enjoyable transport option for short trips. The implementation of the strategy aims to increase the mode share of cycling in the Sydney metropolitan region for short trips that can be an easy 20 to 30 minute ride. The strategy aims to improve access to towns and centres, reduce congestion and increase capacity on the public transport system.

Sydney's Walking Future is intended to complement Sydney's Cycling Future. The actions set out in Sydney's Walking Future propose to make walking the transport choice for quick trips under two kilometres and help people access public transport. Encouraging and enabling more people to make walking trips will ease pressure on public transport and reduce congestion on roads.

As outlined in Sydney's Cycling Future and Sydney's Walking Future, journeys made by cycling and walking are generally for short trips only. Improvements to walking and cycling only would not cater to the diverse travel demands along the M5 corridor that are best met by road infrastructure. Further, improvements to cycling and pedestrian infrastructure alone would not support long-term economic growth through improved motorway access or enhance the productivity of commercial and freight generating land uses.

The WestConnex program of works has been developed as a key transport component of the Transport Master Plan, integrated with the strategic land use outcomes as identified in the Draft Metropolitan Strategy. As an integrated transport solution, the WestConnex program of works, including the project, will include upgrades to the existing cyclist and pedestrian facilities at the western surface works within Beverly Grove Park and along the local road upgrades. New pedestrian and cyclist infrastructure would also be provided, including a pedestrian and cycle bridge over Alexandra Canal, with a direct, grade-separate pedestrian and cyclist bridge across Campbell Road and into Sydney Park.

Upgrades to existing, and the provision of new, pedestrian and cyclist infrastructure would contribute to reshaping local travel by creating new opportunities for short cycling and pedestrian trips using this infrastructure. New pedestrian and cyclist infrastructure around St Peters is considered a benefit to the local community, and would be made possible as a result of the project.

Summary

Public and active transport options would be feasible alternatives to the project should the objectives of the WestConnex program of works be largely concerned with transporting people to and from centres. However, the commuting demand is only a proportion of the demand along the M5 East Motorway corridor. The key customer markets identified for the project include highly dispersed and long distance passenger movements, as well as heavy and light freight and commercial services and businesses whose travel patterns are also highly dispersed and diverse in nature. These customers have highly varied requirements when it comes to the transfer of goods and services. These requirements include the transport of containerised freight by rigid and articulated trucks, light trucks, vans, utility vehicles and cars.

Public transport would only partially address these customer demands. No feasible strategic transport alternatives such as heavy or light rail options or bus corridor enhancements would meet the diverse range of customer needs for travel in this corridor and address the project objectives as effectively as the project and the broader WestConnex program of works.

Rail freight

The current situation for freight movements into and out of Port Botany, and potential future scenarios for freight movements in NSW were considered in assessing improvements to the freight rail network as a viable alternative to the project. The *NSW Ports Trade Report 2012 / 2013* (NSW Ports Corporation, 2013) noted that the 2012 / 2013 financial year held the twelfth consecutive annual throughput record for Port Botany. The record throughput at Port Botany of more than 2.1 million twenty-foot equivalent units (TEU's) (one TEU is equivalent to the dimensions of a standard shipping container) in the 2012 / 2013 financial year was 4.4 per cent greater than the previous year. The *Trade and Logistics Report* for the 2011-2012 financial year (Sydney Ports Corporation, 2012) indicated that 98 per cent of imported containers and 60 per cent of exported containers have their origin and destination within greater Sydney.

The current mode share of the NSW freight task was about 63 per cent road and 33 per cent rail in 2011. When coal-related freight is removed, road-based freight movements account for nearly 90 per cent of the NSW freight task. The relative share of container freight that is moved by rail to and from Port Botany is about 14 per cent. The volumes of all commodities demanding capacity on the freight network are expected to grow as population and economic activity increases across NSW. Port Botany and Sydney Airport are predicted to accommodate much of the rapid growth forecast for containerised cargo and air travel over the next 20 years (Infrastructure NSW, 2014). The implications of this growth for the road and rail network are expected to be significant, with capacity across key parts of the network, particularly the Sydney region are already under pressure to match demand.

Future scenarios

The Transport Master Plan provides a framework to deliver an integrated, modern transport system by identifying NSW's transport actions and investment priorities over the next 20 years. It identifies the key challenges that the NSW transport system must address to support the State's economic and social performance, and identifies a planned and coordinated set of actions to address those challenges.

The Transport Master Plan notes that the domestic freight task across Australia is set to double by 2031 and triple by 2050 from about 504 billion tonne-kilometres in 2008 to more than 1,504 billion tonne-kilometres in 2050 (Transport for NSW, 2012a). In NSW this rate of growth is supported by the the Freight Strategy which identified the freight task of around 409 million tonnes in 2011 will almost double to an estimated 794 million tonnes by 2031.

The Freight Strategy notes that the role of heavy vehicles in moving freight across NSW is substantial, and will continue to be so for the foreseeable future. Typically, bulk commodities such as coal and grain are moved by rail, while commodities transported in smaller quantities are moved by road. The mode share of freight varies significantly based on a range of factors, including; types of commodity and tonnage being moved, the distance between the origin and destination and access to modes of transport.

The NSW road network carried 63 per cent of the total freight task in 2011, or about 256 million tonnes of freight. Increases to freight are projected to impact the performance of all key NSW road freight corridors over the next 20 years, including the M5 Motorway corridor. By 2031, NSW roads are projected to remain the dominant mode, but to carry less of the total freight task at 59 per cent (Transport for NSW, 2013e).

By 2031, the container trade at Port Botany is forecast by Sydney Ports Corporation to increase from the existing throughput of two million 20 foot equivalent units and reach seven million 20 foot equivalent units. The target mode share is to double the proportion of containers carried by rail in 2020 (NSW Department of Premier and Cabinet, 2011). The Freight Strategy acknowledges that even with the targeted increase in rail mode share, early modelling results indicate that the M5 Motorway Corridor would not be able to accommodate the additional container traffic when combined with background growth from employment and population by 2031.

The hourly throughput of vehicles on the M5 Motorway corridor is lower than capacity for many hours of the day due to congestion, low travel speeds and a break down in optimal flow. Accommodating 20 years of growth in this corridor will require a package of solutions to meet the needs of road freight and other road users.

Actions outlined in the Transport Master Plan, which focus on road upgrades and improved rail operations to support a doubling of freight on rail by 2020, are critical to meeting the forecast growth at Port Botany by 2031. The Freight Strategy recognises that there are significant economic efficiency implications for NSW if major changes are not made to ports and related road and rail systems in the next 20 years. While dedicated freight rail lines are relatively well served by capacity development plans, there is limited available capacity on the shared rail network in metropolitan areas for freight traffic. One action of the Transport Master Plan is to implement rail freight infrastructure enhancements to increase the share of freight carried on the rail network.

The Transport Master Plan identifies a number of current and future freight-related projects that aim to improve the efficiency of, and remove existing bottlenecks in the existing freight rail network including:

- Development of intermodal terminals at Enfield (under construction) and Moorebank (Stage 1 of the facility is currently subject to planning and assessment and the concept plan was approved on 29 September 2014). Metropolitan intermodal terminals are critical to increasing rail mode share and managing the rapidly growing import container trade, as well as interstate freight. The primary function of metropolitan intermodal terminals is to facilitate the import container trade and in this context, function like inland satellite ports (Transport for NSW, 2013e). This effectively reduces congestion from the Port Botany precinct and Sydney Airport precinct. The Moorebank intermodal terminal would involve the construction of freight terminal facilities at Moorebank in south-west Sydney, and would be linked to the interstate and freight rail network via a dedicated rail freight line. The project aims to increase Sydney's rail freight mode share by promoting the movement of container freight by rail between Port Botany and western and south-western Sydney. The Moorebank intermodal site is adjacent to the southern Sydney freight line, the East Hills and Airport railway line and the M5 East Motorway
- Completion of the Southern Sydney Freight Line (rail operations commenced 2013). The Southern Sydney Freight Line is a 36 kilometre length of rail track between Macarthur and Sefton. It links the interstate network between Sydney and Melbourne with the Metropolitan Freight Network and is managed by the Australian Rail Track Corporation (ARTC)

- A Western Sydney Freight Line and terminal project (future proposal). The State Infrastructure Strategy notes that to improve the reliability of rail freight in the Sydney greater metropolitan area requires 'unwinding' or improved separation of the passenger and freight rail use of the network. The Western Sydney Freight Line would be a new dedicated freight line connecting the Main West Railway Line and the Southern Sydney Freight Line to a new intermodal precinct at Eastern Creek. This would service growth areas of Western Sydney that connect to Port Botany and regional producers that export from Port Kembla, as well as meeting demand from businesses in the Western Sydney Employment Area for movement of containers by rail. The State Infrastructure Strategy anticipates that by 2036, about 4.3 million truck kilometres a year could be saved through the Western Sydney Freight Line and terminal precinct project.

Realising opportunities to shift more freight onto rail remains a priority for the NSW Government. However, assuming the target of doubling the share of container freight moved by rail is achieved by 2020 (Transport for NSW, 2013e), more than 70 per cent of Port Botany's projected trade would continue to be moved by road, requiring investment in an efficient road network to support the port and airport precincts.

Rail freight transport is more effective for long distance transport of goods to regional centres. However, the freight service and business task within the Sydney metropolitan area relies on dispersed point-to-point transport connections to customers. Freight rail transport predominantly forms the first leg of a freight journey, with containerised freight broken down at distribution nodes and further distributed across Sydney. The management of the freight task requires a primary network for heavy commercial vehicle with high quality connections between major freight hubs, whereas light commercial vehicles depend on a multi-layered network with many connections to service more diverse and dispersed markets across Sydney.

This arrangement means that there are around four times as many light commercial vehicle trips on Sydney's road network as heavy commercial vehicle trips (Transport for NSW, 2013e) (refer to **Figure 4-2**), and this trend is forecast to continue. A key reason for this trend is that heavy freight activity precincts are concentrated in a few key locations near Port Botany and Western Sydney, and this land use pattern is set to continue.

