Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 4

Project development and alternatives

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4 Project development and alternatives

This chapter describes the alternatives that were considered as part of the project development process and explains the selection of the preferred alternative. The preferred alternatives presented in this chapter are based on technical, environmental and planning considerations. Stakeholder and community considerations which have been incorporated into the project development process are outlined in Chapter 7 (Stakeholder and community engagement). Design refinements for particular elements of the project are also outlined.

The Secretary's environmental assessment requirements as they relate to the project development and alternatives, and where in the environmental impact statement these have been addressed, are detailed in Table 4-1.

Table 4-1 Secretary's environmental assessment requirements – Project development and alternatives

Secretary's requirement	Where addressed in EIS
Environmental impact statement	
1. The EIS must include, but not necessarily be limited to, the following: e. an analysis of any feasible alternatives to the project;	An analysis of strategic alternatives is provided in **Section 4.3**.
f. a description of feasible options within the project, including: – alternative methods considered for the construction of the project, including the tunnels; and – staging of the proposal;	Alternative construction methods are detailed in **Section 4.5.1**. Further detail on staging is included in **Chapter 6** (Construction work).
g. a description of how alternatives to and options within the project were analysed to inform the selection of the preferred alternative/option. The description must contain sufficient detail to enable an understanding of why the preferred alternative to and options(s) within, the project were selected, including: – details of the alternative construction methods that were considered for tunnel construction, particularly those areas spanning Sydney Harbour (Middle) Harbour; – details of the short-listed route and tunnel options considered, and the criteria that was considered in the selection of the preferred route and tunnel design; – the alternative tunnel design and ventilation options considered to meet the air quality criteria for the proposal; and – a justification for the preferred proposal taking into consideration the objects of the *Environmental Planning and Assessment Act 1979;*	The assessment of route alternatives is detailed in **Section 4.4** and construction alternatives in **Section 4.5**. Alternative tunnel construction methods and ventilation system designs considered are discussed in **Section 4.5.1** and **Section 4.5.6** respectively. A description of the benefits of the overall program of works and the justification for the project is provided in **Chapter 3** (Strategic context and project need). Justification for the preferred proposal taking into consideration the objects of the *Environmental Planning and Assessment Act 1979* is presented in **Chapter 28** (Synthesis of the environmental impact statement).

Secretary's requirement	Where addressed in EIS
i. a demonstration of how the project design has been developed to avoid or minimise likely adverse impacts during construction and operation of the project;	Project design development is detailed in **Section 4.4** and **Section 4.5**, and **Chapter 5** (Project description).

4.1 Overview

The project has undergone extensive evaluation of alternatives from pre-feasibility and strategic investigations through to design development and refinement, as outlined in Figure 4-1.

Figure 4-1 Alternatives development process

4.2 Historical context

Middle Harbour is a natural feature fundamental to the liveability and amenity of the Northern Beaches area. However, this waterway has historically presented a substantial challenge to the region’s transport network, constraining north-south and east-west journeys to and from the Northern Beaches to limited corridors utilising only two waterway crossings being the Roseville Bridge and the Spit Bridge.

Addressing this transport challenge has been considered since the late 1930s, when a plan for a new road crossing of Middle Harbour, supported by an additional western crossing of Sydney Harbour, was first considered.

While the nature and shape of the city has changed considerably since the 1930s, the fundamental transport challenge for freight services, public transport, and other road users presented by Middle Harbour remains. Advancements in tunnelling technology coupled with the plan for investment in additional crossing capacity at Sydney Harbour have also worked to overcome many of the community and technical challenges associated with the original surface road proposal.

A timeline for the historical development of the Warringah Transport Corridor and additional cross harbour capacity as precursors to the Western Harbour Tunnel and Beaches Link program of works is provided in Figure 4-2.

1924

The (first) Spit Bridge was completed and opened, replacing the existing punt service at Middle Harbour.

1930s

Plans were developed for a new Warringah Transport Corridor, including an additional harbour crossing, to the Northern Beaches.

1948

Plans for the Warringah Transport Corridor were first formally documented as the 'County Road Reservation' in the County of Cumberland Planning Scheme, which was formally adopted by the Cumberland County Council in 1948. This scheme showed a proposed surface road route crossing Middle Harbour at Bluff Head (Northbridge).

1949

In 1949, the Department of Main Roads' *Main Road Development Plan* presented alternative alignments for the Warringah Transport Corridor, one option crossing Middle Harbour at Bluff Head (Northbridge) and another at Sugarloaf Point (Castlecrag). Both options included connectivity between Wakehurst Parkway and the future Burnt Bridge Creek Deviation.

1951

The scheme alignment was prescribed in 1951, dropping the Bluff Head (Northbridge) option in favour of the alignment via Sugarloaf Point (Castlecrag).

1953

The prescribed scheme alignment, as set out in the *Main Road Development Plan*, was later confirmed by the Cumberland County Council's County Road Reservation in 1953, forming part of an inner ring-road extending through a second harbour crossing (Greenwich – Birchgrove).

1960 – 1970

The prescribed scheme was adopted by the planning systems of Warringah, Manly and Willoughby Councils when they were prescribed in 1963, 1968 and 1970 respectively.

1974

The Sydney Area Transportation Study recommended that the Warringah Freeway be part of the long term road network in Sydney.

1977

Following a decision by the State Government (Labour) to drop the proposal to construct an expressway along the Warringah Transport Corridor, the County Road Reservations for the scheme were removed from the planning systems of Warringah, Manly and Willoughby counties in 1977.

1981

The Warringah Transport Corridor Inquiry starts, considering the proposal for the corridor to extend from the Warringah Freeway, across Middle Harbour at Castlecrag, to Seaforth and Balgowlah.

1983

The Commission of Inquiry into the Warringah Transport Corridor found that a new surface road to the Northern Beaches in the identified corridor would result in unacceptable levels of community and environmental impacts. The Inquiry noted that the feasibility of the proposal would be improved by future tunnelling technology alleviating some of the potential environmental and community impacts.

1990 - 2010

Various government proposed feasibility studies were undertaken to widen or duplicate the Spit Bridge or duplicate the Middle Harbour crossing with a tunnel. All these proposals were ultimately not pursued at the time.

2012

The NSW Government's *NSW Long Term Transport Master Plan* (Transport for NSW, 2012) proposed a new harbour crossing to the west of the CBD identifying it as a key 'missing link' in the Sydney motorway network. It also proposed a bus tunnel bypassing Military Road.

2014

Commitments were made in the *NSW State Infrastructure Strategy Update 2014* (Infrastructure NSW, 2014) that the Government would commence work on an additional harbour crossing and would further review and develop Beaches Link.

2015 - 2020

Northern Beaches Hospital road upgrade project is carried out to enhance the road network surrounding the Northern Beaches Hospital at Frenchs Forest. Surface road works along the Wakehurst Parkway would integrate Beaches Link with road network upgrades completed as part of the Northern Beaches Hospital road upgrade project at Frenchs Forest.

2015

Transport for NSW commence development of the B-Line program, to provide more frequent and reliable bus services between the Northern Beaches and Sydney CBD. Beaches Link would provide opportunity for express bus services and reduce pressure on Military Road for existing services.

2015 - 2016

Roads and Maritime carried out preliminary work to establish the viability and high level conceptual design for the Western Harbour Tunnel and Beaches Link program of work.

2016

The draft *North District Plan* (Greater Sydney Commission, 2017b) and draft *Eastern City District Plan* (Greater Sydney Commission, 2017a) released by the Greater Sydney Commission identified the Western Harbour Tunnel and Beaches Link program of works as important initiatives to improve connections and access to and from northern Sydney.

2017

In March 2017, the NSW Government announced the commencement of a community engagement program to inform the development of designs for the Western Harbour Tunnel and Beaches Link program of works, including an additional harbour crossing. Roads and Maritime commences community and stakeholder engagement, preliminary environmental investigations and further design development for the program of works.

2017

The draft *Future Transport 2056 strategy* (NSW Government, 2017) was released which builds on the *NSW Long Term Transport Masterplan*. The Western Harbour Tunnel and Beaches Link program of works is identified in the strategy as a 'Committed' project (ie within the next 0-10 years, subject to final business case).

2018

The *Future Transport Strategy 2056* (NSW Government, 2018), the *NSW State Infrastructure Strategy 2018-2038* (Infrastructure NSW, 2018), the *Greater Sydney Region Plan - A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) and the *North District Plan* (Greater Sydney Commission, 2018b) and the *Eastern City District Plan* (Greater Sydney Commission, 2018c) released. These strategies reference the Western Harbour Tunnel and Beaches Link projects as a transport initiative that will improve connections and accessibility across Sydney.

Figure 4-2 Historical development of additional cross-harbour capacity

4.3 Strategic alternatives

The project aims to provide additional transport capacity across Middle Harbour to improve journey times and journey time reliability for trips between the Northern Beaches and key economic and employment centres. Further information on the strategic context for the project, and the transport needs addressed, is provided in Chapter 3 (Strategic context and project need).

The *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a) and subsequent *Future Transport Strategy 2056* (NSW Government, 2018) set the 40 year vision, strategic directions and outcomes for customer mobility in NSW. These plans identify the transport challenges that would need to be addressed to support NSW's economic and social performance and establish a number of short, medium and long-term actions to address those challenges.

Giving consideration to future land use, population density and transport requirements, both of these strategic plans identified road based transport, including improvements to bus services, as important modes to meet the needs of the Northern Beaches region. Furthermore, the need for additional core motorway capacity at the crossings of Middle Harbour and Sydney Harbour was identified as key to development of an appropriate multi-modal Sydney transport network – and specifically identified the Western Harbour Tunnel and Beaches Link program of works as transport projects required to support the plan.

The Greater Sydney Commission's *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) describes the Northern Beaches region as having a very low population growth rate coupled with a low density urban environment. This makes high capacity and high frequency transport options less appropriate for this region. A more appropriate solution is strategic improvement to road based modes, which would also facilitate substantial improvements to express bus service connections between the Northern Beaches and strategic centres including North Sydney, Sydney Central Business District (CBD), Macquarie Park and St Leonards.

Considering the identified requirements of the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a) and the *Future Transport Strategy 2056* (NSW Government, 2018), a number of strategic alternatives were considered for delivering the required road capacity, as follows:

- Do nothing
- Travel demand management
- Improvements to the existing arterial road network
- A new motorway crossing of Middle Harbour (the project)
- Improvements to alternative transport modes.

These strategic alternatives are described and evaluated in the following sections.

4.3.1 Do nothing

This alternative is to do nothing to the existing crossings of Middle Harbour and the adjoining motorway network and rely on the continued operation of existing transport networks and other transport projects currently proposed to meet future transport demands.

The limited number of existing arterial road connections to the region, including the Military Road/Spit Road, Mona Vale Road and Warringah Road/Eastern Valley Way corridors, currently experience high levels of congestion – particularly during peak periods. This congestion adversely affects travel times, travel time reliability, economic productivity and local amenity.

Excluding the Manly ferry link, bus services are the only mode of public transport for the Northern Beaches region, accounting for about 53 per cent of journeys to the Sydney CBD. However, the performance of bus services to and from the Northern Beaches region, particularly during peak periods, is constrained as a consequence of congestion on the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors that connect the Northern Beaches to strategic centres across Greater Sydney. The implementation of B-Line services in 2017 has resulted in faster and more reliable journey times between Mona Vale and the Sydney CBD, with travel times reduced by about 20 minutes for passengers using the service during peak periods. Nevertheless, without measures to relieve pressure on the surface arterial road network, the capacity of Military Road/Spit Road would place pressure on the effectiveness of B-Line and other express bus services in the future, while also limiting opportunities to develop new express bus services. Capacity constraints on the Warringah Road/Eastern Valley Way corridor would also place pressure on the effectiveness of a new rapid bus service between Chatswood and Dee Why which is currently being planned. Further detail on these transport challenges is provided in Chapter 3 (Strategic context and project need).

As well as hindering daily access for residents, businesses and public transport users, the capacity and geometry of the limited arterial corridors servicing the Northern Beaches region restricts freight connectivity to the Northern Beaches. Vehicles over 19 metres are currently prohibited from using the Military Road/Spit Road corridor and the eastern portion of Warringah Road. For these larger vehicles, journeys to areas such as Dee Why and Brookvale via Mona Vale Road and Pittwater Road can be up to 20 kilometres longer in each direction than the most direct road route.

The do nothing alternative has been rejected as an undesirable strategic alternative because it would not address the identified project need. For example, future traffic modelling (refer to Chapter 9 (Operational traffic and transport)) indicates that without the project, this alternative would be unable to accommodate forecast growth during the peak periods without substantial and unacceptable delays across the Sydney road network. Without the additional capacity for trips into and out of the Northern Beaches that would be provided by the project, accessibility to and from the Northern Beaches would become substantially restricted in the future. Overall, by 2037 in the do-nothing scenario, traffic growth on the road network would result in travel time increases for road users that would make many nearby strategic centres no longer accessible within a 30 minute trip. For example, trips between Frenchs Forest and Balgowlah and North Sydney which currently take about 30 minutes would increase to 50 minutes and 45 minutes respectively by 2037 in the do nothing scenario. This growth in traffic volumes would also result in longer travel times for public transport, with delays to bus services attributed to increased queuing on key bus route corridors between the Northern Beaches region and the North Sydney and Sydney CBDs. The do nothing alternative would adversely impact on:

- Travel time and travel time reliability for freight services, public transport and other road users
- Public transport performance and connectivity for the region, with limited opportunity to deliver new and improved express bus services
- Amenity and environment for local communities, including air quality, noise, visual and traffic related impacts resulting from traffic congestion
- Economic performance of the region, particularly with regard to ongoing congestion costs and access to jobs and services.

These impacts would result in a reduction in the region’s productivity and amenity, and Sydney’s performance as a global city.

4.3.2 Travel demand management

Travel demand management is a measure that focuses on minimising or avoiding the need to invest in new motorway infrastructure, such as the project, by reducing individual trip lengths, reducing peak traffic volumes and making alternative transport mode options more viable. Demand management initiatives may include:

- Land use planning policies which promote urban consolidation and the establishment of town ‘centres’ to reduce the need for travel. For example, the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a), *Future Transport Strategy 2056* (NSW Government, 2018), *Greater Sydney Regional Plan: A Metropolis of Three Cities* (Greater Sydney Commission, 2018a) and *Northern Beaches Transport Action Plan* (Transport for NSW, 2016) aim to bring jobs closer to homes and to areas of increasing population, where feasible

- Augmenting existing public transport and integrating urban regeneration around transport nodes
- Implementing policies which restrict parking provisions in new developments to encourage alternative modes of transport
- Road use charges – such as the congestion charging applied for vehicles accessing central London
- Flexible working arrangements to reduce the number of trips during peak hours.

Sydney's population is forecast to grow from five million to eight million people over the next 40 years. Given the current road network servicing the Northern Beaches is already highly congested, even with considerably reduced per-capita travel demand through demand management and improvements to public transport, an expanded road network would be required to accommodate population growth.

Further, to have a major impact on road traffic, travel demand management measures would require considerable changes in social attitudes, travel behaviour and government policy and can take many years to achieve. Travel demand management changes alone are therefore not a viable strategic alternative to the project. They are, however, viewed as complementary initiatives, together with the project, to reduce the level of congestion on Sydney's road network as the city's population grows.

4.3.3 Improvements to the existing arterial road network

Improvements to the existing arterial road network to provide additional transport capacity from the lower North Shore to the Northern Beaches have been considered.

Options to provide additional capacity without major widening schemes have included investigations into various operational changes to the Military Road/Spit Road corridor, including tidal flow, peak period parking restrictions, introduction of bus lanes and T3 lanes and reductions in Spit Bridge opening times. Given the conflicts with existing signalised intersections, such initiatives only provide minor and short-term benefits.

Ways to increase road capacity across Middle Harbour have been considered for many years (refer to Section 4.2). Aside from the challenges associated with augmenting the existing aging structure, increasing capacity across the Spit Bridge would deliver limited benefit to the Military Road/Spit Road corridor without large investment in widening and reprioritisation schemes along the entire corridor from Mosman through to the Warringah Freeway.

The scale of surface solutions required to provide meaningful improved travel times along the existing surface arterial routes would result in unreasonable amounts of land acquisition and environmental and social impact. These works would heavily impact business and communities along the entire route during construction and operation. Users of the existing surface corridors would also be considerably impacted during construction of these upgrades.

Accordingly, substantial new improvements to the existing arterial road network connecting to the Northern Beaches have been rejected as a strategic alternative.

Transport for NSW has an extensive program of upgrades to the existing road infrastructure across Sydney to address congestion and improve travel times. Information on these projects can be found on the Transport for NSW website (https://www.transport.nsw.gov.au/projects/current-projects). These projects are considered complementary because they would improve the capacity of Sydney's existing motorway and arterial road network, but they would not provide the necessary additional transport capacity between the Northern Beaches and other key centres (refer to Chapter 3 (Strategic context and project need) for additional details on this function).

4.3.4 A new motorway crossing of Middle Harbour

Options for a motorway connection to the Northern Beaches requiring a new bridge over Middle Harbour have been discussed since the 1930s when a new surface road corridor was contemplated in the Cumberland Plan. The concept of building a surface motorway was abandoned some 40 years ago, with the principal concerns being the environmental and community impacts of a surface alignment, and the limited benefits offered given the downstream capacity constraint at the Sydney Harbour crossing. At this time, tunnelling technology was not sufficiently advanced to allow a road tunnel to be cost-effectively implemented.

The release of the *NSW Long Term Transport Master Plan* (Transport for NSW, 2012a) and *State Infrastructure Strategy Update 2014* (Infrastructure NSW, 2014) confirmed new motorway crossings of Sydney Harbour and Middle Harbour as transport priorities for the city and State.

In combination with the Western Harbour Tunnel and Warringah Freeway Upgrade project, a new motorway crossing of Middle Harbour would address the project need by:

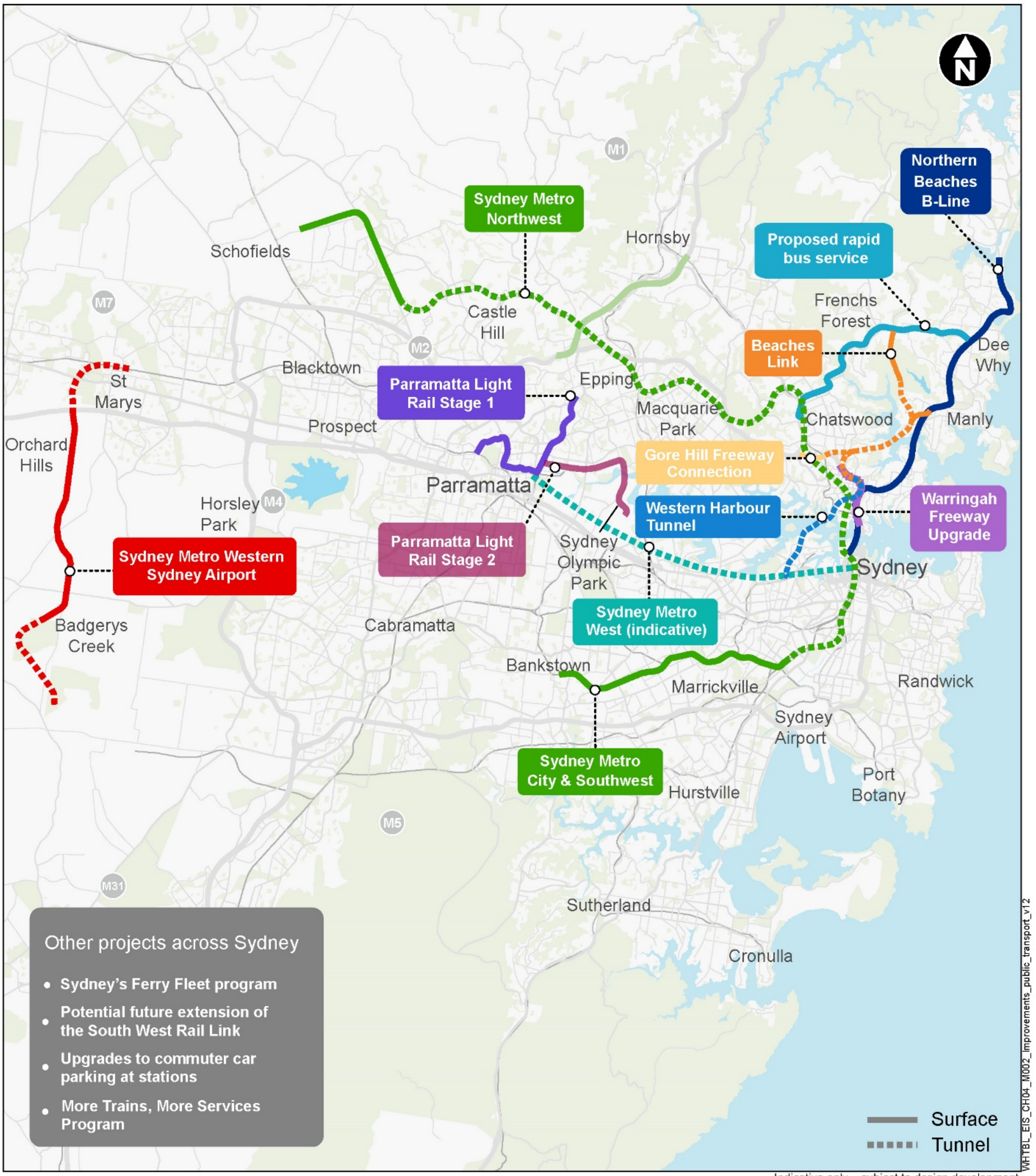
- Providing a new, safer, more efficient and reliable motorway link for freight services, public transport and other road users travelling between the Northern Beaches and strategic centres across Greater Sydney
- Increasing arterial road network capacity between the Northern Beaches region and strategic centres across Greater Sydney by 60 per cent - reducing pressure and congestion on existing arterial routes that run over capacity during peak periods
- Delivering travel time savings and travel time reliability benefits for users of existing surface routes, including freight delivery and bus services, by reducing pressure on surface arterial routes
- Increasing the resilience of the North District transport network to incidents by providing a new alternative motorway standard road corridor between strategic centres
- Creating opportunity for new express bus services between the Northern Beaches region and strategic centres such as North Sydney, Sydney CBD, Macquarie Park and St Leonards via the new motorway – including opportunities for efficient interchange with the new Victoria Cross Metro Station at North Sydney.

4.3.5 Improvements to alternative transport modes

The NSW Government, through Transport for NSW, is currently planning and delivering a series of new and upgraded transport projects and initiatives, consistent with the *Future Transport Strategy 2056* (NSW Government, 2018). The key public transport projects in the Greater Sydney area are shown in Figure 4-3.

Alternative transport modes to the project, and their effectiveness in meeting the project need, are described in the following sections.

Information on these projects can be found on the Transport for NSW website (transport.nsw.gov.au/projects/current-projects).



Indicative only – subject to design development

Legend

Approved

- Sydney Metro
- Northern Beaches B-Line
- Parramatta Light Rail Stage 1

Proposed

- Western Harbour Tunnel
- Warringah Freeway Upgrade
- Beaches Link
- Gore Hill Freeway Connection
- Sydney Metro West
- Parramatta Light Rail Stage 2
- Proposed rapid bus service
- Sydney Metro Western Sydney Airport

Existing heavy and light rail

Figure 4-3 Key public transport projects in the Greater Sydney area

Improvements to the Sydney bus network

Improvements to the Sydney bus network as a strategic alternative to the project include additional bus routes, additional buses on existing routes and bus priority measures.

Buses play a crucial role in Sydney's public transport system. Sydney's bus network currently includes more than 600 routes. For more than 90 per cent of Sydney residents, 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.

A well planned bus network is the most efficient means of providing public transport in areas where there is a less dense population, meaning that origins and destinations of commuters are more dispersed, as is the case for the Northern Beaches region. Bus services can also be put into service more rapidly and with considerably less infrastructure and disruption than any other type of public transport.

Furthermore, recent advancements in technology have provided the opportunity to develop fully electric buses – reducing noise generation, eliminating at source emissions, and providing a much smoother journey for passengers. Electric buses are already operating on several routes in Sydney's Inner West. The NSW Government plans to introduce additional electric buses in the Inner West, as well as other areas of Greater Sydney over the coming 12 months.

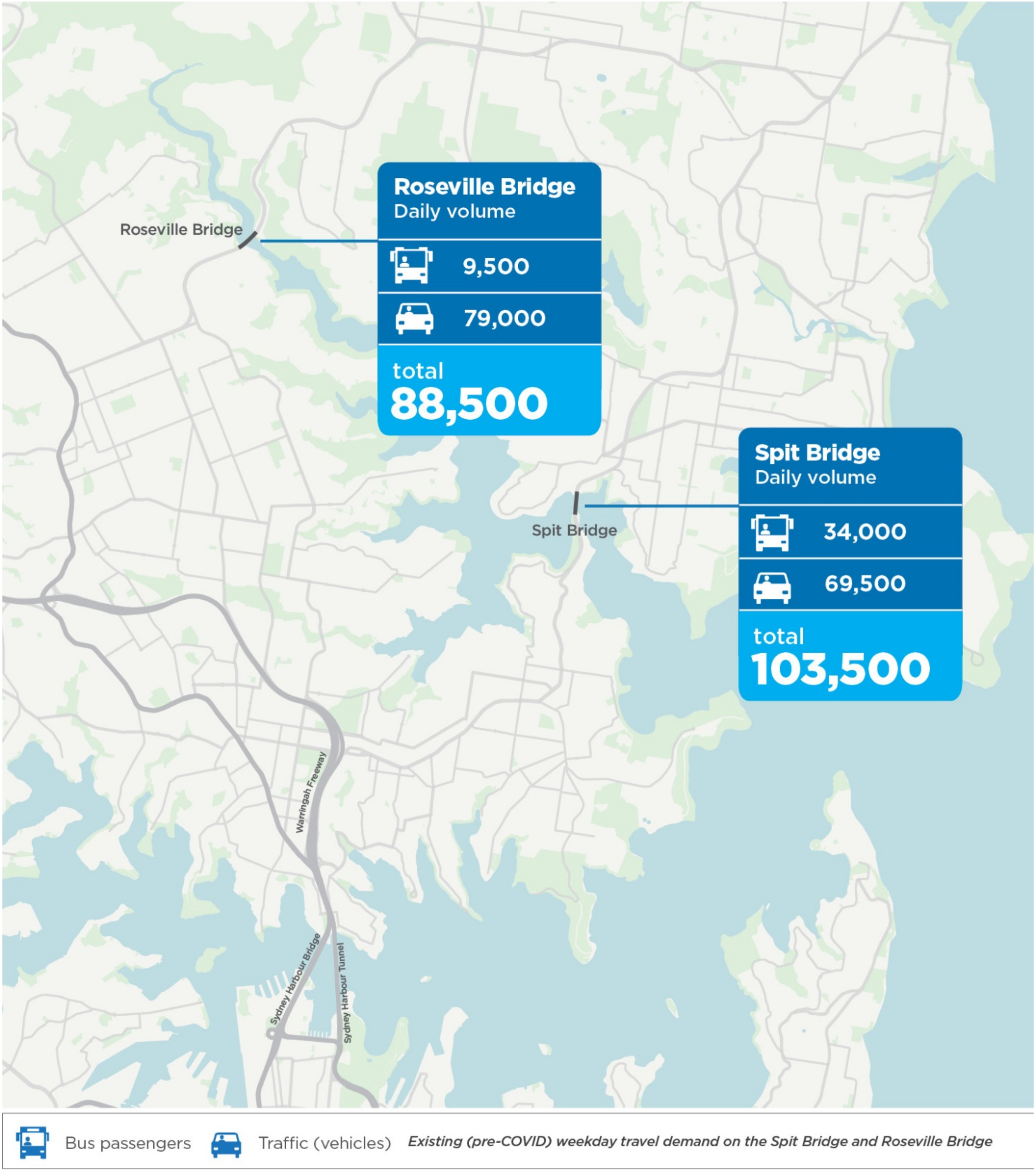


Figure 4-4 Average weekday trips via key transport corridors (existing conditions)

Sydney's Bus Future (Transport for NSW, 2013a) acknowledges that improvements to the bus network are essential to meet changing customer needs, including access to major centres outside the Sydney CBD. *Sydney's Bus Future* aims for seamless connection to other transport modes to deliver the right mix of services. In response to changing passenger needs and an increase in demand, additional services have already been added to the Sydney bus network. However, without measures to improve journey times by increasing the road efficiency or capacity, the addition of more buses to the network can contribute to congestion, making bus services less effective at meeting customer needs.