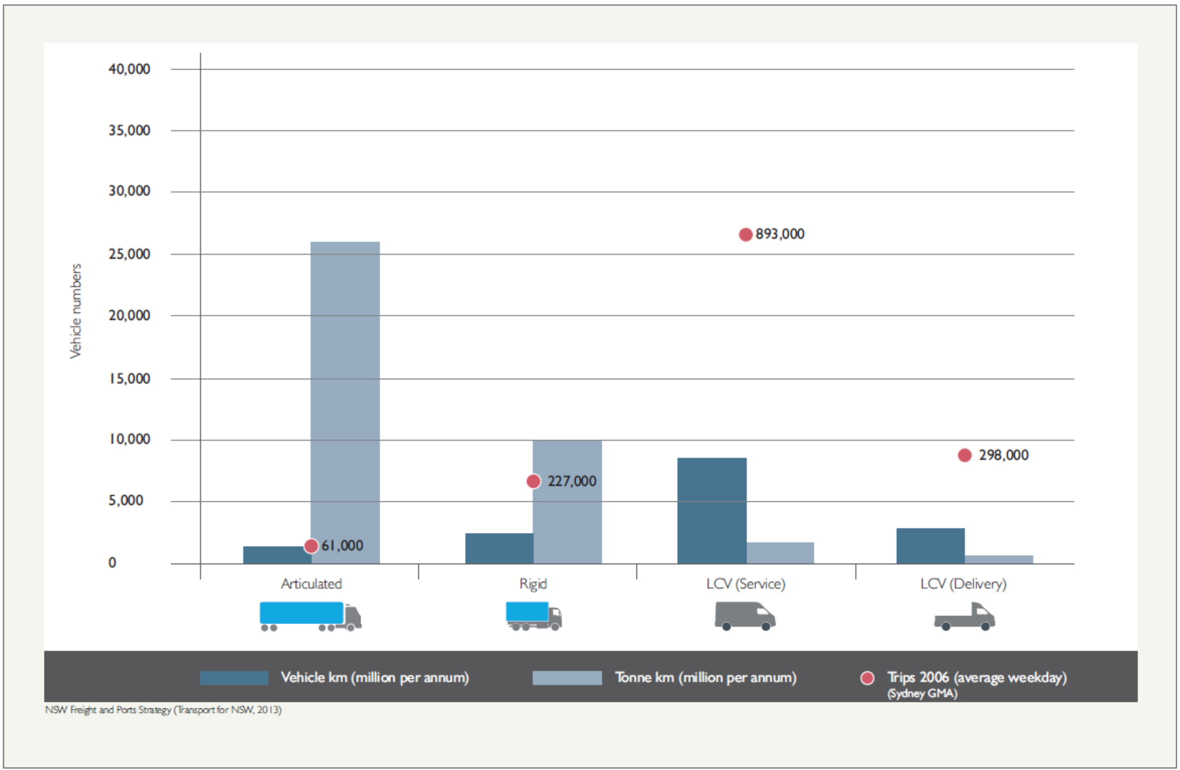

Figure 4-2 Comparison of truck and light commercial activity in NSW with trips on an average weekday (Transport for NSW, 2013e)

The development of the Western Sydney Airport has the potential to change the way some freight is moved around Sydney, by providing an alternative entry or exit point for freight. Overall, however, the movement of freight around Sydney would not be significantly altered by the introduction of the new airport, for the following reasons:

- The operation of the Western Sydney Airport would be staged, ramping up over time, with initial operations only commencing in the mid-2020s (a minimum of five years after the anticipated completion of the New M5 project)
- The proportion of freight transported by air is small compared to transport by road and rail
- Freight arriving at the new airport would still have destinations across wider Sydney
- Port Botany and Sydney Airport would still be key freight entry and exit points, with the new airport to complement the existing airport.

In combination with the freight-related projects identified above, the project and the broader WestConnex program of works would provide a robust freight solution and would best address the project objectives.

Summary

Neither strategic public transport nor rail freight alternatives would fully meet the diverse range of needs for travel along the M5 Motorway corridor, and address the project objectives as outlined in **Section 3.5**. Public transport and rail freight options are seen as complimentary services supporting the project and the broader WestConnex program of works, and the NSW Government is currently implementing a number of public transport alternatives.

Improvements to the freight rail network will contribute to relieving road congestion by shifting freight away from the road network. However, as the freight task and Sydney's population continue to expand and the east-west road transport demand along the M5 East corridor continues road congestion will persist as the freight and business task within the Sydney metropolitan area continues to rely on dispersed point-to-point transport connections. This will continue to impede the economic growth of Sydney, and would not enhance the productivity of freight generating land uses such as Port Botany. Although improvements to freight rail would enhance movements along the rail network, these initiatives would not cater for diverse travel demands along the M5 Motorway corridor. As such, improvements to the freight rail network as an alternative to the project would not meet the project objectives.

4.2.3 Alternative 4 – Demand management

Demand management relates to reducing individual trip lengths and making various transport mode options more viable. Demand management initiatives include:

- Land use planning policies which promote urban consolidation and the establishment of town 'centres' to reduce the need for travel. For example, the Transport Master Plan aims to prioritise the development of local centres to bring jobs closer to homes and to areas of increasing population such as the South West Growth Centre
- Implementing policies which restrict parking provisions in new developments to encourage alternative modes of transport
- Implementing intelligent transport systems to improve public transport operation, management of clearways and transit lanes and to provide greater priority over general traffic
- Pricing transport options to reduce travel demand. This includes demand based tolling or transport pricing to discourage discretionary travel by private vehicles for trips that can be catered for by public transport.

Growing Sydney indicates that Sydney's population is expected to grow by more than 1.6 million people in the next 20 years and there is anticipated to be an additional 689,000 job opportunities. However, housing is more affordable in Western Sydney and there is a greater demand for additional jobs in the east in areas that are part of or support Port Botany, Sydney Airport and the surrounding industrial areas, resulting in a disparity in employment opportunities close to people's homes. Population growth, combined with the growing road freight task in the Sydney Metropolitan area, will result in a continued demand for use of roads providing an east-west connection such as the M5 East corridor. The continued demand and use of this corridor would result in additional, prolonged congestion as Sydney's population and freight movements continue to increase.

Demand management measures such as additional and / or more appealing public transport options would help to spread the demand for peak travel to less congested time periods. However, to have a major impact on road traffic, demand management measures would require considerable changes in social attitudes, travel behaviour and government policy. Therefore, while demand management could help to spread the demand for peak travel to less congested time periods, its effectiveness would be limited by other constraints, such as:

- The availability of other travel modes at the user's origin and destination
- Flexibility of working arrangements to take advantage of 'time of day' tolling or transport pricing benefits.

Summary

Although the introduction of demand management measures would contribute to relieving congestion and would create opportunities for improved public transport initiatives, the implementation of these measures alone would not satisfy the project objectives.

As such, the implementation of demand management initiatives is seen to present a complementary initiative to the project, rather than a feasible alternative.

4.2.4 Alternative 5 - Construction of the New M5

The State Infrastructure Strategy notes that investment in Sydney's strategic road network can be sustainable if complemented by strategies to manage congestion and environmental impacts, and should be undertaken in tandem with investment in public transport.

The WestConnex program of works is a key component of the Transport Master Plan, the State Infrastructure Strategy and Growing Sydney. The project forms part of a broader integrated transport solution which supports the coordinated approach to the management of freight and passenger movements, as well as all other modes of transport, including road, rail, bus, ferries, light rail, cycling and walking.

The strategic planning framework and policy documents for Sydney, discussed in **Chapter 3** (Strategic context and project need) of this EIS, also recognise that freight, commercial and services tasks would continue to require distribution of goods and services across the greater Sydney metropolitan region. The continued delivery of such freight, commercial and services tasks would continue to rely on more diverse and dispersed point to point transport connections that can only be provided by the road network.

The construction of the project was identified as forming part of the WestConnex program of works. It would provide for more reliable trips between Western Sydney and the Sydney Airport / Port Botany precinct to support Sydney's urban freight movements by providing additional motorway capacity within the M5 Motorway corridor. Further, the construction of the project would improve connections between employment and population centres along the M5 motorway corridor and beyond to cater for existing and future demand.

4.2.5 Preferred strategic alternative

The assessment of the strategic alternatives against the project objectives as described in **Section 4.2.1** to **Section 4.2.3** has determined that the project as summarised in **Section 1.2** and described in **Chapter 5** (Project description) of this EIS is the preferred strategic alternative.

The preferred strategic alternative has evolved from a series of ongoing concept developments and evaluations since 2009. **Chapter 3** (Strategic context and project need) demonstrates the need for the project and provides detail on its strategic context. The preferred strategic alternative best achieves all of the project objectives as described in **Section 3.5**.

A summary of the assessment of the strategic alternatives against the project objectives is provided in **Table 4-2**.

Table 4-2 Summary assessment of the strategic alternatives against the project objectives

Project objective	Alternative 1 Base case or do nothing	Alternative 2 Optimising the performance of existing infrastructure	Alternative 3 Investment in public transport and rail freight improvements	Alternative 4 Demand management	Alternative 5 Construction of the New M5
Support Sydney's long-term economic growth through improved motorway access and connections linking Sydney's international gateways and Western Sydney and places of business across the city	×	×	×	×	✓
Relieve road congestion so as to improve the speed, reliability and safety of travel in the M5 Motorway corridor, including parallel arterial roads	×	✓	×	✓	✓
Cater for the diverse travel demands along these corridors that are best met by road infrastructure	×	✓	×	×	✓
Enhance the productivity of commercial and freight generating land uses strategically located near transport infrastructure	×	×	✓	×	✓
Fit within the financial capacity of the State and Federal Governments, in partnership with the private sector	✓	✓	✓	✓	✓
Optimise user pays contributions to support funding in an affordable and equitable way	×	×	×	×	✓
Provide for integration with other WestConnex projects while not significantly impacting on the surrounding environment in the interim period	×	✓	✓	✓	✓

4.3 Motorway options

As outlined in **Section 4.1.1**, there has been ongoing development of the project since 2009. This section discusses the motorway options that have been considered for the project.

4.3.1 Early options development

2009/ 2010 Strategic concept

The *M5 Transport Corridor Study* (RTA, 2009) identified the M5 East Duplication as the preliminary preferred option for alleviating congestion and improving amenity along the M5 East Motorway. The strategic concept for the M5 East Duplication consisted of:

- Duplicating the existing M5 East Motorway between King Georges Road, Beverly Hills and the Cooks River, Mascot
- Construction of a new connection from the M5 East Motorway at Arncliffe to Euston Road, Qantas Drive and Gardeners Road, Mascot.

The strategic concept for the M5 East Duplication was placed on public exhibition between November 2009 and March 2010 for community and stakeholder feedback. In response to the feedback received from the community and key stakeholders including Government agencies as well as local interest groups and associations, the strategic concept design for the M5 East Duplication was further refined and developed. The strategic concept for the M5 East Duplication was later used as part of the motorway options development for the current New M5 project, forming the basis of the southern alignment in the early options development undertaken by the Sydney Motorway Projects Office and industry partners.