Sydney's Bus Future proposes major changes to the Sydney bus network to meet current and future demands by providing express service routes to connect major centres along transport routes with mass transit demand. Suburban and local service routes would build on the foundation of these express service routes to improve access to local, neighbourhood destinations. An example of the major changes to the Sydney bus network as a result of *Sydney's Bus Future* is the B-Line program. Its success to date has encouraged the planning of a rapid bus service between Dee Why and Chatswood.

Despite the complementary nature of the aforementioned projects, improved bus services on existing surface corridors alone would not be sufficient to provide the level of additional transport capacity that is required for the Northern Beaches region. The ability for the bus network to provide extra capacity is strictly limited by the capacity of the road network itself – particularly the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors.

While the B-Line program has been successful in improving capacity and travel times in the short to medium-term, additional road capacity is required to deliver long-term benefits for bus services and unlock the opportunity for new and improved express services between key centres.

Improvements to the rail network

The physical and urban geography of the Northern Beaches region presents barriers to the consideration of rail-based solutions in addressing the transport challenges faced by the region. The hilly, harbour-based Eastern Harbour City with its established urban area and therefore limited available space to develop a rail corridor, means that provision of rail infrastructure would be expensive with a long lead time to development. The topography on either side of Middle Harbour introduces challenges for constructing a tunnel with a gradient that would be acceptable in terms of engineering design and safety for rail infrastructure, with steep elevation changes as well as geology characterised by substantial rock fracturing. The necessity to build deep station boxes for a tunnelled rail link under Middle Harbour was another key consideration when developing the preferred solution. These physical constraints would result in substantial challenges for engineering, with large implications for cost and amenity during construction.

The provision of rail infrastructure is also reliant on the location of and accessibility to high density residential or commercial property close to the proposed location of stations as well as along its route. Given the high cost of constructing and operating rail infrastructure and the low density nature of the Northern Beaches, it is considered that demand would not be high enough to make investing in a specific or dedicated rail link to the Sydney CBD a viable alternative.

Similarly, provision of light rail would entail high capital and operating costs which would require high passenger demand in order to be a viable solution. Due to the low population density and population growth rate for the Northern Beaches region, when considering the distances proposed, light rail would not be considered a suitable mass transit solution. Light rail also performs best when completely separated from other road traffic, so that the introduction of light rail into an already congested road transport network would have the potential to further reduce road capacity where a segregated light rail corridor would replace traffic lanes.

Due to the high cost and long lead time for a heavy or light rail solution, the alternative approach for public transport improvement is to focus on improving the speed and reliability of road based public transport such as bus services – for example, by implementing bus priority measures and developing rapid bus services. Such investment can be delivered as part of a long-term, staged approach to increasing corridor capacity, as and when required, at substantially lower cost than heavy and light rail infrastructure. With a relatively high carrying capacity, rapid or express bus services offer a mass transit solution for bus corridors where a rail based solution is unsuitable. As such, adequate, reliable and efficient public transport using road infrastructure (ie rapid and express bus services) is considered a more suitable and appropriate public transport solution for the area.

The *Northern Beaches Transport Action Plan* (Transport for NSW, 2016), outlined proposed rail initiatives of relevance to the project. These included a second harbour rail crossing as well as a new rail line to the Sydney CBD. Subsequently, this new rail line to the CBD was realised by the Sydney Metro City & Southwest project, which is a 30 kilometre extension of metro rail line from the end of the existing Sydney Metro Northwest terminus at Chatswood. The Sydney Metro City & Southwest project will travel from Chatswood, under Sydney Harbour, through newly established stations in the Sydney CBD through to Bankstown in the south west of the city. The Sydney Metro City & Southwest project will enhance the Sydney rail network and enable it to carry an additional 100,000 people per hour in peak periods, delivering sufficient capacity to serve the city well into the future.

Supplemented by a rapid bus service between Dee Why and Chatswood that is currently being planned, this means more people are likely to travel by rail, helping to reduce the number of buses travelling into the Sydney CBD from locations north of Sydney Harbour. This would also provide increased capacity for buses and cars travelling from the Northern Beaches to the Sydney CBD.

While these projects would contribute to reducing congestion on the existing road network, they would not be sufficient to resolve the existing road network capacity constraints between the lower North Shore and the Northern Beaches. This is due to the complexity of journey patterns and trip purposes within Greater Sydney and the dispersed nature of origin and destination points for an individual journey. This means that roads remain a critical element in the integrated transport network, servicing buses, freight, commercial and many other individual journey needs.

Improvements to the freight rail network would assist with the efficient distribution of freight particularly for freight travelling longer distances. However, a large proportion of Greater Sydney's freight, commercial, and services tasks require distribution of goods and services to customers within the Sydney basin. This requires a diverse and dispersed point-to-point transport system that is most efficiently provided by the road network.

Improvements to the ferry network

Additional ferry services on Sydney Harbour were considered as a strategic alternative to the project. Additional ferry services would provide an improved cross-harbour public transport link and would contribute to relieving congestion on existing cross-harbour road connections. While this would contribute to reducing congestion on the existing road network, it would not resolve the existing cross-harbour road congestion and capacity constraints. This is due to comparatively small number of journeys currently using these crossings that would be transferable to the ferry network.

Improvements to active transport

Improvements to active transport infrastructure (cyclist and pedestrian facilities) that were considered as strategic alternatives to the project included additional cycling and pedestrian routes and facilities as identified in *Sydney's Cycling Future* (Transport for NSW, 2013b) and *Sydney's Walking Future* (Transport for NSW, 2013c).

Sydney's Cycling Future aims to make cycling a safe, convenient and enjoyable transport option for short trips by:

- Investing in separated cycle ways and providing connected bicycle networks to major centres and transport interchanges
- Promoting better use of the existing network
- Engaging with stakeholders across government, councils, developers and bicycle users.

Sydney's Cycling Future aims to increase the mode share of cycling in the Sydney metropolitan area for short trips that can be an easy 20 to 30 minute ride. The strategy aims to improve access between suburbs and major centres, reduce congestion on the road network and increase capacity on the public transport system by investing in connected bike routes within five kilometres of major centres and public transport interchanges. The strategy commits to expanding bike route connectivity within 10 kilometres of major centres in the longer term. The 'Bike and Ride' initiative would make it convenient for customers to cycle to transport hubs, leave their bikes securely locked up and transfer to public transport to continue their journey.

Sydney's Walking Future complements *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 would ease pressure on public transport, reduce congestion on roads and promote a healthier transport alternative.

As outlined in *Sydney's Cycling Future* and *Sydney's Walking Future*, journeys made by cycling and walking are generally for short trips only, which would not meet the project need of improving existing capacity constraints between the strategic centres across Greater Sydney and the Northern Beaches. For example, it takes about 30 minutes to cycle from Manly Beach to the Spit Bridge at Mosman. Improvements to active transport alone would not cater for the diverse travel demands within the North District that are best met by road infrastructure. Improvements to active transport alone would not be sufficient to support long-term economic growth or enhance the productivity of commercial and freight generating land uses. The active transport network is therefore complementary to other modes of transport as part of an integrated transport solution.

As part of an overarching integrated transport network, the project includes the development of new or improved active transport links in a number of locations, generally associated with surface works for the project. These links would improve connectivity between communities, open space areas, public transport modes and the existing active transport network. This is described in further detail in Chapter 5 (Project description) and Chapter 9 (Operational traffic and transport).

Summary

As detailed in the previous sections, alternative transport modes, including bus, rail, light rail and active transport, could be considered as strategic alternatives to the project. While many of these modes and upgrades are complementary to the project as part of a broader integrated transport network, none would be as effective in providing improvements to journey times and journey time reliability for freight services, public transport and other road users, while improving efficiency and amenity along existing surface road corridors.

The array of journey patterns and trip purposes within Sydney, and the dispersed nature of origin and destination points for an individual journey mean that roads remain a critical element in the integrated transport network, servicing freight, commercial, bus and many other journey needs.

While improvements to the freight rail network would reduce pressure on the core motorway network, Sydney's freight, commercial and services tasks require distribution of goods and services within the Sydney basin, which relies on diverse and dispersed point-to-point transport network that is most efficiently provided by the road network. Providing high-quality motorway links to meet this need is key to growing Sydney's economic prosperity while reducing surface traffic through communities.

Extending the tunnelled motorway network to address capacity, efficiency and reliability issues on critical road corridors would not only provide faster, more efficient and more reliable journeys for users of the network, but would also deliver much broader benefits through reduced congestion on existing local and arterial road networks.

The project would materially improve the functionality and performance of the bus network, providing opportunities for faster and more reliable express bus services to travel via the tunnel and motorway network from the Northern Beaches to strategic centres including North Sydney, the Sydney CBD, Macquarie Park and St Leonards. The design for Beaches Link would also allow for these services to interchange with the new Victoria Cross Metro Station at North Sydney. Furthermore, the use of the Beaches Link tunnel for express bus services would reduce pressure on the Military Road/Spit Road and Warringah Road/Eastern Valley Way bus corridors, allowing for further optimisation of surface services.

The project would improve active transport links through the provision of new and upgraded shared user paths in Artarmon, Balgowlah, Killarney Heights, Seaforth and Frenchs Forest, as well as a number of new shared user underpasses and new shared user and pedestrian bridges which would provide connectivity across the Wakehurst Parkway.

4.3.6 Preferred strategic alternative

When considering the strategic alternatives and complementary projects discussed in previous sections, it was concluded that the construction and operation of a new tunnelled motorway crossing of Middle Harbour (the project) was the preferred solution. This, in combination with the Western Harbour Tunnel, Warringah Freeway Upgrade, and WestConnex network would provide a step-change in transport capacity between the Northern Beaches and strategic centres across Greater Sydney. This would materially improve journey times and journey time reliability for freight services, public transport and other road users on both the new motorway link and bypassed surface routes. Reduced pressure on existing surface routes would also improve the safety, efficiency and amenity of these corridors.

The project is part of a suite of current and future transport initiatives outlined in *Future Transport Strategy 2056* (NSW Government, 2018) that together, would provide the cross-harbour transport capacity required to cater for a diverse array of journeys and future population growth. Further, as discussed in Chapter 3 (Strategic context and project need), a new tunnelled harbour crossing would allow new public transport routes to be developed in response to diverse travel demands and support new social and economic development such as the emerging Northern Beaches Hospital Precinct in Frenchs Forest.

4.4 Corridor alternatives

Following identification of a new tunnelled motorway as the preferred strategic alternative, a design development process was carried out to determine the most appropriate alignment and construction method to deliver the tunnel. This began with consideration of the broad corridors that would best service the road transport demands between the Northern Beaches and strategic centres across Greater Sydney.

The process for selection of the preferred tunnel alignment and construction method included consideration of five strategic corridors and over seven different combinations of tunnelling methods.

Options were developed and assessed by a multidisciplinary team including design engineers, construction engineers, transport planners and environmental advisors with direct experience in delivering major transport infrastructure in NSW, Australia and internationally. Selection of the preferred corridor required consideration of various technical, environmental and community factors including:

- Strategic traffic demands and how they define the required connectivity to achieve transport outcomes
- Physical and operational interfaces with other major infrastructure (eg Sydney Metro, the Warringah Freeway and Northern Beaches Hospital Precinct and associated road upgrades)
- Integration with the proposed Western Harbour Tunnel and Warringah Freeway Upgrade project in the future
- Horizontal alignments and waterway crossing methodologies that allow the tunnel to achieve acceptable vertical gradients to achieve the desired transport product, reduce whole of life emissions, operational costs, and improve safety outcomes
- Surface connections and interchanges that integrate with the arterial road network and connect bus routes and public transport nodes
- Interfaces with commercial and recreational maritime traffic
- Construction and operational efficiencies
- Topography along the alignment
- Potential impacts on local communities including amenity and connectivity
- Results of geotechnical, groundwater and contamination investigations

- Basements and foundations of structures along the routes
- Maritime heritage, biodiversity and marine ecology
- Turbidity and hydrodynamic monitoring and modelling for Middle Harbour.

4.4.1 Description of shortlisted corridor alternatives

Following preliminary technical and environmental analysis, five preferred corridor alternatives were shortlisted for a new tunnelled motorway connection to the Northern Beaches (refer to Table 4-2 and Figure 4-5). The shortlisted corridor alternatives were termed the green, red, purple, pink and blue alternatives.

Table 4-2 Shortlisted corridor alternatives

Corridor alternative	Summary of alternative
Green	• Tunnelled alignment between Burnt Bridge Creek Deviation, Balgowlah and the Gore Hill Freeway, Naremburn – passing beneath Castlecrag • Tunnelled crossing of Middle Harbour between Pickering Point and Sugarloaf Point • Tunnelled ramps to and from the Gore Hill Freeway at Artarmon • Tunnelled ramps to and from the Wakehurst Parkway at Killarney Heights • Wakehurst Parkway upgraded to two lanes in each direction between tunnel connection and Warringah Road interchange, Frenchs Forest • Connectivity: – Signalised connection to and from Burnt Bridge Creek Deviation at Balgowlah – Ramps to and from the Wakehurst Parkway at Killarney Heights – Ramps to and from the Gore Hill Freeway at Artarmon – Ramps to and from the Warringah Freeway at Naremburn.
Red	• Tunnelled alignment broadly following the Military Road/Spit Road corridor • Tunnelled crossing of Middle Harbour located immediately west of Spit Bridge • Connectivity: – Ramps to and from Condamine Street at Manly Vale – Connection to North Sydney and Sydney CBD via signalised intersection at Falcon Street interchange.
Purple	• Tunnelled alignment to the east of the Military Road/Spit Road corridor • Tunnelled crossing of Middle Harbour between Rosherville Reserve and Clontarf • Wakehurst Parkway upgraded to two lanes in each direction between tunnel connection and Warringah Road interchange, Frenchs Forest • Connectivity: – Signalised connection to and from Burnt Bridge Creek Deviation at Balgowlah – Ramps to and from the Wakehurst Parkway at Killarney Heights – Connection to North Sydney and Sydney CBD via signalised interchange at Falcon Street – Tunnelled ramps at Cammeray providing access to and from the Gore Hill Freeway corridor – Underground connections to and from the Western Harbour Tunnel at Neutral

Corridor alternative	Summary of alternative
	Bay/Cammeray.
Pink	• Alignment identified in Strategic Business Case, with surface connection from Burnt Bridge Creek Deviation (with onward tunnel from the Wakehurst Parkway), connecting to a tunnelled alignment broadly following the Military Road/Spit Road corridor • High-level bridge over Middle Harbour east of the existing Spit Bridge • Open trough structure under the Sydney Road/Burnt Bridge Creek Deviation junction • Diamond interchange at the Sydney Road/Burnt Bridge Creek Deviation junction • Tunnelled ramps between Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst parkway at Killarney Heights • The Wakehurst Parkway upgraded to two lanes in each direction between tunnel connection and Warringah Road interchange at Frenchs Forest • Connectivity: – Signalised connection to and from Sydney Road/Burnt Bridge Creek Deviation junction at Balgowlah – Ramps to and from the Wakehurst Parkway at Killarney Heights – Connection to North Sydney and Sydney CBD via signalised interchange at Falcon Street – Tunnelled ramps at Cammeray providing access to and from the Gore Hill Freeway corridor – Tunnelled ramps at North Sydney providing access to and from the Sydney Harbour Bridge – Underground connections to and from the Western Harbour Tunnel at Neutral Bay/Cammeray.
Blue	• Tunnelled alignment between Burnt Bridge Creek Deviation, Balgowlah and the Warringah Freeway at Cammeray – passing beneath Northbridge • Tunnelled crossing of Middle Harbour between Clive Park and Seaforth Bluff • Tunnelled ramps to and from the Gore Hill Freeway at Artarmon and from the Wakehurst Parkway at Killarney Heights • The Wakehurst Parkway upgraded to two lanes in each direction between the tunnel connection and Warringah Road interchange at Frenchs Forest • New access road between Burnt Bridge Creek Deviation and Sydney Road • Connectivity: – Free-flow connection to Burnt Bridge Creek Deviation northbound – signalised connection southbound – Signalised connection to and from Sydney Road (via new access road) – Ramps to and from the Wakehurst Parkway at Killarney Heights – Ramps to and from the Gore Hill Freeway and Reserve Road at Artarmon – Ramps to and from the Warringah Freeway at Cammeray – Underground connections to and from the Western Harbour Tunnel at the Warringah Freeway.

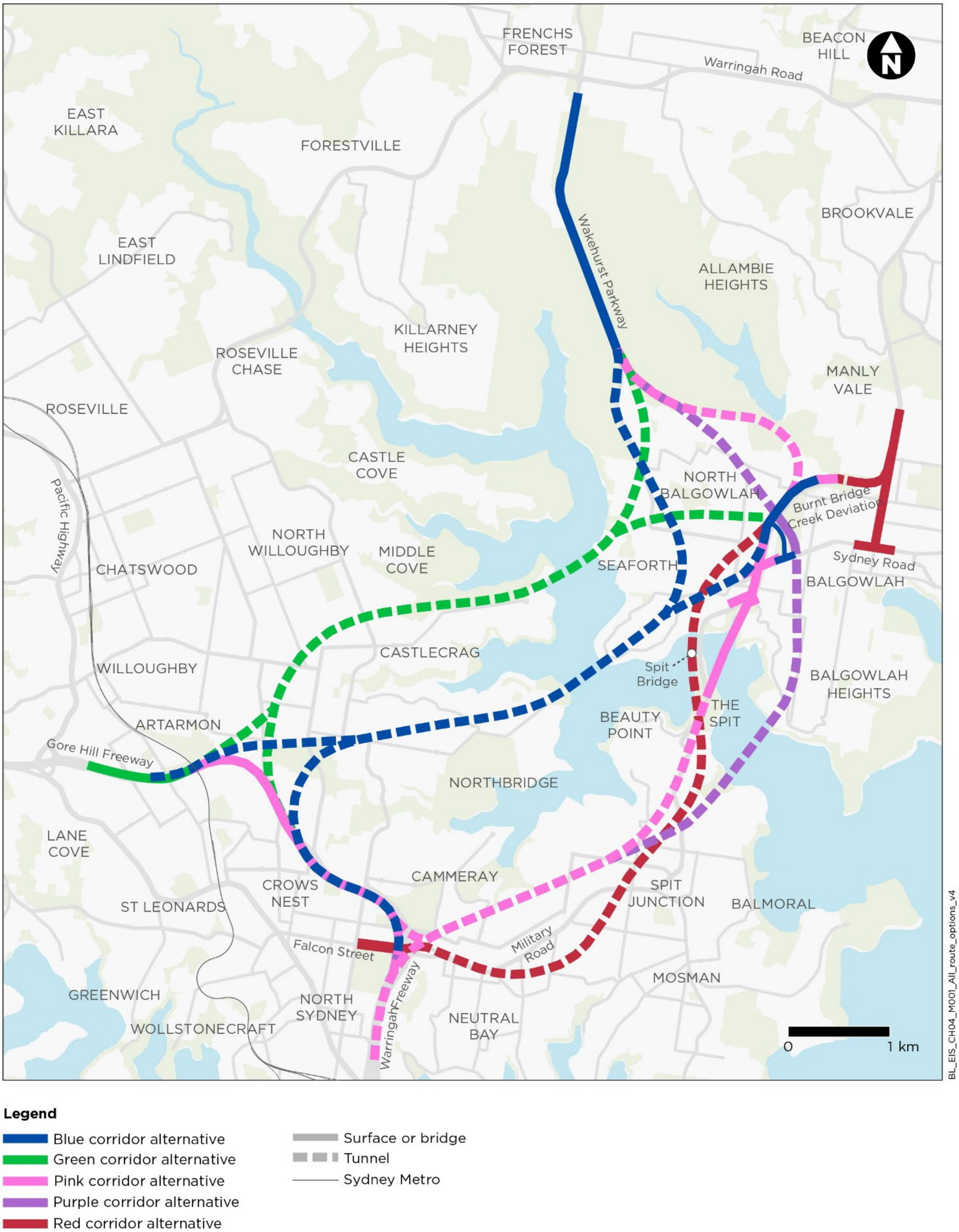


Figure 4-5 Main corridor shortlisted alternatives

4.4.2 Evaluation of corridor alternatives

The five shortlisted corridor alternatives were evaluated by a multidisciplinary team including design engineers, construction engineers, transport planners and environmental advisors to identify the solution that best balanced technical, community and environmental outcomes while meeting the transport objectives. The evaluation criteria used were an expansion of the project objectives with the addition of design and constructability criteria to reflect the more detailed comparison required (Figure 4-6).

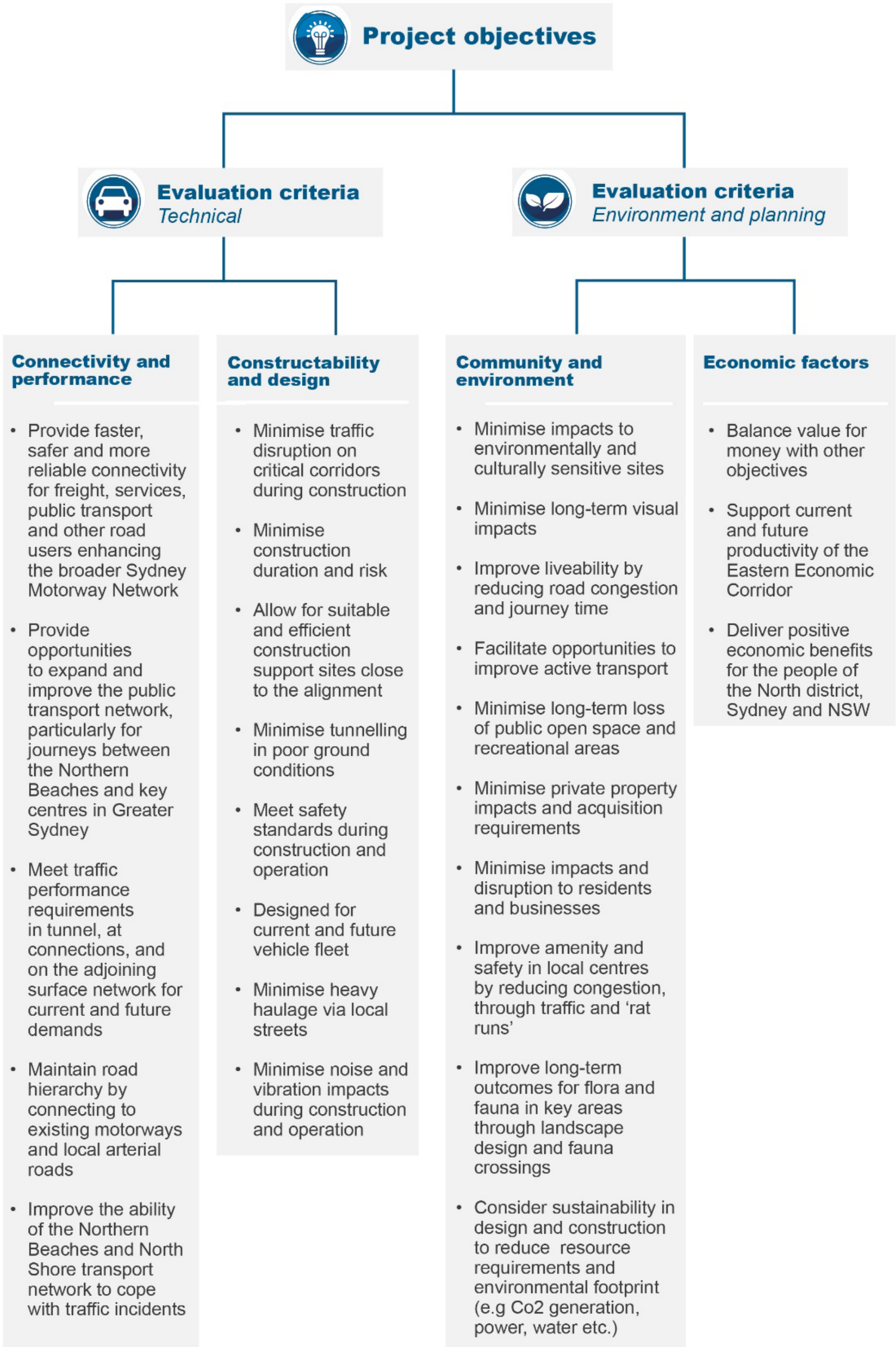


Figure 4-6 Evaluation criteria for corridor alternatives

A summary of the key strengths and weaknesses of each corridor alternative with respect to the evaluation criteria, are shown in Figure 4-7 to Figure 4-13.