M5 East duplication

The duplication of the M5 East Motorway was included in the State Infrastructure Strategy (as the expansion of the M5 East) and *WestConnex – Sydney's next motorway priority* (Infrastructure NSW, 2012) and included widening the existing surface road west of Bexley Road and constructing two new two lane tunnels to the east.

Industry partner development

Following the advice of Infrastructure NSW for "greater private sector involvement at the design phase" (Infrastructure NSW, 2012), four Australian and international construction industry consortia leas by Ferrovial Agroman, Leighton Contractors, Thiess and Baulderstone/ Bouygues were selected as partners to assist with developing improved design and construction solutions for specific sections of WestConnex. Thiess and Baulderstone / Bouygues were assigned to the Southern Corridor, comprising the M5 East Motorway to the Airport Link at St Peters. Ferrovial Agroman and Leighton Contractors were assigned to the Northern Corridor, from the existing M4 Motorway and Parramatta Road at Homebush Bay Drive to Campbell Street at St Peters.

The purpose of these engagements was to ensure that a wide variety of efficient and innovative options were identified and considered in the development of WestConnex. Preferred options were subject to multi-criteria analysis and further design refinement using traffic, financial and economic evaluation as part pf the development of the 2013 business case.

The further development of design options for the M5 East Motorway expansion component of WestConnex was led by the Sydney Motorway Project Office and the industry partners to assess the technical and commercial viability of the project. The options development undertaken as part of this process examined a range of alignment options and resulted in the short-listing of three strategic alignment options for the New M5 component of WestConnex: the southern (Option S1), central (Option S4) and northern (Option S6) alignment options. The three alignments included a combination of surface and tunnel configurations and are shown on **Figure 4-3**.

The three strategic alignment options included consideration of likely environmental impacts and were subject to independent review and challenge by the infrastructure solutions review and challenge team, which was established to act as a peer review body for the two parallel design processes. The three strategic alignment options are described below and shown on **Figure 4-3**.

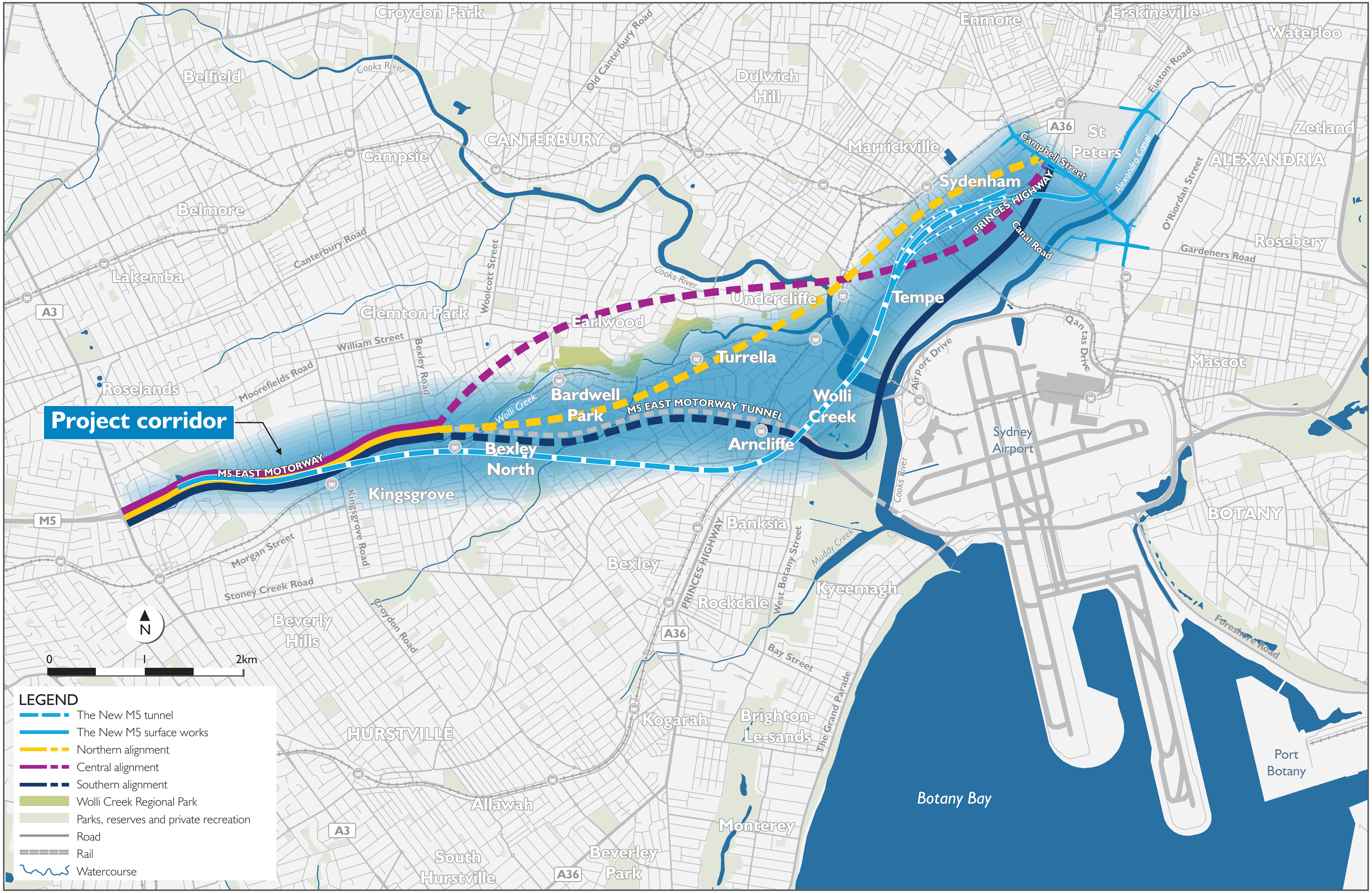

Figure 4-3 Project motorway options

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Southern alignment option

The southern alignment option was generally based on Roads and Maritime's 2009 / 2010 strategic concept design for the M5 East Duplication. It included a road tunnel that would duplicate the M5 East Motorway to Arncliffe, and a surface connection from Arncliffe to St Peters. It mostly followed existing road reserves and corridors and would have provided connectivity from Western Sydney to Sydney Airport and Port Botany. The advantages of the southern alignment option were that the issues associated with the steeper grade and resulting exhaust haze at the existing M5 East Motorway portals would not be present, avoiding issues around current reductions to travel times and facilitating improvements to road safety. The southern alignment option design also provided sufficient flexibility to allow for future upgrades, minimised tunnelling, and used a surface road design solution to the north of the airport.

Construction of the southern alignment option would be complex due to its proximity to the existing M5 East Motorway eastern tunnel portals and Marsh Street, and would potentially impact on Tempe residents and the Tempe Reserve and wetlands. Construction of the southern alignment would also involve construction through Tempe landfill. Further, the alignment through Kogarah Golf Course would need further design investigations and there would be potential issues associated with Sydney Airport's operational constraints.

Central alignment option

The central alignment would have included a shorter tunnel option. The tunnels for the central alignment option were located north of the southern alignment, and extended further north than the southern alignment, under Gough Whitlam Park, Tempe and along the Princes Highway. The eastern portals for the central alignment option were located south-east of the Princes Highway between the Port Botany Railway Line and Canal Road.

The benefits of the central alignment option being further north of the southern alignment option included:

- Removing some of the complexities associated with the construction of the southern alignment option in highly trafficked areas around Marsh Street and the tunnel portals of the existing M5 East Motorway
- Providing a more direct route to Sydney Airport and industrial areas near Mascot
- Reducing land acquisition around Marsh Street and the Kogarah Golf Course
- Avoiding construction of bridge crossings over the Southern and Western Suburbs Ocean Outfall Sewer, Marsh Street and the Cooks River.

The central alignment option was considered to be advantageous as it provided a lower cost solution than the southern alignment option, while achieving similar traffic and road network outcomes, including taking pressure off Marsh Street and providing a new gateway to Sydney Airport. Further, the central alignment option avoided impacts to Tempe Reserve and wetlands. This alignment option was considered to be limited in that there would be difficulties associated with the design and connectivity to the airport precinct, local road network and to a potential future southern connection that would require further detailed investigation. The central alignment option would also require a large amount of property acquisition and would not directly address the grade and visual haze associated with the existing M5 East Motorway tunnels, due to the required grade of the exit ramps.

The central alignment option was identified, at the time, as the preferred alignment option and carried forward for the 2013 business case. The business case acknowledged that more detailed analysis would be necessary on the route.

Northern alignment option

The northern alignment option comprised twin two-lane tunnels with the western portals located either side of the existing M5 East Motorway tunnels at Bexley Road and eastern tunnel portals located near Bayview Avenue on land adjacent to Waterworth Park, Undercliffe. The surface alignment in the east would continue in an easterly direction through open space and parkland to connect to the airport precinct.

The benefits of this alignment were considered to be:

- Avoiding work to the existing M5 East Motorway tunnels
- Minimising works to existing roadways around tunnel portals
- Being located in favourable geotechnical conditions in the eastern section with sandstone outcropping
- Minimising property acquisition at some locations by constructing an interchange on vacant land at St Peters that could be separated out from live traffic
- Avoiding direct impacts to Tempe Reserve and wetlands.

However, the connection to the Sydney Airport / Port Botany precinct as part of this strategic alignment option presented limitations due to its distance from Sydney Airport, which may affect the level of traffic usage, and may also impact on connectivity to the local road network. The northern alignment option was considered to have inherent difficulties associated with providing a future southern Sydney connection, it would require a large amount of property acquisition and it would not address the grade / visual haze issues associated with the existing M5 East Motorway.

2013 WestConnex Business Case

In September 2013, the Sydney Motorway Project Office released the WestConnex Business Case Executive Summary. The M5 East Duplication was proposed to improve travel times and reliability along the M5 Motorway Corridor by doubling the number of surface and in-tunnel lanes in each direction. The Business Case Executive Summary acknowledged that the final route would be subject to further investigation and analysis.

4.3.2 Tender reference design

The constraints identified during assessment of the early alignment options were used to inform a project corridor. The project corridor was then used as the boundary for developing a reference design ahead of the competitive tender process for the project (refer to **Section 4.1.3** for additional detail regarding the design and construct tender process). The project corridor is shown in **Figure 4-3**.