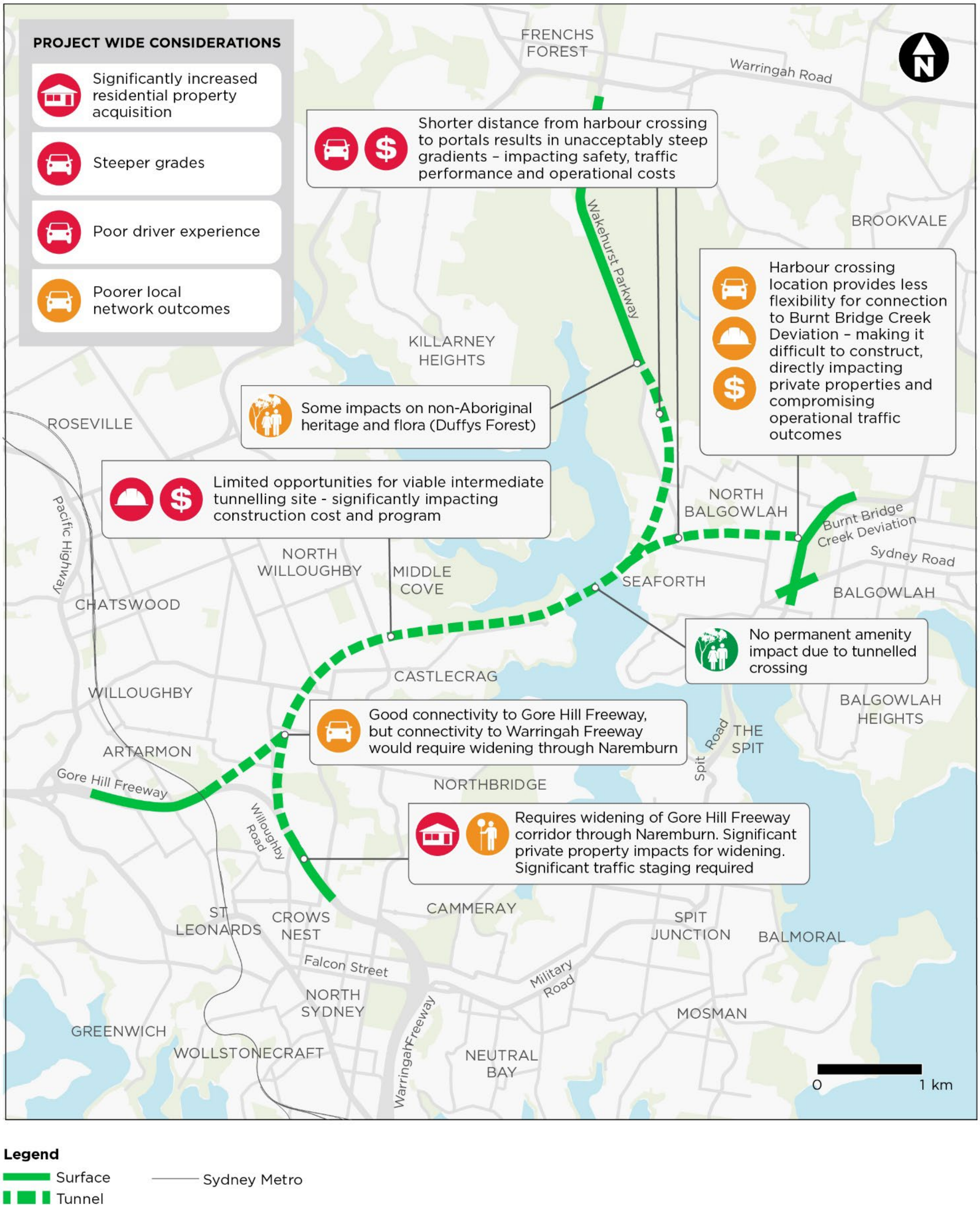
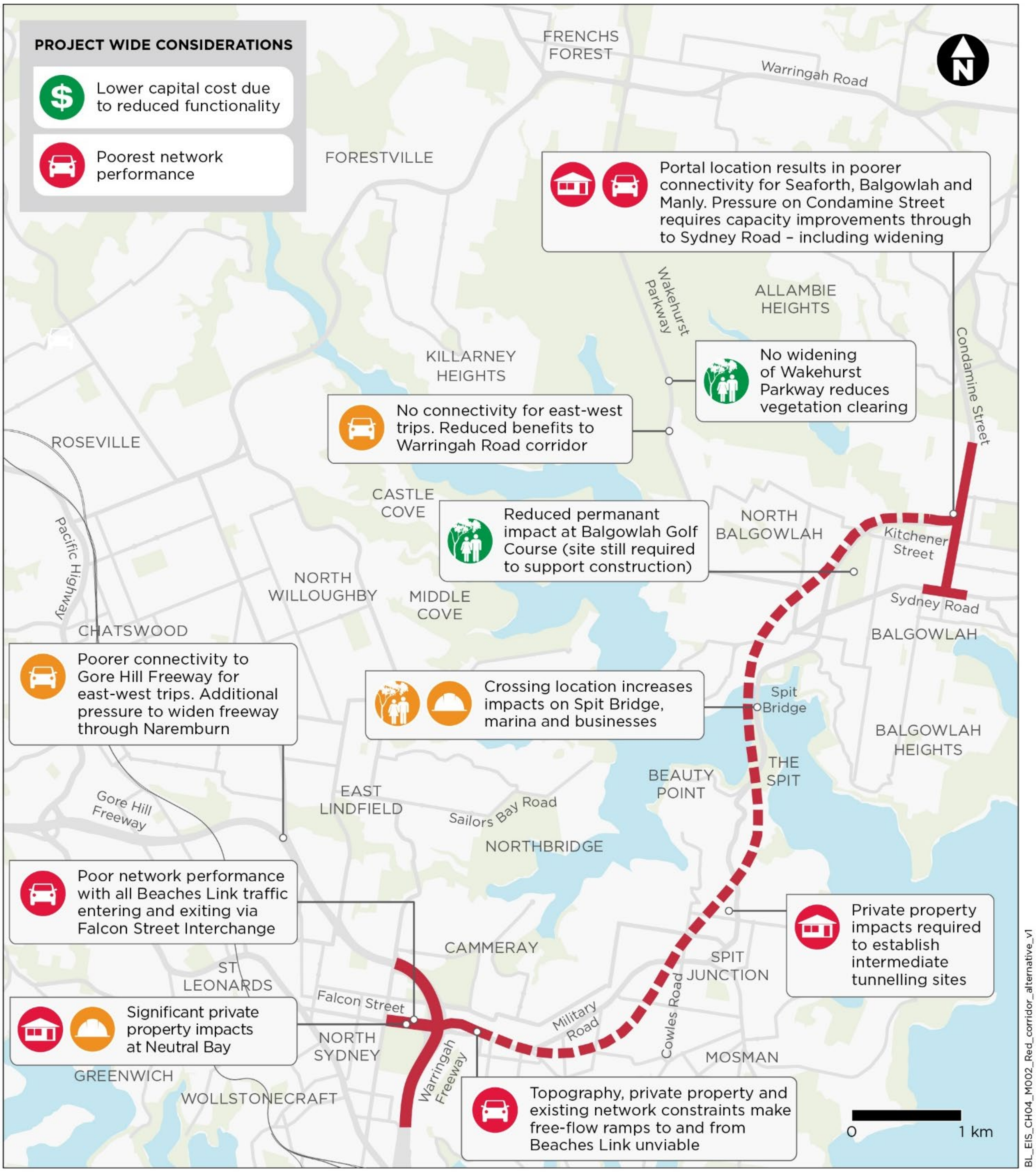


Figure 4-7 Green corridor alternative



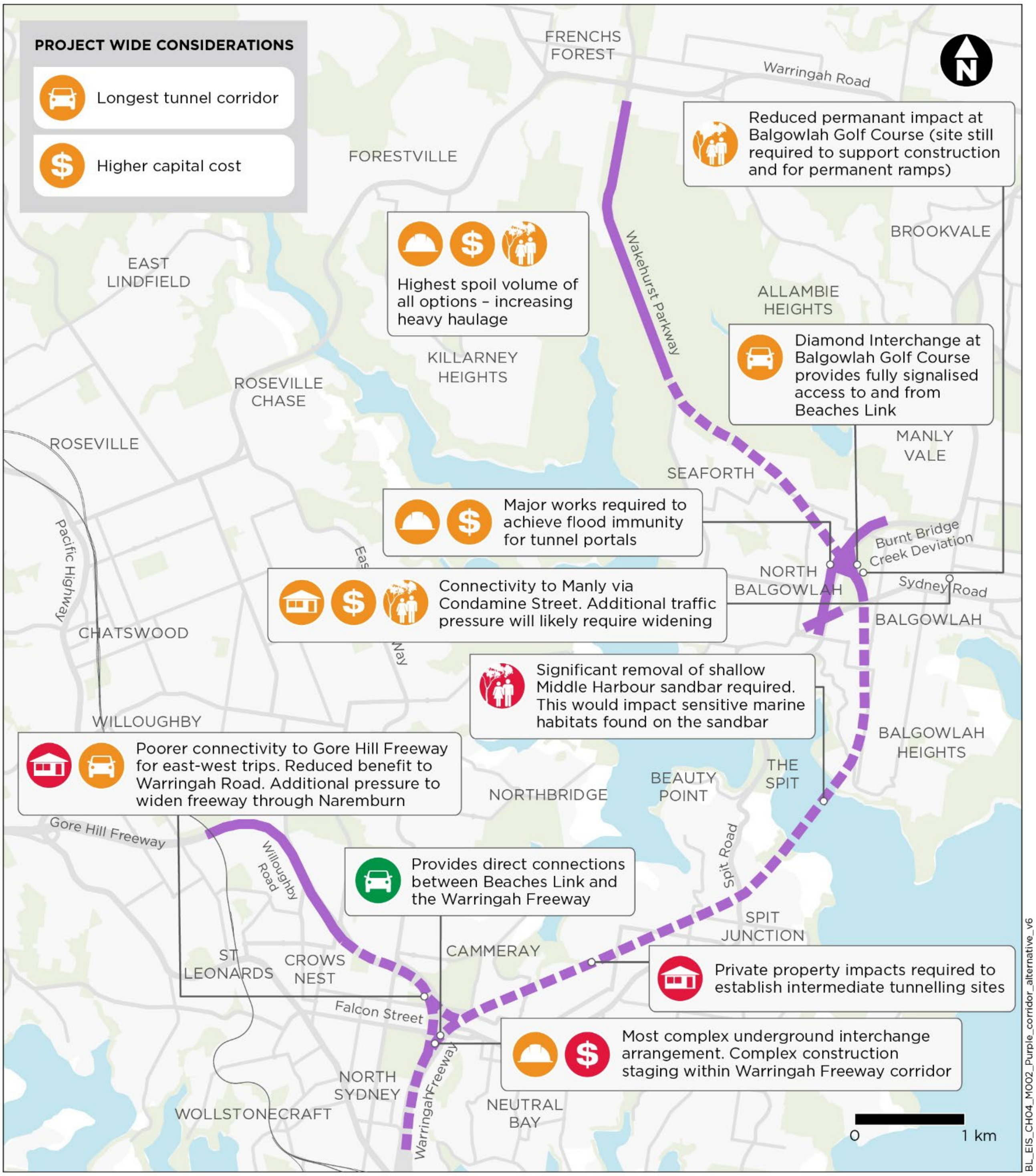
Legend

Surface

Tunnel

Sydney Metro

Figure 4-8 Red corridor alternative



Legend

- Surface
- Tunnel
- Sydney Metro

Figure 4-9 Purple corridor alternative

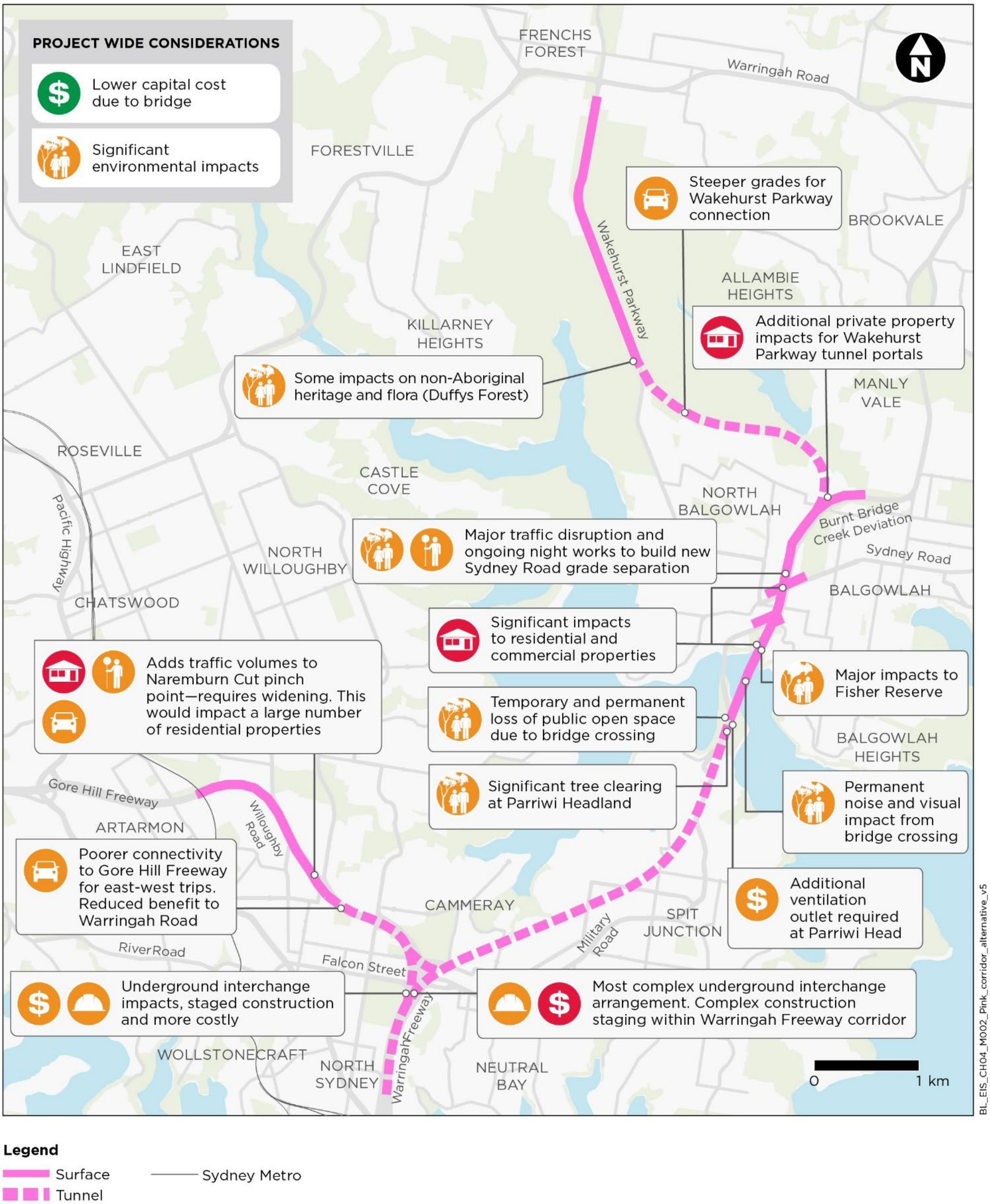


Figure 4-10 Pink corridor alternative

Figure 4-11 Indicative concept design for bridge over Spit Bridge (aerial view) – Pink corridor alternative (image 1)

Figure 4-12 Indicative concept design for bridge over Spit Bridge (aerial view) – Pink corridor alternative (image 2)

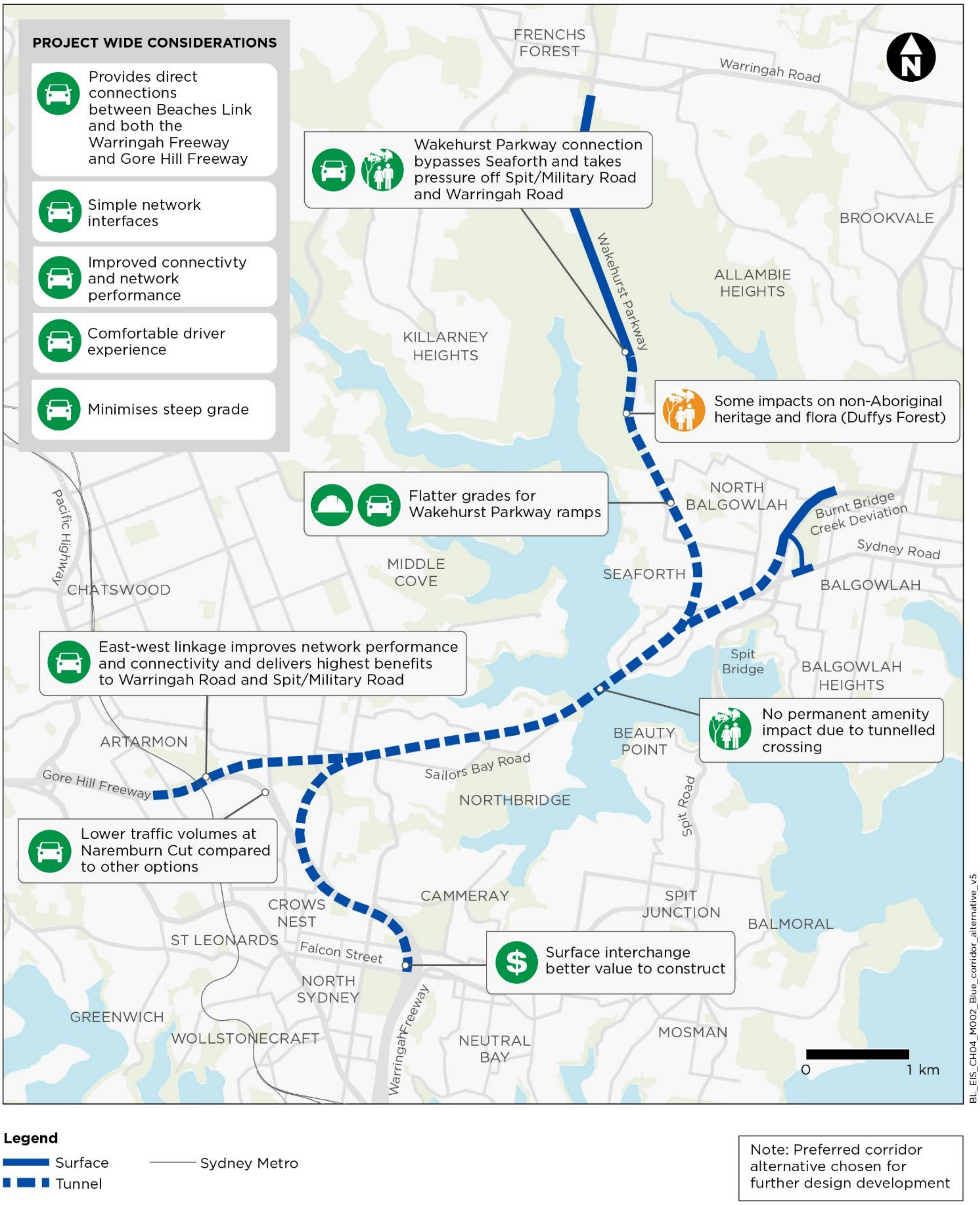


Figure 4-13 Blue corridor alternative

A summary of the evaluation of each of the corridor alternatives is outlined below:

- Green corridor – Not shortlisted on the basis of steep grades required to connect to the Wakehurst Parkway and Burnt Bridge Creek Deviation, impacting journey experience and efficiency of the road and the number of residential properties that would need to be acquired
- Red corridor – Not shortlisted on the basis of unacceptable construction impacts associated with construction method across Middle Harbour, traffic management issues associated with Sydney CBD-bound traffic at Falcon Street and widening of Sydney Road as well as private property impacts
- Purple corridor – Not shortlisted on the basis of having a higher capital cost than the other options without offering additional connectivity or constructability benefits. Also has substantial environmental impacts associated with dredging of the Middle Harbour sandbar that would be required to be traversed
- Pink corridor – Shortlisted for further analysis on the basis of having a lower capital cost to a tunnelled crossing of Middle Harbour
- Blue corridor – Shortlisted for further analysis on the basis of providing strong connectivity and also having lower amenity and environmental impacts compared to the other corridor options, including the pink corridor.

4.4.3 Preferred corridor

Both the pink and blue corridor alternatives provide connections to the Wakehurst Parkway and Burnt Bridge Creek Deviation, providing connectivity for residents and businesses in the north and south of the Northern Beaches peninsula. However, the blue corridor alternative has a number of connectivity and network performance advantages relative to the pink corridor, as outlined in the following sections.

Consistency with project objectives

The blue corridor alternative achieves a greater alignment with transport and city-shaping objectives. This reflects the fact that it delivers more direct east-west connectivity relative to the pink corridor alternative, while also providing strong north-south connectivity. This delivers more congestion relief to arterial roads, such as Warringah Road, and also provides the opportunity for new express bus services for customers travelling between the Northern Beaches and strategic centres such as North Sydney, the Sydney CBD, Macquarie Park and St Leonards.

The superior east-west connectivity means that the blue corridor alternative also performs better with respect to productivity objectives. This is a result of enabling greater access to jobs for residents in the Northern Beaches and associated reductions in the cost of business travel.

Connectivity and network performance

The evaluation of how the blue corridor outperforms the pink corridor in regard to connectivity and network performance is as follows:

- More direct connectivity between the Northern Beaches and strategic centres west of North Sydney, including Macquarie Park and St Leonards through an alignment that enables direct ramps to Lane Cove Tunnel and Reserve Road at Artarmon. Journeys between the Northern Beaches and Lane Cove Tunnel would be four kilometres longer each way via the pink corridor alternative – an extra 40 kilometres or 30 minutes travel each week per bus or car commuter
- Alleviating the requirement to widen the Gore Hill Freeway through the Naremburn Cut – a key pinch point on the motorway network. The pink corridor alternative would require widening of this section of motorway as a result of users travelling between Beaches Link and Lane Cove Tunnel needing to travel through the Naremburn Cut. This widening work would present substantial engineering challenges and related community impacts. The blue corridor alternative diverts about 25,500 vehicles per day from this section of motorway relative to the pink corridor alternative

- Enabling a surface interchange at Warringah Freeway rather than an underground interchange (pink corridor alternative), improving legibility for drivers
- Providing a more direct connection between the Wakehurst Parkway and the mainline carriageways under Seaforth, rather than requiring users of the Wakehurst Parkway to first connect to Burnt Bridge Creek Deviation.

Constructability and engineering

The blue corridor alternative also ranks higher overall with respect to constructability and engineering, particularly given it has a smaller construction footprint at Middle Harbour compared to the pink corridor alternative (ie bridge construction). The pink corridor alternative entails less direct construction with respect to the Middle Harbour crossing, as it is a bridge rather than a tunnelled crossing – notwithstanding that it would require major marine works to construct bridge supports with access by water. Construction of an immersed tube tunnel west of Spit Bridge would require passage of steel shell immersed tube tunnel units across the Middle Harbour sandbar and through Spit Bridge. A constructability assessment carried out for the project indicates this is feasible, based on steel shell immersed tube tunnel units being used with final fit out with reinforced concrete being carried out adjacent to Spit West Reserve.

The blue corridor alternative has a number of constructability advantages relative to the pink corridor alternative, including:

- An alignment further west of the Spit Bridge enabling a connection to the Warringah Freeway that alleviates the need for a complex underground interchange within Western Harbour Tunnel. Removing the need for an underground interchange also facilitates staging of Western Harbour Tunnel and Beaches Link
- A tunnelled crossing of Middle Harbour alleviates the requirement to grade separate Beaches Link and Sydney Road north of the Spit Bridge under live traffic. This would be required as part of the pink corridor alternative to facilitate passage of the motorway between the bridge crossing and Burnt Bridge Creek Deviation
- A tunnelled crossing alleviates the requirement to establish substantial work sites on both sides of Middle Harbour to enable bridge construction as part of the pink corridor alternative. The blue corridor alternative would require a work site at Spit West Reserve; however, work would primarily be carried out from the tunnel portal sites.

With respect to grades, the blue corridor alternative achieves about a four per cent mainline and off ramp grade to Burnt Bridge Creek Deviation. A four percent grade is also required for the off ramp connecting the mainline carriageway and the Wakehurst Parkway. The pink corridor alternative necessitates a higher grade of five per cent for the connection to the Wakehurst Parkway.

Community and environment

In terms of community and environmental considerations, the blue corridor alternative performs better than the pink corridor alternative. Of particular note are the greater residential property, heritage, flora and fauna, public open space and visual amenity impacts associated with the pink corridor alternative compared to the blue corridor alternative. The pink corridor alternative would require bridge infrastructure to be installed in Parriwi Park and Fisher Bay Bushland Reserve. These sites are known to contain Littoral Rainforest in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions, which is listed as endangered under the *Biodiversity Conservation Act 2016* and critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999,* and other threatened ecological communities and flora species.

From a community perspective, the pink corridor alternative introduces a visually dominant bridge structure and associated elevated operational noise source that does not currently exist. The blue corridor alternative does not introduce permanent impacts at these sites.

Property

The pink corridor alternative would permanently impact a large number of residential properties, many of which would require acquisition. Residential properties at Clontarf would need to be acquired to allow for construction of the northern bridge abutment and associated cutting, in addition to residences at Sydney Road within the footprint for the grade separated interchange. The connection with Burnt Bridge Creek Deviation would also require permanent acquisition of some of the land occupied by the Balgowlah Golf Course, along with some nearby residential properties.

The blue corridor alternative would impact fewer residential properties than the pink corridor alternative. Residential properties to the east of Burnt Bridge Creek Deviation would need to be acquired to enable construction of tunnel portal structures for the blue corridor alternative, and Balgowlah Golf Course would be permanently closed. At the Wakehurst Parkway connection, both blue and pink corridor alternatives would impact a number of residential properties, although it should be noted that Transport for NSW owns the affected properties. The blue corridor alternative would also impact 12 apartments adjacent to the Cammeray Golf Course due to widening required to connect the Beaches Link portal to the Warringah Freeway. In designing the project, the aim has been to minimise further property impacts by connecting at one of the widest points on the Warringah Freeway. The blue corridor alternative would also require some commercial properties to be acquired at Artarmon as part of the Gore Hill Freeway Connection.

Capital cost

As part of the optioneering process, strategic estimates were prepared for both alignments. Based on these estimates, the P90 Total Outturn Cost of the pink corridor alternative is estimated to be marginally less expensive than the blue corridor alternative.

The key differences in the underlying cost build up for the pink and blue corridor alternatives are as follows:

- Higher construction cost of a tunnel under Middle Harbour (blue corridor alternative) compared to a bridge (pink corridor alternative)
- Higher property impacts of the bridge option (144 residential properties under the pink corridor alternative compared to 54 under the blue corridor alternative).

Given the substantial property, environmental and amenity impacts associated with the pink corridor alternative, it was determined that a decision between either corridor alternative should not be made on the basis of cost difference.

As such, on the basis of its superior performance in these other areas of consideration, the blue corridor alternative was identified as the preferred corridor to be carried forward for further design development, including refinement of interchange options (refer to Section 4.5).

Summary of key advantages of preferred corridor

Key advantages of the blue corridor alternative include:

- Reduced environmental and amenity impacts:
  - The blue corridor alternative would avoid impacts to the areas around Parriwi Park and Fisher Bay Bushland Reserve, where endangered and threatened species have been recorded. Large areas of vegetation would be required to be cleared at these sites to construct the bridge crossing for the pink corridor alternative, and a sizeable portion of these areas would become part of the permanent motorway corridor
  - The blue corridor alternative would avoid major dredging and piling within the Middle Harbour sandbar, which is one of the most sensitive marine habitat areas within Middle Harbour
  - The blue corridor alternative would avoid permanent visual and noise impacts within Middle Harbour

- The blue corridor alternative would avoid major impacts to heavily utilised areas of Middle Harbour, including areas around The Spit, the Spit Bridge and the Middle Harbour Yacht Club.