The development of the reference design for the New M5 tender process commenced with a review of the alignments shortlisted during early alignment options analysis process (**Section 4.3.1**). The major factors influencing the development of the reference design for the New M5 tender process were:

- Constructability (noting the geology constraints of the Bayview Ridge and Cooks River Paleovalleys, and interface with the existing M5 East Motorway)
- Connectivity with the existing road network and potential future motorways
- The western portal configuration
- Overall length of tunnel.

The alignments of both Industry Partners were heavily influenced by the desire to exploit the favourable geology, shorter tunnel length, and reduced interface with the existing M5 East Motorway offered by alignments north of the existing tunnels. In contrast, the Sydney Motorway Project Office southern alignment sought to augment the connectivity of the existing M5 East Motorway by duplicating the existing tunnels, pushing the eastern portal to Marsh Street. None of these alignments considered the Southern extension (a possible future motorway connection from Arncliffe to Kogarah, which would connect the project to the southern and bayside suburbs of Sydney), as this element was not conceived until after the Industry Partners design phase was completed.

Following the introduction of a possible future Southern extension, the alignment needed to consider a compromise between geology, overall length of the mainline tunnel, length of the Southern extension tunnels, and constructability issues associated with the Southern extension tunnels. This optimisation process resulted in a mainline tunnel alignment that was further south than those considered during the industry partners design and business case.

4.3.3 Development of tunnel options as part of tender selection process

The following design elements were further refined during the tender selection process:

- Tunnel length
- Tunnel alignment
- Tunnelling excavation and construction method.

The options for each of these elements are presented below and have been analysed against performance criteria.

Tunnel length

Two tunnel length options were considered for the project:

- A longer tunnel option with western tunnel portals located to the west of Kingsgrove Road, in Kingsgrove
- A shorter tunnel option with western tunnel portals located close to the existing M5 East Motorway tunnel portals near Bexley Road, Bexley.

Although a shorter tunnel option would require fewer construction compound sites and the length of construction would be shorter, the longer tunnel option was identified as preferred for the following reasons:

- Reduced impact on local residents: the portals for the shorter tunnel option would be located near Bexley Road, adjacent to residential properties. Conversely, the portals for the longer tunnel option would be generally located adjacent to commercial and industrial properties in Kingsgrove, reducing the impact of the project on local residents
- Fewer properties would require surface acquisition: the proposed portal location for the longer tunnel option aligns within land already with the motorway reserve, and necessary property acquisition would largely comprise industrial and commercial properties. Construction of the portals near Bexley Road would require the acquisition of a greater number of properties, including mostly residential dwellings
- Reduced construction traffic impacts: construction staging in the vicinity of Bexley Road would have been complex and would have had significant traffic impacts for both Bexley Road and the M5 East Motorway
- Improved air quality outcomes and reduced visual impacts: due to the longer tunnel, the portal design for the longer tunnel option would be able to achieve a lesser grade, providing better operational air quality outcomes and less impact to visual amenity as the size of the cut and cover structure would be smaller.

No short tunnel options were short-listed as part of the development of tunnel options by the preferred tenderer.

Tunnel alignment

The options identification and assessment process conducted by the preferred tenderer for the tunnel alignment considered safety, traffic operations and performance, public transport operations, environmental costs and benefits, future proofing and constructability. The options development process relating to the tunnel alignment also considered integration with a future Southern extension, availability of land for construction compounds and tunnel construction methodology.

Three primary alignment options were considered by the preferred tenderer, generally within the project corridor. The alignments included a common western tunnel portal location between King Georges Road and Bexley Road, and an eastern portal at the former Alexandria Landfill at St Peters. The three alignment options considered by the preferred tenderer include:

- A northern alignment, located between the existing M5 East Motorway tunnel in the south and the Airport, Inner West and South railway line to a mid-tunnel point, where the alignment heads north-east towards St Peters
- A central alignment, generally following the tender reference design, which stays south of the existing M5 East Motorway tunnel until about Arncliffe where it heads north-east, generally under the Princes Highway towards St Peters
- A southern alignment which heads south-east immediately from the western tunnel portal, passing underneath Forest Road to its most southerly point, where the alignment then passes underneath the north-western side of Kogarah Golf Course, the Cooks River to the east of the Princes Highway and then generally follows underneath the Princes Highway from about the Ikea property, avoiding areas of known contamination.

In considering the options for the vertical and horizontal geometry of the main alignment tunnels, key factors influencing the project design included a focus on minimising cost and managing program and safety risks associated with tunnel excavation. Factors considered included:

- Maximising tunnel excavation through Hawkesbury Sandstone
- Avoiding interference with the existing M5 East Motorway tunnels
- Minimising or avoiding interference with high risk geological features, including palaeochannels and dyke formations
- Minimising disturbance to or avoiding known and potentially contaminated sites
- Minimising tunnel length.

Providing optimal vertical geometry is beneficial to heavy vehicles using the tunnel as it minimises differences in speed between heavy and light vehicles and limits the emissions generated by heavy vehicle traffic on long and steep uphill grades.

The geology of the project corridor was influential in determining the vertical alignment of the main alignment tunnels. Hawkesbury Sandstone is considered an excellent tunnelling and excavation medium as it is high strength with relatively widely spaced geological defects. In comparison, Ashfield Shale is also of high strength, but has a deeper soil profile; more closely spaced geological defects (commonly affected by faulting) and the fresh shale can readily deteriorate on exposure. As a result, the main alignment tunnels have been designed to maximise the length of the tunnels within Hawkesbury Sandstone and minimise the length within Ashfield Shale.

Tunnelling excavation and construction method

Four tunnelling excavation and construction methodologies were considered for the project

- Excavation using a tunnel boring machine (TBM)
- Excavation using road headers in combination with drill and blast
- Excavation using drill and blast
- Excavation using a combination of road header and TBM.

The advantages and disadvantages of each of these tunnel construction methods is summarised below.

Excavation using a tunnel boring machine

A TBM excavates a circular bore of fixed diameter using a rotary action. The machine comprises a rotating head fitted with disc cutters, drag bits and a clay spade. TBMs are usually custom made to suit the particular requirement of the individual project and require a considerable amount of time to deliver and assemble for full operations. The world's largest TBM would be required for construction of the project.

Generally advantages of using a TBM include potentially faster tunnelling rates than other construction methods, improved safety (ie no explosives and reduces chances of rock fall on construction workers), the need for minimal tunnel support and minimal ground disturbance.

The disadvantages of using a TBM for construction of the project include:

- Low productivity rates associated with a large diameter TBM
- The requirement for large areas of open space for TBM assembly
- The generation of larger spoil volumes compared to other construction methods
- The excavation of caverns using a TBM are expensive and take longer to construct
- Creates unnecessary increase in risk due to the unique operation, longer tunnel, uncertainty of delivery and reduced productivity
- Requirement for a large concrete segment pre cast facility at Arncliffe
- The diameter of the tunnel constructed using a TBM would not provide the adequate tunnel dimensions to allow for heavy vehicles.

Excavation using road headers in combination with drill and blast

A road header is a commonly used machine for excavation in sandstone and has been successfully used in recent tunnel projects in Sydney. It is a specialist tunnelling plant, which excavates with picks mounted on a rotary cutter head attached to a hydraulically operated boom. Road headers have been used extensively in Sydney tunnelling including the M2 Motorway, M5 East Motorway, Eastern Distributor, Cross City Tunnel and Lane Cove Tunnel.

In areas of very hard rock, ripper dozers and rock breakers may also be used to assist with the excavation. The excavated material would be continually removed by conveyors onto special dumpers designed to operate in an underground environment. The excavated material would then be stockpiled near the tunnel access where it would be removed via truck to nominated disposal or reuse locations. As the excavation advances, ground support would be installed behind the excavation face. The support could be permanent or temporary and would normally include rock bolts, steel mesh and sprayed concrete.

Ancillary excavation, where necessary or desirable, can be carried out by other means such as drill and blast or surface miner for benching (excavation of the tunnel floor) or hydraulic excavator for trenching.

The construction of the main alignment tunnels using road headers is considered advantageous for the following reasons:

- Provides a cost effective construction method
- Provision of a more certain delivery program
- Produces about 20 per cent less spoil across the length of the main alignment tunnels
- More flexibility in tunnel construction
- Less area required for tunnel support compounds throughout construction.

The primary disadvantage of road headers alone relate to tunnelling speed and maintenance. However in areas of hard rock, the disadvantage of slower tunnelling rates of roadheaders alone would be mitigated through the use of drill and blast.

Excavation using drill and blast

Excavation of the mainline tunnels using the drill and blast method involves drilling holes within the tunnel, charging the holes with explosive, blasting, mucking out and installing the roof and wall ground support. Drill and blast is considered to be an efficient and cost effective method of rock excavation.

In comparison to the use of a TBM, this construction method is considered to be more cost effective, would produce about 20 per cent less spoil across the length of the tunnel and would provide more flexibility in the construction staging and program. Additionally, no concrete pre-cast tunnel segments would need to be produced and transported to the tunnel face. The use of drill and blast excavation could potentially have unacceptable impacts to properties and natural features above the main alignment tunnels as a result of vibration. To minimise vibration impacts, smaller blasts could be undertaken; however, this would result in a sub-optimal, inefficient blasting methodology.

Compared with excavation of the mainline tunnels with a TBM, the drill and blast method is more cost effective, more flexible, suited to tunnelling in sandstone, and would also provide a reduction in generated spoil of around 20 per cent across the project. However, the frequency of blasts required to maintain an efficient rate of tunnelling would potentially generate greater vibration impacts and consequently, using drill and blast methodology as the primary excavation method is not preferred.

Excavation using a combination of road header and TBM

This tunnelling construction methodology would use a TBM to excavate the main alignment tunnel to the west of Arncliffe and around the Cooks River, and road headers to the east. The use of a TBM and road headers in combination would continue to have the advantages and disadvantages of these methodologies. Specifically:

- Areas where a TBM would be used for construction of the project would:
  - Have program risks associated with longer assembly and site establishment times
  - Require larger space for the TBM to access the main alignment tunnel entry and exit portals
  - Generate additional spoil when compared to road headers
  - Require 90 per cent more concrete than road header construction for the use of concrete segments.
- The use of road headers to the east of Arncliffe at around the Cooks River would:
  - Provide some efficiency and flexibility with regards to certainty of program delivery
  - Require less concrete pre-case tunnel segments to be produced and transported to the tunnel face when compared to the TBM only tunnel construction methodology
  - Be more cost effective.