- Connectivity and network performance:
  - The blue corridor alternative would result in fewer vehicles relying on the section of the Gore Hill Freeway through Naremburn (known as the Naremburn Cut). This reduces pressure on this constrained section of the existing motorway network, reducing the pressure to widen the corridor in an area where widening would present substantial engineering challenges and associated community impacts. This would result from providing a direct connection between Beaches Link and the Lane Cove Tunnel and Reserve Road at Artarmon, which would avoid the need for east–west journeys between these corridors to travel through the Naremburn Cut
  - Journeys between the Northern Beaches and north-west centres including St Leonards, Chatswood and Macquarie Park would be shorter via the blue corridor alternative compared to all others considered, with the exception of the green corridor alternative, which would be equivalent. This would deliver greater congestion relief to key east-west arterial roads, such as Warringah Road, and would also provide the opportunity for new express bus services for passengers travelling between the Northern Beaches and strategic centres such as North Sydney, Sydney CBD, Macquarie Park and St Leonards
  - With the blue corridor alternative, freight services, public transport, and other road users would save an average of 30 minutes travel time per week for journeys between the Northern Beaches and the lower North Shore when compared to the pink, red and purple alternatives – a large time saving, particularly when extrapolated annually across all users making this journey
  - Journeys between the Northern Beaches and North Sydney, the Sydney CBD and centres to the south and south-west would see considerable improvements delivered by the blue corridor alternative. The challenging topography and highly constrained freeway corridor south of Ernest Street at Cammeray mean that providing non-signalised connectivity to and from the Warringah Freeway is a key challenge for all alignment options, which is achieved by the blue corridor alternative
  - The superior connectivity means that the blue option would also perform best with respect to productivity objectives. This would be a result of enabling greater access to jobs for residents in the Northern Beaches and reducing the cost of business travel.

4.5 Further project development

Following identification of the blue corridor alternative as the preferred corridor for the project, further detailed project development work has been carried out, including:

- Extensive community and stakeholder engagement to identify key local issues to be taken into account in the development of the project (refer to Chapter 7 (Stakeholder and community engagement))
- Detailed environmental and other site investigations along the corridor, including desktop and field investigations to obtain additional data and identify further environmental considerations
- Design development and value engineering of multiple options within the blue corridor alignment to ensure benefits are realised, while reducing costs, program, constructability risks and community and environmental impacts where possible. This process also included consideration of community and stakeholder feedback and the outcomes of environmental and other site investigations.

This project development work included detailed consideration of the following, with further detail on these key issues provided in sections 4.5.1 to 4.5.10:

- Tunnelling methodology, both land-based and the preferred harbour crossing method, including alternatives to reduce the extent of dredging in Middle Harbour
- Location and configuration of the surface connections
- Ventilation alternatives, including the ventilation system design and outlet locations
- Temporary construction support site locations, layouts and alternatives
- Spoil transport, reuse and disposal alternatives.

Other factors considered during design development included:

- Detailed construction staging within the Warringah Freeway corridor to minimise disruption and optimise the corridor for future operations
- Construction staging and work methodologies at all surface connection locations to reduce impacts on surrounding communities, the environment, and the transport network
- Integration with and enhancements to existing public transport infrastructure, particularly along the Warringah Freeway corridor
- Opportunities to integrate with, and enhance, walking and cycling routes
- Utilities impacts and relocation requirements
- Minimising interfaces with heritage items
- The opportunity to improve long-term functionality and amenity at Balgowlah post construction by delivering new and improved open space and recreation facilities (subject to further community consultation)
- The opportunity for additional new and improved open space and recreation facilities would also be supplemented post construction by the re-purposing of residual land from the acquisition of Dudley Street private properties used for the Balgowlah Golf Course construction support site (BL10) and staging of the Balgowlah connection portal.

The development and evaluation of detailed components of the preferred corridor included consideration of options against a localised set of criteria that was consistent with the project objectives. These included connectivity, transport network performance, constructability, design, community, environmental, and economic criteria specific to the scope item and area being considered.

4.5.1 Tunnelling method alternatives

The methods used to deliver tunnels at different locations around the world varies greatly, primarily in response to the geology encountered and the cross-section that is required along the alignment. Roadheaders, tunnel boring machines, immersed tube tunnels, cut and cover tunnels, and the drill and blast methods are all used to deliver tunnels in different conditions around the world.

The process for selection of the preferred tunnel alignment and tunnel construction method for the project included the development and evaluation of over seven different combinations of tunnelling methods.

These options were developed and assessed by a multidisciplinary team of design, constructability, and environmental specialists with direct experience in delivering major tunnels in NSW, Australian and international contexts.

The assessment considered various technical and environmental factors including:

- Strategic traffic demands and how the vertical alignment and gradients might impact connectivity and performance

- Results of geotechnical and groundwater investigations
- Maritime heritage investigations
- Biodiversity and marine ecology surveys
- Lessons from domestic and international tunnelling projects with comparable constraints
- Turbidity and hydrodynamic monitoring and modelling of Middle Harbour
- Opportunities for viable temporary intermediate tunnelling sites that minimise impacts on sensitive vegetation, heritage sites, private property, local communities and the functionality of public open space
- Implications for physical and operational interfaces with other major infrastructure (for example Sydney Metro City & Southwest tunnels, the Northside Storage tunnel, the Western Harbour Tunnel and Warringah Freeway Upgrade project and building foundations in Artarmon and Seaforth)
- Horizontal alignments and waterway crossing methods that allow the tunnel to achieve acceptable vertical gradients to achieve the desired transport product, reduce whole of life emissions, operational costs, and improve safety outcomes
- Interfaces with commercial and recreational maritime stakeholders
- Market engagement, including technical engagement with 14 construction contractors
- Construction and operational costs.

The major change in geology beneath Middle Harbour introduces a constructability challenge that is very different to the alignment north and south of the harbour. Compared to the bedrock either side of the harbour, the rock beneath Middle Harbour is characterised by fracturing and is therefore prone to major water ingress under pressure. Given the depth and pressure, this creates a challenging tunnelling environment. Without suitable mitigation measures, major water ingress issues would be likely to arise during construction using a driven or bored tunnelling method. Accordingly, the following sections discuss the methodologies for the harbour crossing and the tunnels north and south of Middle Harbour separately.

Tunnelling north and south of Middle Harbour

Favourable tunnelling conditions are expected north and south of Middle Harbour, with the majority of the tunnel alignment expected to be constructed in high-quality Hawkesbury Sandstone. These geotechnical conditions typically make the use of roadheaders the most efficient and effective tunnelling methodology for delivery of road tunnels. Notwithstanding this, the challenge introduced by the Middle Harbour crossing also led to the consideration of tunnel boring machine construction methods for these segments. Examples of roadheaders and tunnel boring machines are shown in Figure 4-14.

Roadheaders are made up of rotating cutting heads mounted on a boom or similar structure. They are typically used where the rock being tunnelled through is very sound without being too hard. In these conditions roadheaders can be used to efficiently cut away the rock to form a tailored cross-section to match the exact cross-sectional area of the tunnel, minimising spoil generation and internal structure.

When using the roadheader method, multiple roadheaders are typically deployed via intermediate construction support sites along the alignment. This allows the tunnel to be constructed from multiple fronts, typically providing substantially reduced construction durations when compared to tunnelling from a single site.

The roadheader tunnelling method has been the preferred construction technique for all major motorway tunnels in Sydney, with the exception being the existing Sydney Harbour Tunnel, which was delivered mainly using the immersed tube tunnel technique and limited driven tunnelling on the northern approach to the immersed tube tunnel. The favourable Hawkesbury Sandstone geology combined with the requirement for a wide but short cross-section are the key variables that have combined to make roadheaders the most efficient and cost effective method for delivering motorway tunnels in Sydney.

Tunnel boring machines are much larger than roadheaders, and use a circular rotating cutting head that houses many individual cutting tools. Due to the circular cutting head, tunnel boring machines excavate and produce a circular tunnel cross-sectional area.

To allow for tunnelling in many different types of geology, there are many different types of tunnel boring machines. With no one type of machine ideally suited to tunnelling through both rock and soft ground, major changes in geology, such as the transition to the soft sediments found beneath Middle Harbour, or the highly fractured rock below this, would require a different type of tunnel boring machine to the landside tunnels being constructed through Hawkesbury Sandstone.

This is best demonstrated by the construction method adopted for construction of the new Sydney Metro crossing of Sydney Harbour, where the poor geology under Sydney Harbour required a different type of tunnel boring machine to the landside tunnels. Accordingly, the Sydney Metro City & Southwest project used five tunnel boring machines – two north and two south of the harbour to complete tunnelling through rock, with one specialised machine for the crossing of Sydney Harbour. This required the establishment of large shafts at Barangaroo and Blues Point either side of Sydney Harbour to launch, retrieve and support the tunnel boring machine for the harbour crossing.

Figure 4-14 Examples of a roadheader (left) and tunnel boring machine (right)

At about seven metres in diameter, the tunnel cross-section required to deliver a metro rail tunnel is well suited to a small diameter tunnel boring machine. In contrast, at 15.5 metres wide, a modern three lane motorway tunnel requires a wide, but stout cross-section. This does not fit very efficiently into a circular cross-section, meaning that delivering a motorway with a tunnel boring machine requires considerably larger machines than employed on metro rail projects. This means that the tunnel boring machine required to deliver each Beaches Link tunnel would have an area five times that of a machine used to construct the Sydney Metro City & Southwest tunnels.

The indicative cross-sections of the Beaches Link tunnel if roadheaders or tunnel boring machines are used are shown in Figure 4-15. This diagram demonstrates that the cross-section required for a modern motorway does not fit efficiently within the circular cross-section provided by a tunnel boring machine. This geometric challenge creates several practical obstacles to the deployment of tunnel boring machines for the Beaches Link tunnel:

- Large increase in spoil generation, increasing heavy haulage
- Increased structural costs, as the pavement level within the tunnel needs to be raised to the widest point in the cross-section
- Tunnel boring machines 16 metres in diameter and larger are not a common tunnelling solution, increasing construction cost and risk
- Tunnel boring machines are typically not preferred where there are multiple major changes in cross-section or geology. These occur at several locations along the Beaches Link alignment.

This means that roadheaders would still be required to build access tunnels from intermediate sites to construct the caverns where ramps merge and diverge from the tunnels under Northbridge and Seaforth, and at either side of the harbour crossing.

When considering the above, roadheaders emerge as the preferred tunnelling methodology for all tunnelling north and south of the Middle Harbour crossing.

Options to build multi-level roadways within a single cross-section were also considered (for example two lanes above two lanes), but these would require tunnel boring machines with even larger diameters.

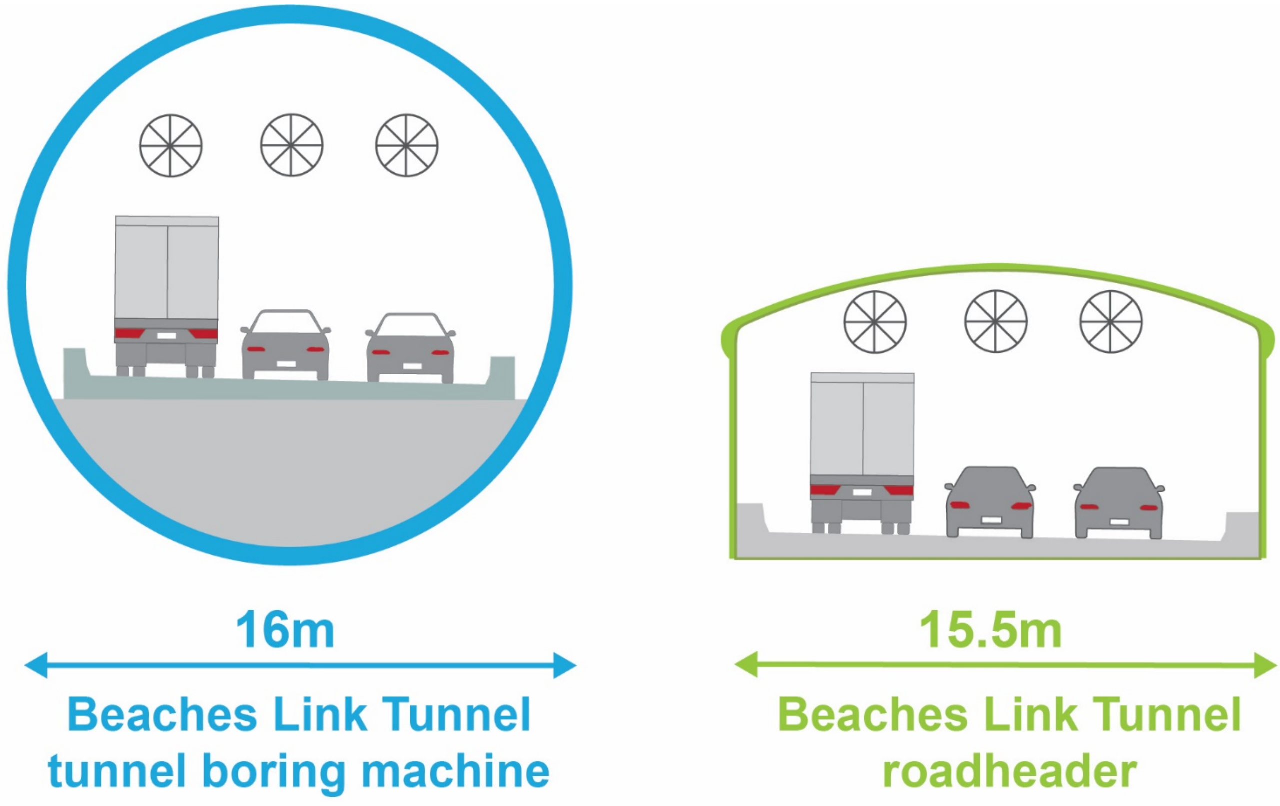


Figure 4-15 Comparison of tunnel cross-sections using a tunnel boring machine and a roadheader

A comparative evaluation of alternative tunnelling methods for tunnelling north and south of Middle Harbour is summarised in Table 4-3.