Analysis of short-listed tunnel options

Within the three tunnel alignments, five tunnel options were short-listed. All five tunnel options were considered long-tunnel options, and were developed using a range of tunnelling excavation and construction methodologies.

The short-listed tunnel options were assessed against a set of performance criteria which were developed based on the project objectives (refer to **Section 3.5**). The performance of each option was rated against each criterion using the ratings as described in **Table 4-3**. A summary of the analysis of the short-listed tunnel options against the performance criteria is provided in **Table 4-4**.

Table 4-3 Description of performance ratings used in analysis of tunnel options

Rating		Description
Highly positive	✓✓✓	Meets all aspects of the criterion. The option would achieve superior outcomes relative to this criterion. Through performance against this criterion, the option contributes positively in terms of performance against other criteria longer term.
Positive	✓✓	Clearly consistent with the criterion. On balance, the option performs well against the criterion. The option does not limit performance outcomes when considering other criteria.
Slightly positive	✓	Generally consistent with the criterion across the majority of the project extent (ie limited ability to achieve the criterion in the short term or in isolated areas along the corridor). May slightly impair performance against other criteria, but be generally positive when considered as a whole.
Neutral	-	Overall, considering all project elements across the project's full geographic extent, the option results in a neutral performance against the criterion.
Slightly negative	✗	Somewhat inconsistent with the criterion and may be focussed on realising better performance against other criteria and may have minor negative impacts as a result. Impacts or inconsistency with the criterion can be managed adequately.
Negative	✗✗	Generally inconsistent with the criterion. On balance, performs poorly against the criterion and may result in poor performance against other criteria with limited ability to manage impacts.
Highly negative	✗✗✗	Clearly inconsistent with the criterion and may actively work against the objective of the criterion. The option would likely have serious, long term or structural impediments to meeting the criteria in the future. Limited or no potential to re-scope or mitigate impacts associated with the option.

Table 4-4 Summary of analysis of short-listed options against performance criteria

	Option 5	Option 14	Option 15	Option 19	Option 20
Alignment option	Northern	Central	Central	Southern	Southern
Tunnel excavation method	Excavation using a combination of roadheaders and TBM	Excavation using roadheaders in combination with drill and blast	Excavation using a combination of roadheaders and TBM	Excavation using roadheaders in combination with drill and blast	Excavation using a combination of roadheaders and TBM
Minimises construction phase risks, including risk to achieving the construction program.	××	-	×	✓	✓
Minimises planning approvals risk, including Matters of national environmental significance and community impacts.	×	-	-	-	-
Minimises interaction with and construction activities in / near contaminated sites	-	-	-	-	-
Minimise haulage distances and use of non-arterial road network for construction vehicles.	×	-	-	✓	✓
Minimise impacts to areas of environmental sensitivity, including heritage and ecology	-	✓	-	✓	-
Minimise construction and operational noise and air quality impacts on communities	-	✓	-	✓	-
Minimises temporary and permanent property acquisition requirements	×	-	-	✓✓	-
Maximises beneficial re-use of property required for construction that is surplus to operational needs.	-	✓✓	-	✓✓	-
Minimises the extent of impact to areas of public open space and reserves.	×	-	×	-	×
Minimise construction costs and whole of life costs while maximising design durability.	×××	✓	××	✓✓	××

4.3.4 Preferred tunnel option

Having considered the potential tunnel options for tunnel length, alignment and excavation method, the preferred motorway option is a longer tunnel generally following a central alignment, similar to the tender reference design.

Based on the known geological conditions along the project corridor (refer to **Section 19.2**), the length of the main alignment tunnels and the advantages and disadvantages of the tunnel construction methods, excavation of the main alignment tunnels using road headers was identified as the preferred excavation method, with conventional excavation (excavators) and drill and blast excavation methods also used for secondary locations such as cross passages, benches and trenches.

4.4 Eastern interchange options

Locating an interchange in an area immediately north of Sydney Airport is complex as the area is heavily urbanised to the north of the Princes Highway and has been subject to historical and ongoing residential, commercial and industrial development. Further, due to historical land uses, the area includes contaminated lands and is constrained by other infrastructure, including railways and the Alexandra Canal.

In recognition of the highly constrained nature of the area, options for the interchange location were assessed against a set of interchange-specific objectives and the overarching project objectives. The interchange-specific objectives were identified to ensure that the selection of a preferred location took into account the operational and functional requirements of the interchange as part of the New M5 and the wider WestConnex program of works. Locations considered as potential locations for the St Peters interchange are shown on **Figure 4-4**.

4.4.1 Interchange objectives

The objectives for identifying a suitable location for the interchange included:

- Minimise impacts to the road network during construction
- Maximise connectivity with the local road network and nearby areas of urban growth, including:
  - Connections for key desire lines for vehicles using the New M5 and the wider WestConnex program of works
  - Connections to areas of predicted future population growth in inner south-west Sydney, such as Green Square and Mascot.
- Optimise the benefits and minimise the adverse impacts on the local social environment, including reducing impacts on homes and open spaces
- Minimise impacts to areas which contain key commercial and industrial sites
- Provide value for money.

4.4.2 Interchange location options

Six locations were considered for the St Peters interchange, comprising a combination of surface and underground options. The potential options were assessed against the interchange objectives to identify a preferred option. Potential interchange locations are shown in **Figure 4-4**. Of these options, two were short-listed for further investigation and assessment (refer to interchange options 1 and 2). The following three options were considered at a high level, but were dismissed as they did not meet the interchange objectives listed in **Section 4.4.1**:

- A surface interchange north of the Princes Highway within an area bound by Railway Road in the West, Unwins Bridge Road in the north, Campbell Street in the east and the Princes Highway in the south (interchange option 4). This option would require large amounts of property acquisition and was not carried forward for more detailed assessment as the impacts to the local community were considered unacceptable. Further, this option would not allow for adequate connectivity with the future WestConnex program of works and the local road network and would have considerable impacts to the existing traffic network during construction

- An underground interchange north of the Princes Highway between Unwins Bridge Road and the Princes Highway at one of two locations: between Foreman Street and Railway Road (interchange option 5) or between Railway Road and Campbell Street (interchange option 6, situated underground at the same location as interchange option 4). An interchange at either of these locations would include tight bends, making it unsuitable for use by heavy vehicles and would limit the ability of the interchange to function adequately. An underground interchange at these locations was therefore considered unsuitable and not carried forward for further investigation and assessment
- A surface interchange within the Cooks River Container Terminal intermodal site bound by the Princes Highway in the north, Canal Road in the east, the Botany Goods Line in the south and Swamp Road in the west (interchange option 3). The use of this site for an interchange would minimise impacts to the local community and the road network as it could be constructed largely offline, and would provide opportunities for local road connectivity. However, it was deemed unsuitable as the interchange would have an unacceptable impact on the use of the Cooks River Container Terminal intermodal site, which is a critical component of Port Botany's operation.

Additional detail regarding the two interchange locations subject to further assessment are discussed and assessed against the interchange objectives below.

Interchange option 1 – Burrows Road

A surface interchange along Burrows Road in the vicinity of the intersection with Campbell Road was considered. This location was considered to provide a suitable level of connectivity and would limit the amount of residential property acquisition required for construction and operation of the interchange.

The interchange would require the acquisition of a large number of industrial and commercial properties along Burrows Road, and would have considerable impacts to the road network during construction. An interchange along Burrows Road would be restricted in its configuration due to its proximity to Alexandra Canal. The interchange would require some tight turning movements to provide connectivity with the local road network, and with the wider WestConnex program of works including the potential southern extension and the Sydney Gateway. This would limit its ability to operate effectively and would have inherent road safety issues.

This option was not preferred as the impacts to the road network during construction, combined with potential road safety implications and impacts to key commercial and industrial land were too significant.

Interchange option 2 – Alexandria Landfill

The current Alexandria Landfill site was identified as a potential location for the St Peters interchange. Construction of the interchange at this location would be advantageous as construction could largely be undertaken offline from the local road network and would minimise residential property acquisition. Additionally, this location would maximise opportunities to provide connectivity to the WestConnex program of works as connections between the New M5 and the future M4-M5 Link would be provided for within the space afforded by the site, and a direct connection to the local road network would be able to be provided through a connection of the interchange to the intersection of Campbell Road and Euston Road. Further constructing the interchange at this location would minimise the adverse impacts of the project on the local social environment, including reducing impacts on homes and open spaces. The construction of the interchange within the current Alexandria Landfill site is considered to best meet the project interchange objectives and is therefore considered to be the preferred interchange location. The St Peters interchange is described in detail in **Section 5.6** and is shown on **Figure 5-26**.

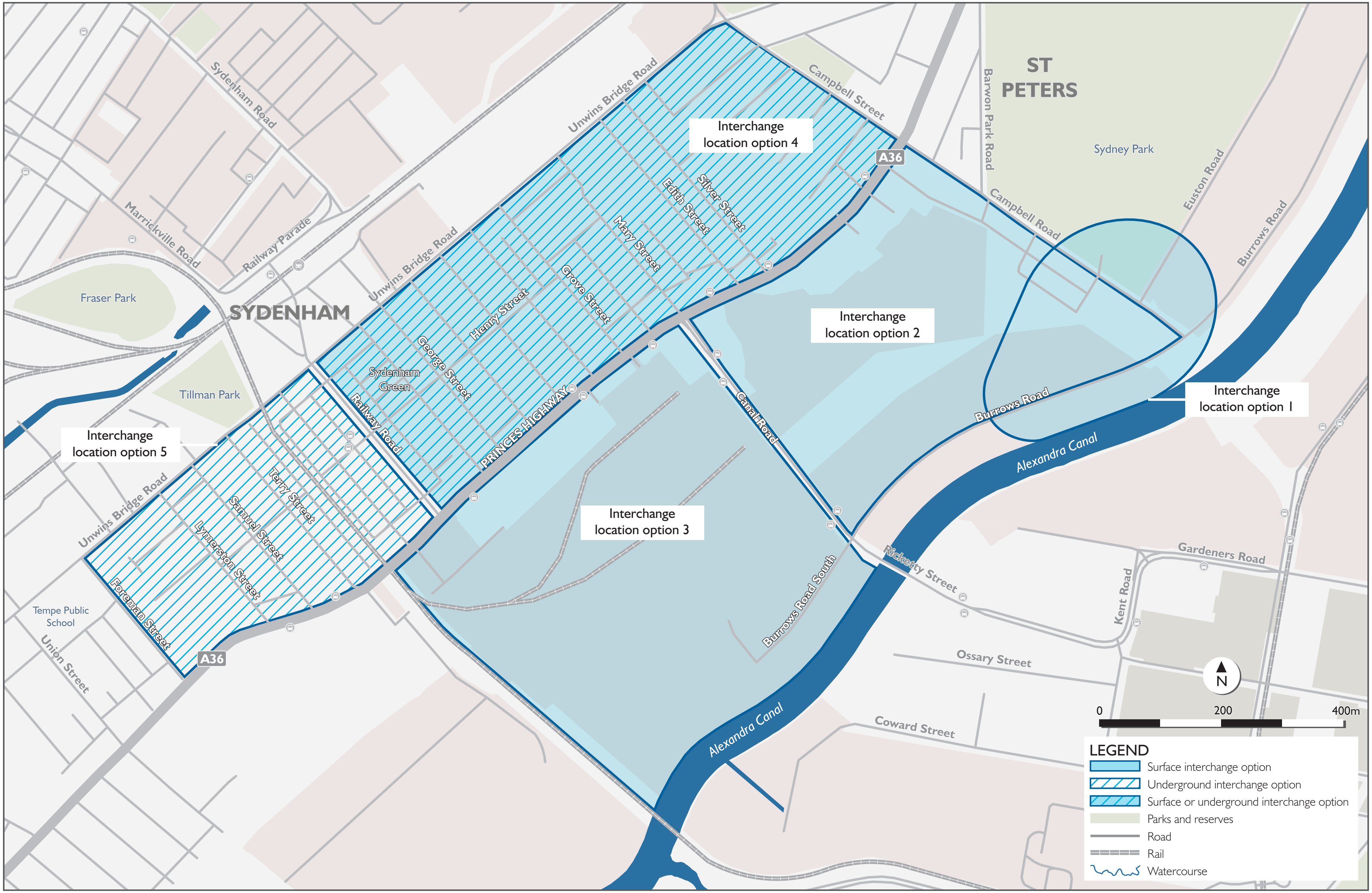

Figure 4-4 Options considered for the location of the St Peters interchange

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4.4.3 Tender reference design

A reference design for the St Peters interchange was developed to support the competitive tender process. The major factors influencing the development of the reference design for the St Peters interchange were:

- Restricting the footprint of the interchange to within the boundary of the former Alexandria landfill and surrounding industrial properties owned or proposed to be acquired by Roads and Maritime
- Known and potential contamination present within the boundary of the St Peters interchange site
- Traffic considerations, including:
  - provision for all traffic movements
  - Traffic efficiency, including appropriate ramp grades and lengths to allow posted speed limits to be maintained
  - Ensuring that the connections and number of lanes are able to provide the required traffic performance.

The tender reference design that was prepared comprised a three level interchange. The lowest (below-grade) level of the interchange comprised the New M5 ramps and the highest provided connectivity between the future M4-M5 Link and the future Sydney Gateway. The remaining two levels provided for grade-separated connectivity for all other road connections within the interchange.

4.4.4 Interchange configuration and connectivity

The configuration of the St Peters interchange tender reference design was designed to provide an integrated connection to the local road network and direct connections between:

- The New M5 and the future Sydney Gateway
- The future M4-M5 Link and the Sydney Gateway
- The local road network and the future M4-M5 Link
- The local road network and the Sydney Gateway.

In addition to the overall interchange objective of maximising connectivity with the local road network and nearby areas of growth (refer to **Section 4.4.1**), connections to the local road network via the St Peters interchange aimed to:

- Draw through traffic off local roads
- Distribute traffic using the established urban arterial road network where possible, and provide upgrades to these roads where required.

The preferred configuration of the St Peters interchange to provide connections between the New M5, and the future Sydney Gateway and future M4-M5 Link with the local road network was as follows:

- Euston Road via the on and off ramps at the eastern end of the main alignment tunnels. Euston Road runs in a north-south direction, connecting to Green Square and precincts around Alexandria. It is also of strategic importance, as Euston Road is contained within an existing road reserve that extends northwards from the St Peters interchange
- Campbell Road / Campbell Street on and off ramps at the eastern end of the main alignment tunnels. Campbell Road / Campbell Street provides an opportunity to service traffic travelling to and from Marrickville and surrounding suburbs, providing a more direct connection to the Sydney orbital network and reducing the requirement to travel along local roads
- Gardeners Road via the Gardeners Road Bridge. Gardeners Road is one of few remaining east-west road links that was not severed by the construction of the Eastern Distributor. Gardeners Road also has valuable connections to other major arterial roads in Sydney, including O’Riordan Street, Botany Road and Anzac Parade.

These connections to the local road network were identified as preferred as they provide connections to key desire lines for vehicles using the New M5 and the wider WestConnex program of works, as well as with the areas of predicted future population growth in inner south-west Sydney.

The reference design was modified by the preferred tenderer during the tender selection process to comprise a four-level interchange. The modified layout of the interchange was preferred over the tender reference design as it:

- Achieves all of the traffic movements required by the mandatory functional requirements and reference design
- Simplifies ramp movements with larger ramp radii, which also provides for safer movements for heavy vehicles
- Is less expensive to construct when compared to the reference design.

This configuration provides for connectivity between the local road network and the WestConnex program of works, and comprises a grade separated interchange that provides suitable geometry to allow for free-flowing traffic without signals within the boundary of the St Peters interchange site. The St Peters interchange is described in detail in **Section 5.6** and is shown on **Figure 5-26**.

4.5 Preferred motorway alignment

The preferred motorway alignment includes the following key features:

- Provision of a tunnel alignment located further south than all three of the early strategic alignment options (refer to **Section 4.3.1**). The more southerly alignment removed potential impacts to existing palaeovalleys, Wolli Creek Regional Park as well as Tempe Reserve and wetlands. The alignment was also located within areas considered to have geological conditions suitable for tunnelling and facilitates the proposed southern connection
- Longer tunnels which extended to St Peters, removing the need to construct bridges over the Southern and Western Suburbs Ocean Outfall Sewer, the Cooks River and Marsh Street and minimising property acquisition between the Cooks River at Arncliffe and St Peters
- Positioning of the western tunnel portals in the vicinity of the M5 East Motorway portals at Bexley
- Construction of an interchange at St Peters. By constructing an interchange at this location the pressure from additional traffic at Marsh Street would be minimised and better connectivity with the future M4-M5 Link component of the WestConnex program of works, a potential southern connection and gateway to Sydney Airport and Port Botany could be achieved. The options considered for the location of the St Peters interchange are detailed and discussed in **Section 4.4**
- Provision of opportunities for future connections to Sydney Airport, Port Botany and Southern Sydney from the New M5, subject to additional design and investigation.

The early alignment options alignments and preferred motorway alignment are shown on **Figure 4-3**.

4.6 Design development of operational ancillary facilities

4.6.1 Ventilation

Ventilation system design

On an open roadway, vehicle emissions are diluted and dispersed by natural surface flows. A tunnel is generally considered an enclosed roadway that is greater than 120 metres in length and all tunnels in NSW are unidirectional, meaning that traffic travels in one direction only within the tunnel. Usually two tunnels are constructed side by side (for example, the Lane Cove Tunnel), or one on top of the other (for example, the Eastern Distributor), to enable traffic to travel in both directions.

The basic function of tunnel ventilation is the dilution of vehicle emissions by providing fresh air to, and removing exhaust air from, the tunnel. The movement of vehicles through a tunnel drives air flow, called the ‘piston-effect’, drawing fresh air in through the tunnel entrance, diluting the vehicle exhaust emissions. In short tunnels up to around 500 metres long, this volume of fresh air is usually adequate to manage in-tunnel air quality. In longer tunnels, under some circumstances, additional air may need to be forced through the tunnel by fans to dilute emissions and maintain appropriate air quality.

The requirements for tunnel ventilation are determined by the vehicle emissions in the tunnel and the limits of pollutant levels set by regulatory authorities. The levels of pollutants increase along the length of the tunnel as vehicles generate emissions as they travel through the tunnel. Air quality is managed by ensuring that the volume of fresh air coming into the tunnel adequately dilutes the pollutants. For longer tunnels the flow of fresh air can be supplemented where required by ventilation fans or by air exchanges which remove exhaust air and/or supplies additional fresh air depending on tunnel size and length and number and mix of vehicles. Elevated ventilation outlets are used for longer tunnels in urban areas to disperse tunnel air to protect local air quality.

There are four broad types of road tunnel ventilation systems, and each of these was considered for application to the project:

- Natural ventilation
- Longitudinal ventilation
- Transverse ventilation
- Semi-transverse ventilation

A number of options for design of the ventilation system were considered. The advantages and disadvantages of the various systems are described below, and shown in **Figure 4-5**. The New M5 project has been designed to include a longitudinal mechanical ventilation system, as the preferred approach to meeting in-tunnel and ambient air quality standards. Further discussion on the ventilation system can be found in **Chapter 10** (Air quality).

Natural ventilation

Road tunnels with natural ventilation rely on vehicle movements, prevailing winds and differences in air pressure between the tunnel portals to move air through the tunnels without the assistance of mechanical ventilation (for example, through the use of fans). In the case of unidirectional naturally ventilated tunnels, the piston effect generated by traffic using the tunnels also assists in the movement of air. Because naturally ventilated tunnels do not have mechanical ventilation outlets, all air from within the tunnels is emitted via the tunnel portals.

Natural ventilation is only acceptable for use in relatively short tunnels. This is because without the assistance of mechanical ventilation, vehicle emissions can build up within the tunnels leading to unacceptable in-tunnel air quality. Emergency smoke management considerations can also dictate a mechanical solution. It is for these reasons that natural ventilation is not practical for longer road tunnels like those proposed for the project. Natural ventilation would not allow acceptable in-tunnel air quality to be achieved, under low vehicle speed conditions and during emergencies, and is therefore not a viable ventilation design for the project.

Longitudinal ventilation

The simplest form of ventilation is longitudinal ventilation in which fresh air is drawn in at the entry portal and passes out through the exit portal with the flow of traffic. For longer tunnels, the air flow is supplemented by fans that are used when traffic is moving too slowly to maintain adequate air flow, or to draw air back from the exit portals against the flow of exiting traffic. This air is then exhausted through an elevated ventilation outlet to maximise dispersion into the outside air. All road tunnels built in Australia in the last 20 years have been designed and operated with longitudinal ventilation systems.

Transverse ventilation

Another way to ensure adequate dilution of emissions is to provide fresh air inlets along the length of the tunnel along the side and to balance the amount of air coming in using outlets on the opposite of the side. This system requires two ducts to be constructed along the length of the tunnel: one for the fresh air supply and for the exhaust air. Transverse ventilation has been used in the past when vehicle emissions produced greater levels of pollutants than they do today in Australia. A transverse ventilation system is more expensive to construct because of the additional ducts that need to be excavated for each tunnel. This type of system is less effective than a longitudinal system at controlling smoke in the tunnel in case of a fire.

Semi transverse ventilation

Semi-transverse ventilation combines both longitudinal and transverse ventilation. Fresh air can be supplied through the portals and be continuously exhausted through a duct along the length of the tunnel. Alternatively fresh air can be supplied through a duct and exhausted through the portals.

Summary

The development of cleaner vehicles in response to cleaner fuel and emission standards means that a significant reduction in vehicle emissions has occurred over the past 20 years. Longitudinal ventilation has historically not been suitable for long tunnels due to the need to supply large volumes of fresh air to dilute vehicle emissions. A well-designed longitudinal ventilation system can now easily maintain acceptable air quality in long tunnels and is considered the most efficient and effective tunnel ventilation system (Roads and Maritime, 2014a).

Although all three ventilation systems could be designed to ensure that in-tunnel air quality criteria would be met, a longitudinal system has been selected for the project. Longitudinal ventilation was considered the most appropriate as it is more effective for the management of smoke in the main alignment tunnels, and is more affordable to construct and operate than transverse ventilation systems.

A longitudinal ventilation system with elevated ventilation outlets is the preferred ventilation system for the project. Discharging tunnel air through an elevated ventilation outlet ensures that it is dispersed and diluted so that there is minimal or no effect on ambient air quality. The effectiveness of elevated ventilation outlets in dispersing emissions is well established. The air quality assessment for both external and in-tunnel air quality is described in **Chapter 10** (Air quality).

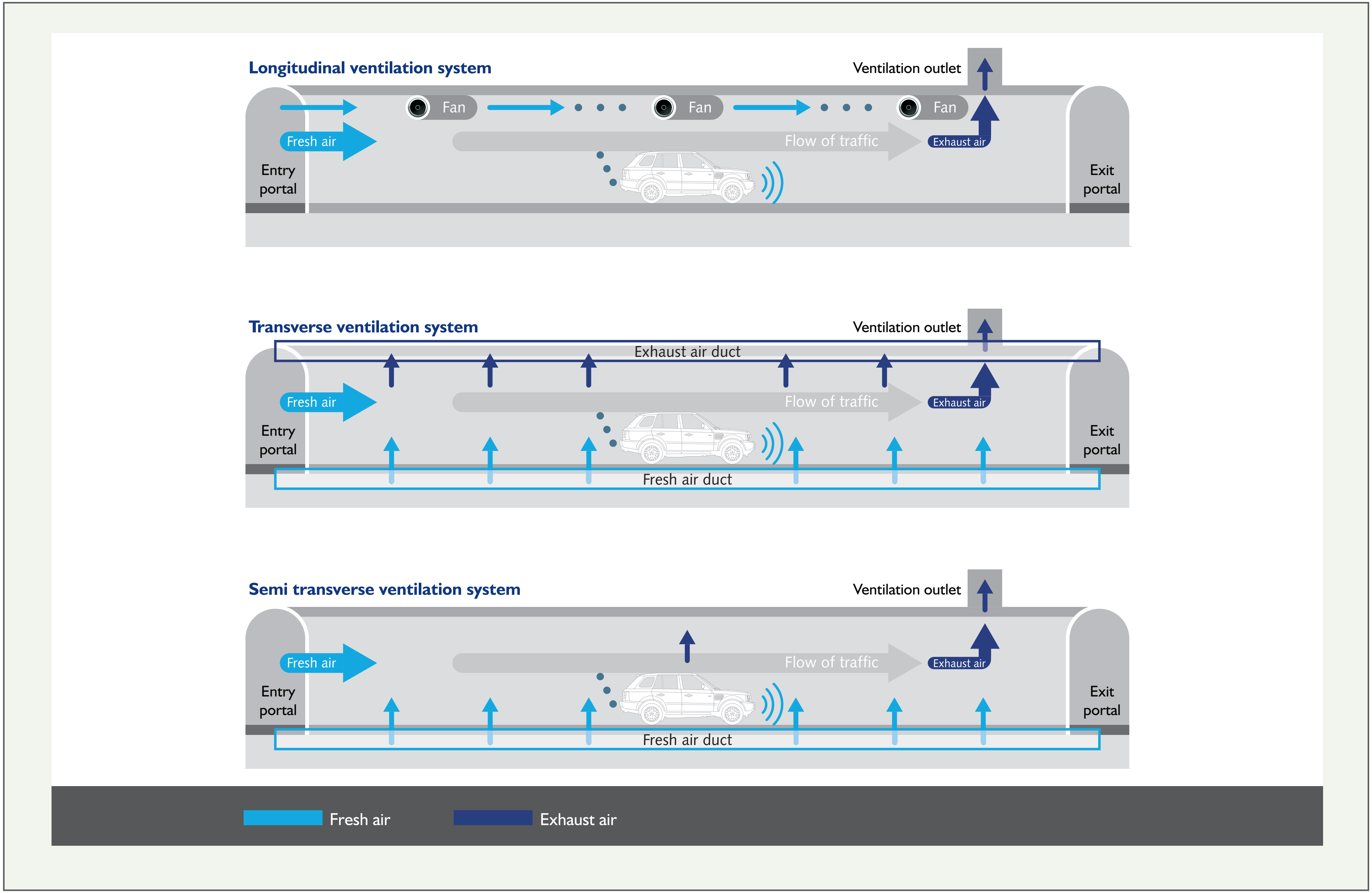

Figure 4-5 Ventilation system design options

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Analysis of the need for tunnel ventilation filtration

There are several air treatment system options for mitigating the effects of tunnel operation on both in-tunnel and ambient air quality. Where in-tunnel treatment technologies have been applied to road tunnels, these technologies have focused on the management and treatment of particulate matter. The most common of these is the electrostatic precipitator, often used for improving visibility in long tunnels. Other techniques include filtering, denitrification and biofiltration, agglomeration and scrubbing.

Air pollution control technology has previously been installed in a limited number of tunnels in a few countries including Norway, Austria, Germany and Japan (though in many cases the capability is rarely, if ever, operated), as well as trialled in the M5 East Motorway tunnel in Sydney. This technology can include the use of electrostatic precipitators to remove particles as well as catalytic and biological processes and adsorption technologies to remove nitrogen oxides. Evidence to date suggests that the effectiveness of such measures when applied to road tunnels is questionable (Roads and Maritime, 2014a).

These technologies are pollutant specific, only address local and not regional transport related air pollution, generate chemical waste and have significant capital and operational costs (NZ Transport Agency, 2013).

The French government undertook an international assessment of the air in road tunnels (CETU, 2010), and concluded that filtration systems are 'bulky and less cost-effective than conventional ventilation systems, both in terms of investment and operation. Generally-speaking, these systems are also energy-intensive given the surplus ventilation requirements.'

In Australia, the issue of air treatment frequently arises during the development of new tunnel projects. However, all tunnel projects rely instead on the primary approach of dilution of air pollution in the tunnel and effective dispersion through elevated outlets through ventilation systems (CETU 2010, Roads and Maritime Services 2014a).

A trial filtration system was constructed to filter the air in the westbound tunnel of the M5 East Motorway. For a period of 18 months an extensive assessment of system performance was carried out by CSIRO and AMOG Consulting. While the system did remove nitrogen oxides and particulate matter, it was expensive to run and did not operate reliably. The M5 East Motorway filtration trial removed 200 kilograms of PM10 per year, at an operating cost of around $3.8 million per tonne and a total cost of $17.4 million per tonne (including civil and machinery costs) (AMOG, 2012).

In 2010, the then Department of Environment, Climate Change and Water engaged Sinclair Knight Merz (SKM, 2010) to undertake a study to identify and analyse a range of emissions abatement initiatives. In the Sydney region, 12 emissions reduction measures were identified with costs ranging from $1,000 to $274,000 per tonne of PM10 removed. The study demonstrated that there are many measures that are both more effective and more cost effective than filtration (as trialled on the M5 East Motorway).

In 2013, the NSW EPA commissioned PAEHolmes to develop a valuation methodology that accounted for the health impacts associated with changes in particulate matter emissions (PAEHolmes, 2013). This study estimated the health benefit of removing one tonne of $PM_{2.5}$ in Sydney to be $280,000.

Nearly all of the particles removed in the M5 East Motorway trial consisted of $PM_{2.5}$. Based on the above valuation, the M5 East Motorway filtration trial had operational costs of more than ten times the estimated health benefit. All of the measures considered by the SKM 2010 study cost more than ten times less than the M5 East Motorway filtration trial and would remove substantially more particulate matter, delivering a much greater health benefit than tunnel filtration. This is consistent with the conclusions of the National Medical and Health Research Council (NHMRC, 2008). This report found that the most effective method to manage air quality in and around road tunnels is through vehicle fleet emission reductions.

As a comparison, Roads and Maritime and the NSW EPA instigated a smoky vehicle strategy on the M5 East Motorway in 2006. This strategy involves the use of smoke detectors, video and still cameras to detect smoky vehicles. Fines and suspensions are issued to encourage vehicles to be repaired or removed from the road network. This strategy has proven to be effective in resulting in improvements to air quality within the M5 East Motorway tunnels, and the air which is exhausted from the M5 East Motorway tunnels to the environment. One measure of in-tunnel air quality is visibility which is measured as an extinction coefficient. Visibility can be used as a measure of in-tunnel particulate matter using a conversion factor from the Permanent International Association of Road Congress (2012) (PIARC). The PIARC definitions of extinction coefficients (visibility) as follows:

- 0.003 m^{-1} means a clear air tunnel (visibility of several hundred metres)
- 0.007 m^{-1} approximates a haziness of in-tunnel air
- 0.009 m^{-1} approximates a foggy atmosphere
- 0.012 m^{-1} is the threshold value that should not be exceeded during operation and which results in a very uncomfortable in-tunnel atmosphere. However, there is normally enough visibility to stop safely at an obstacle.

In 2004, prior to the implementation of the strategy, the extinction coefficient (a measure of visibility) within the M5 East Motorway tunnels exceeded 0.004 m^{-1} in most months. Contemporary data (from April 2013 to April 2014) shows that the M5 East Motorway now operates with an extinction coefficient of less than 0.003 m^{-1} (ie a clear air tunnel) for the majority of the time. The New M5 project would also include smoky vehicle regulatory measures similar to the M5 East Motorway. Further details on the improvement in air quality in the M5 East Motorway tunnels since the implementation of the smoky vehicle strategy, and the New M5 strategy in relation to smoky vehicles are provided in **Chapter 10** (Air quality).

The air quality assessment (refer to **Chapter 10** and **Appendix H**) demonstrates that ventilation outlets are effective at maintaining local air quality. Provision of a tunnel filtration system does not represent a feasible and reasonable mitigation measure, and is not being proposed.

Tunnels form only a small portion of the road network, and hence have a negligible effect on regional air quality. More important considerations for tunnel design are optimising in-tunnel and local ambient air quality. For tunnels that are ventilated through well-designed ventilation outlets, the effects on local air quality of reducing emissions will be very small (Roads and Maritime, 2014a).

In 2008, the National Medical Health and Research Council found that the most effective long-term measure for improving air quality in and around tunnels, and throughout the road network is to continue to implement measures to reduce emissions from vehicles (Roads and Maritime, 2014a).

The main measure to address vehicle emissions is the NSW Cleaner Vehicles and Fuels Strategy (DECC, 2008a). This strategy outlines NSW Government actions for cleaner fuels and a cleaner motor vehicle fleet to reduce transport-related air emissions.

The implementation of actions from this program, including the NSW Diesel Retrofit Program, Smoky Vehicle Detection Program and the NSW FleetWise partnership have contributed to a steady reduction in motor vehicle emissions despite continued growth in the total number of vehicles and kilometres driven. As new cleaner vehicles replace older, more polluting vehicles, emissions are predicted to continue to fall over the next 10 to 15 years (DECC, 2008a).

Location of ventilation facilities

The main considerations in relation to the location of ventilation facilities were minimising local and regional air quality impacts and maximising the operational efficiency of the tunnel ventilation system.

Vehicles travelling through tunnels create a piston effect, whereby the movement of vehicles draws air into the tunnel system through the entrance portals, with emission levels rising toward the tunnel exit in a tunnel with longitudinal ventilation as proposed for the project. As a consequence of the requirement for zero portal emissions (Roads and Maritime, 2014a), the most efficient location for ventilation facilities is as close to the tunnel exit portals as possible. This minimises the distance within the tunnel through which the air flow must be forced against traffic flow back to the ventilation outlet. This forced reverse flow is achieved by "over-extraction" at the ventilation facility. Minimising the use of these fans increases the performance of the tunnels, reduces operational power consumption and reduces operational cost. This also has environmental benefits, by reducing energy consumption and greenhouse gas emissions associated with energy generation.

In the case of the New M5, which includes twin road tunnels, this would mean a ventilation outlet located at each end of the project as close as possible to the tunnel portals would be the optimum approach to management of in tunnel air quality. To achieve this, two ventilation facilities were proposed, with one to be located in Kingsgrove, at the western end of the project and one to be located at St Peters, at the eastern end of the project.

The St Peters ventilation facility, which would be located near the eastern tunnel portals, would be situated on land that is beneath airspace regulated by the Civil Aviation Safety Authority to ensure the ongoing safe operation of the Sydney Airport. In this area, restrictions are placed on the height of structures as well as the velocity of discharges from activities such as road tunnel ventilation facilities and industrial emissions stacks.

Through detailed consultation with the Civil Aviation Safety Authority during the development of the ventilation design for the project, Roads and Maritime has identified that operation of a single ventilation outlet at St Peters near the eastern portals could not, for the most conservative combinations of in tunnel traffic and atmospheric conditions, comply with both:

- The discharge velocity / air turbulence requirements imposed by the Civil Aviation Safety Authority to ensure safe ongoing operation of the Sydney Airport
- The ventilation requirements of the project to ensure acceptable in tunnel air quality and good dispersion of ambient emissions.

For this reason, an additional ventilation outlet would be required. The third ventilation facility would be located at Arncliffe (the Arncliffe ventilation facility, in the south-western corner of the existing Kogarah Golf Course site). Including a third ventilation facility would allow both in tunnel and ambient air quality requirements to be met, without compromising the safety of aircraft operations at Sydney Airport.

The operation of three ventilation facilities would be required in order to minimise environmental and land use impacts while avoiding adverse impacts on the viable operation of Sydney Airport.

Kingsgrove ventilation facility

The Kingsgrove ventilation facility would be located immediately to the south of the M5 East Motorway corridor at Kingsgrove. Locating the western ventilation facility to the south of the M5 East Motorway corridor within an established commercial and industrial area was preferred to limit potential impacts on residential dwellings to the north and south-west of the motorway.

The general area surrounding the proposed location for the project's western portals was considered at a broad scale to identify a suitable location for the ventilation facility. However, due to the built-up nature of the surrounding area, there are no other reasonable alternatives for the location of the western ventilation facility.

Arncliffe ventilation facility

The Arncliffe ventilation facility would be located in the south-western corner of the Kogarah Golf Course site. Situating the third ventilation facility in this location avoids the need for acquisition of private residences and minimises impacts on both the operation of Kogarah Golf Course and on the potential future development on this site.

St Peters ventilation facility

The location of the St Peters ventilation facility within the St Peters interchange provides a ventilation facility location that would be suitable for the eastbound New M5 tunnel as well as the eastbound M4-M5 Link tunnels. The location of the St Peters ventilation facility within the St Peters interchange also avoids the need for additional property acquisition.

If the future M4-M5 Link proceeds, a ventilation facility for the north and south bound tunnels of the future M4-M5 link may also be situated within the St Peters interchange. This would be considered separately as part of an assessment and approval for the future M4-M5 Link project.

Location of emergency smoke extraction outlets

A key aspect of safe tunnel operation is the efficient removal of smoke in the event of a fire in the main alignment tunnels to maintain visibility and in-tunnel air quality. One option to achieve this is to provide emergency smoke extraction functionality in combination with other proposed ventilation facilities. For operational efficiency and safety reasons for the main alignment tunnels two emergency smoke extraction facilities are proposed along or close to the main alignment tunnels for the project. Through the provision of reversible fans, emergency smoke extraction outlets could also be used to draw air in and supply fresh air to the tunnels. Additionally, the provision of reversible fans could potentially reduce the number of jet fans within the tunnels.

Provision has been made for a mid-tunnel emergency smoke extraction outlet located at Bexley. In addition, the Arncliffe ventilation facility would also provide emergency smoke extraction functionality.

The general area was considered for emergency smoke extraction facilities. Alternative locations for these facilities would have involved additional impacts on residential development, requiring additional property acquisition, and were not preferred.

4.6.2 Motorway control centre

Each stage of the WestConnex program of works, should it proceed, would require a control centre to monitor in-tunnel conditions and to manage operations. The respective merits of a stand-alone control centre for each stage compared to a single control centre for all stages, have been considered for the project.

In the instance that the separate components of the WestConnex program of works be operated by different managing contractors, a stand-alone control centre for each stage would be preferred. Should all stages of the WestConnex program of works be operated by a single managing contractor, a combined motorway control centre could be constructed. In this case, the motorway control centre constructed for the New M5 project could be used as the primary control centre or as a backup facility.

The location of the motorway control centre for the project was selected because it is within the boundary of the St Peters interchange and would be on residual land following completion of construction. Alternative locations would likely require additional property acquisition.

A maintenance facility would also be provided at the western surface works area, in Kingsgrove.

4.6.3 Construction compound locations

Potential construction compound locations were assessed against the following criteria:

- Be positioned more than 50 metres from a waterway
- Be located within or adjacent to land which would form part of the operational project footprint
- Have ready access to the road network
- Minimise the need for heavy vehicles to travel through residential areas
- Be located on relatively level land
- Be separated from residential dwellings by more than 200 metres, or 300 metres for temporary concrete batching plants
- Be situated in an area of low ecological significance and not require additional vegetation clearance (above that required for the operational footprint of the project)
- Not impact on Aboriginal or historic heritage items
- Not affect land use of adjacent properties
- Have no / minimal impact on flood storage and does not obstruct floodplain or culverts
- Be positioned outside of the 20 year ARI flood level
- Have sufficient area for the storage of raw materials to minimise the requirement for out-of-hours deliveries.

Fourteen construction compounds have been identified for the construction of the project, required to support both civil and tunnelling construction works. Where the identified construction compounds could not meet the criterion listed above, additional specific mitigation measures were identified to manage impacts associated with their use. Details of each construction compound are provided in **Section 6.6.3** of this EIS.

4.6.4 Spoil disposal

Construction of the project would generate around 2.7 million cubic metres of spoil. As described in **Chapter 6** (Construction work) and **Chapter 24** (Resource use and waste minimisation), spoil reuse and disposal would be prioritised in accordance with the following hierarchy:

- Within the project for earthworks fill
- Environmental works/community works
- Development works/land restoration.

Chapter 6 (Construction work) also identifies the proposed locations for spoil use and disposal.

Consideration has been given to the various modes available to transport spoil, as outlined below.

Rail

The movement of spoil via rail was considered as an option. The benefit of rail is the ability to move large volumes of spoil, while reducing the number of heavy vehicle movements in the wider road network (noting that heavy vehicles would still need to transport spoil to the rail loading facility). However, this method presents the following issues:

- There are very few spare train paths on the Sydney rail network, which presents logistical challenges
- The material would need to be double (or possibly triple) handled, as trucks would be required to move material to the train loading facility, and potentially from the rail facility to its final location, if this does not have rail access
- Infrastructure upgrades could be necessary to allow the train loading facility to receive the material.

Barge

The movement of spoil via barges was considered as an option. As with rail, the main benefit of barge transport is the ability to move large volumes of spoil, while reducing the number of heavy vehicle movements in the wider road network (noting that heavy vehicles would still need to transport spoil to the barge loading facility). However, as for the rail option, this option presents a number of issues including:

- The material would need to be double (or possibly triple) handled, as trucks would be required to move material to the barge loading facility, and potentially from the barge to its final location, if this does not have barge access
- Infrastructure upgrades could be necessary to allow the barge loading facility to receive the material.

Heavy vehicle

Spoil removal and disposal using trucks would involve transporting material from the construction site directly to the final disposal location. This option would streamline the handling of spoil, but would result in a higher number of trucks on the road. However, this increase in truck numbers is not considered to be any more significant than the alternatives, since other transport options (rail and barging) would still require trucks to initially move material to the loading facility and, potentially, to the final destination. Consequently, transporting spoil by truck was selected as the preferred option.