Table 4-3 Alternative tunnelling methods

Method	Summary of evaluation
Roadheader (preferred method)	**Advantages:** • The technology required is well understood and has been proven to be most efficient and cost-effective for motorways in Sydney's geological conditions • All major motorway tunnels in Sydney to date have been built successfully by roadheader (excluding the Sydney Harbour Tunnel) • Reduced construction risk relative to using a tunnel boring machine for a three lane road tunnel (further details below) • Ability to cut an exact cross-section reduces infrastructure or fill

Method	Summary of evaluation
	required within the tunnel to achieve desired road level • Substantially lower spoil volumes and heavy vehicle movements relative to using a tunnel boring machine • Machines are relatively inexpensive and readily available in the Sydney market • Roadheaders can generally be deployed much faster than tunnel boring machines, due to shorter procurement, establishment and commissioning times. **Disadvantages:** • Tunnelling rate of roadheaders is less than tunnel boring machines when both reach peak production • Depending on the length of tunnel, roadheaders may require intermediate surface construction and access sites.
Tunnel boring machine	**Advantages:** • If the geology and cross-section are consistent, tunnel boring machines can usually construct much longer tunnels with fewer intermediate surface access points • Provides for faster excavation rates than roadheaders when the machine is ideally matched to the project geology and major changes in cross-section or geology along the tunnel are minimised • Provides safer tunnelling conditions in poor ground conditions when compared to roadheaders. **Disadvantages:** • Require larger tunnelling and access sites than roadheaders • Tunnel boring machines are considerably more expensive to procure and operate than roadheaders • The timeframe for procuring, commissioning and launching tunnel boring machines would be much longer than for roadheaders • A three lane motorway cross-section would require tunnel boring machines about 16 metres in diameter. These would be within the top five largest globally. Given that mega diameter machines are uncommon, machines of such size are likely to pose considerably more construction risk than a roadheader solution • Being a circular excavation, tunnel boring machines require much greater over-excavation compared to roadheader construction. This results in substantially increased spoil volumes for the rock tunnelling and associated heavy vehicle hauling or barging and disposal, as well as a need to backfill within the tunnel to build the road level back up • Tunnel boring machines require long stretches of tunnel to outperform roadheaders on a cost and production basis. The maximum drive length for the Beaches Link tunnel would be two kilometres; therefore, there would be minimal efficiencies from using tunnel boring machines • Roadheaders and intermediate sites would still be required to excavate caverns and ramp connections ahead of tunnel boring machine arrival, as tunnel boring machines cannot accommodate these changes in cross-section • Major intermediate sites would be required at the northern and

Method	Summary of evaluation
	southern shorelines of Middle Harbour to retrieve landside machines and launch specialised machines if the project was to select tunnel boring machines that are matched to geology. The sites would need to be large to accommodate tunnel boring machines of the size and type required.

Middle Harbour crossing

While the majority of the tunnelling for the project is expected to be constructed through high-quality Hawkesbury Sandstone, the portion of tunnel crossing Middle Harbour presents particular challenges. These include:

- **Large changes in elevation:** Middle Harbour is a trench formed in bedrock, at its deepest being 60 metres below the water surface and 30 metres below the deepest rock level of the bed of the harbour. The bedrock is covered by up to 30 metres of clay, cobbles and silty sands. The tunnel would rise about 145 metres in elevation to connect from 30 metres below Middle Harbour with the Wakehurst Parkway at 115 metres in elevation. Considering the elevation change between the rock level under the bed of the harbour and the surface road connections at Cammeray, Artarmon, Balgowlah and Killarney Heights, it becomes apparent that the vertical grade of the proposed tunnel would be a key challenge – with gradient having implications for long-term operations of the tunnel in terms of safety and generation of emissions). A tunnel boring machine would be required to travel deep under Middle Harbour and travel underground for a long distance, producing steep tunnel gradients. This would present implications for safety and emission generation
- **Poor geology and rock fracturing at the harbour crossing:** Geotechnical testing has been conducted for the proposed harbour crossing. Unlike the bedrock either side of the harbour, the rock beneath the bed of the harbour is generally highly fractured. Without mitigation measures like forward probing and pre-grouting, this fracture zone is likely to cause major water ingress issues during construction using a driven or bored tunnelling method. This was observed during construction of the Northside Storage Tunnel beneath Middle Harbour in the late 1990s using a tunnel boring machine. These water ingress issues are normally controlled and managed through pre-grouting ahead of tunnelling operations where required and installing appropriate waterproof linings following tunnel excavation. Despite utilising forward grouting on the Northside Storage Tunnel project, the project encountered considerable water ingress during construction due to cracking of grout from initial rock relaxation along with substantial water pressures at depth. Utilisation of this knowledge would allow for a specialist tunnel boring machine to be designed to accommodate this risk in the future. Above the layer of fractured rock are layers ranging from stiff clay through to sand and sediment. Depending on the vertical alignment of the tunnels, they may need to be constructed through rock, through sediment, or a combination of these. Generally tunnelling through sediment is undesirable as it is prone to instability. However, high-quality Hawkesbury Sandstone is very deep beneath the harbour, giving rise to the need to balance between the preference to tunnel through rock and the gradient of the tunnels – with the gradient of the tunnels affecting traffic performance, emission generation, ventilation design, and long-term operational costs for the tunnels
- **Limited intermediate sites:** For most of its alignment, the proposed Beaches Link tunnels would pass beneath the suburbs of Willoughby, Naremburn, Northbridge, Seaforth and Balgowlah, which are characterised by highly urbanised areas with narrow streets. This presents a sizeable challenge to the establishment of viable intermediate tunnelling sites as these would likely require acquisition of a large number of private properties and/or unacceptable haulage routes via narrow local streets. This is a particular challenge when considering the scale of sites required to support large diameter slurry shield or tunnel boring machines for the harbour crossing. Furthermore, the topography means that the Beaches Link tunnels would generally be very deep, meaning that very deep shafts would be required to provide access at intermediate sites. Given the depth of the tunnels, establishment of

intermediate shafts near the harbour would take a long time to construct, and would be very inefficient points for construction access and egress

- **Cross-section:** The cross-section required for a modern three lane motorway crossing of Middle Harbour is about 15.5 metres wide. Given the poor geology (refer to Figure 4-16), this creates a considerable challenge for tunnel boring machines or roadheaders. If using a tunnel boring machine, this would require one of the largest machines of its type ever used in the world – substantially increasing construction cost, engineering and safety risk.

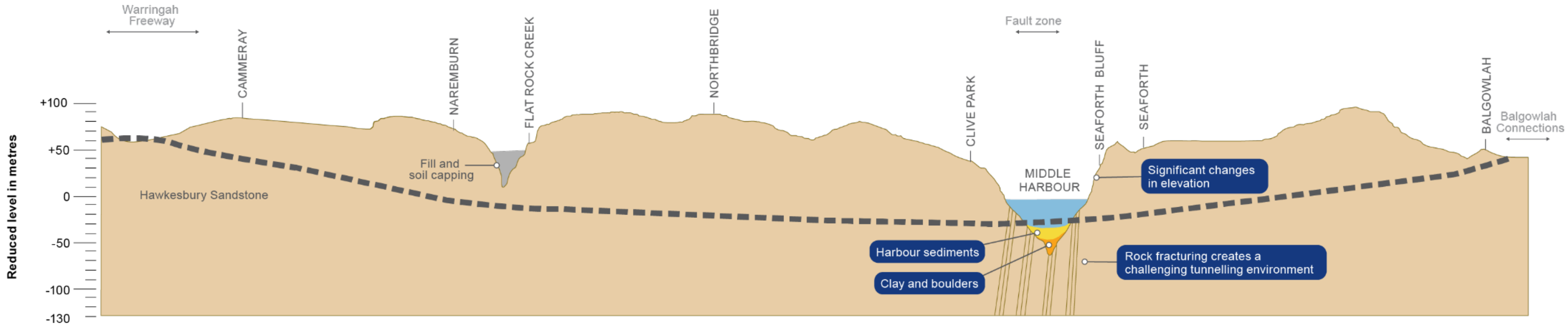


Figure 4-16 Indicative vertical alignment of the mainline and ramp tunnel

Design development for the project included a strong focus on evaluation of potential tunnelling methods for the crossing of Middle Harbour. This analysis was carried out by a multidisciplinary team including design, construction, transport planning, and environmental specialists to ensure a comprehensive analysis. It included the consideration of the roadheader method, specialised slurry shield tunnel boring machines, and an immersed tube tunnel (similar to the existing Sydney Harbour Tunnel).

Roadheader options for the Middle Harbour tunnel crossing were discounted early in the process for the following reasons:

- The tunnel depth required to deliver this method beneath Middle Harbour would compromise the gradients of the mainline tunnel, affecting traffic performance, emissions generation, and construction and operational costs
- The highly fractured geology beneath Middle Harbour, which creates a risk of major water ingress during construction if using the roadheader method.

Although tunnel boring machines are a viable alternative, the diameter and type of machines required for the crossing of Middle Harbour cannot be considered a conventional solution. Depending on the depth of the alignment, the tunnel boring machines required to cross Middle Harbour would need to be very large diameter slurry shield machines, as shown in Figure 4-17.

Slurry shield tunnel boring machines use clay slurry and compressed air to carefully control the pressure at the tunnelling face. This is required to maintain stability ahead of construction of the permanent concrete lining when tunnelling through poor ground conditions, such as those expected beneath Middle Harbour. The pressure at the tunnelling face needs to be carefully controlled as the machine advances to respond to the ground conditions as they vary.

These are highly sophisticated and specialised machines, and have rarely been used for sub-sea tunnelling at the diameter that would be required for the project. Slurry shield tunnel boring machines also require large landside sites, likely needing additional land acquisitions to accommodate these additional facilities which are not required for roadheader tunnelling:

- Segment production and storage
- Clay slurry production and processing.

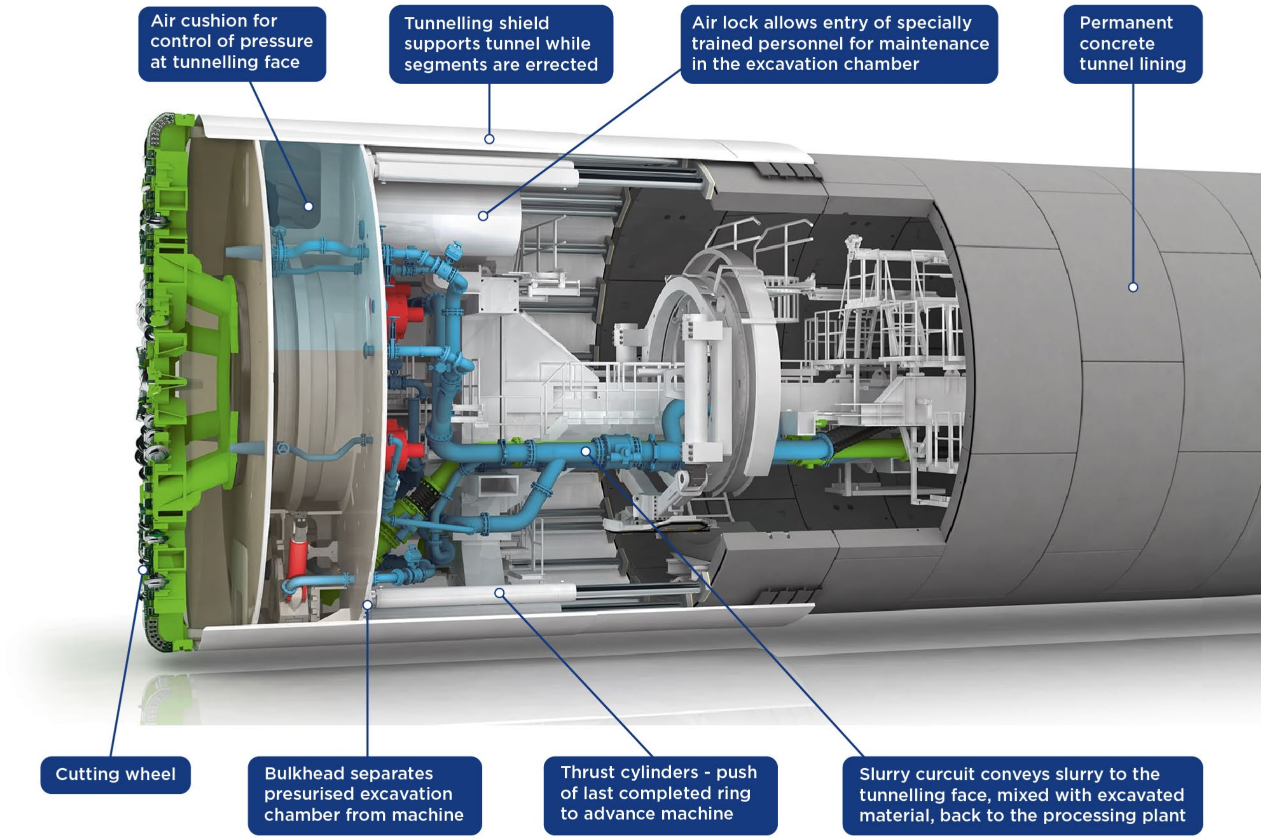


Figure 4-17 Example of a slurry shield tunnel boring machine

An alternative to tunnelling through rock or sediment using roadheaders or tunnel boring machines would be to place precast tunnel units on top, or within, the top layers of harbour rock and sediments. This method is known as an immersed tube tunnel and has been applied to over 150 major road and rail tunnels around the world to overcome similar combinations of geology, topography and cross-sectional challenges, including the existing Sydney Harbour Tunnel.

This alternative would involve excavation of the bed of the harbour and placement of immersed tube tunnel units within the excavated trench of varying depth as shown in Figure 4-18.

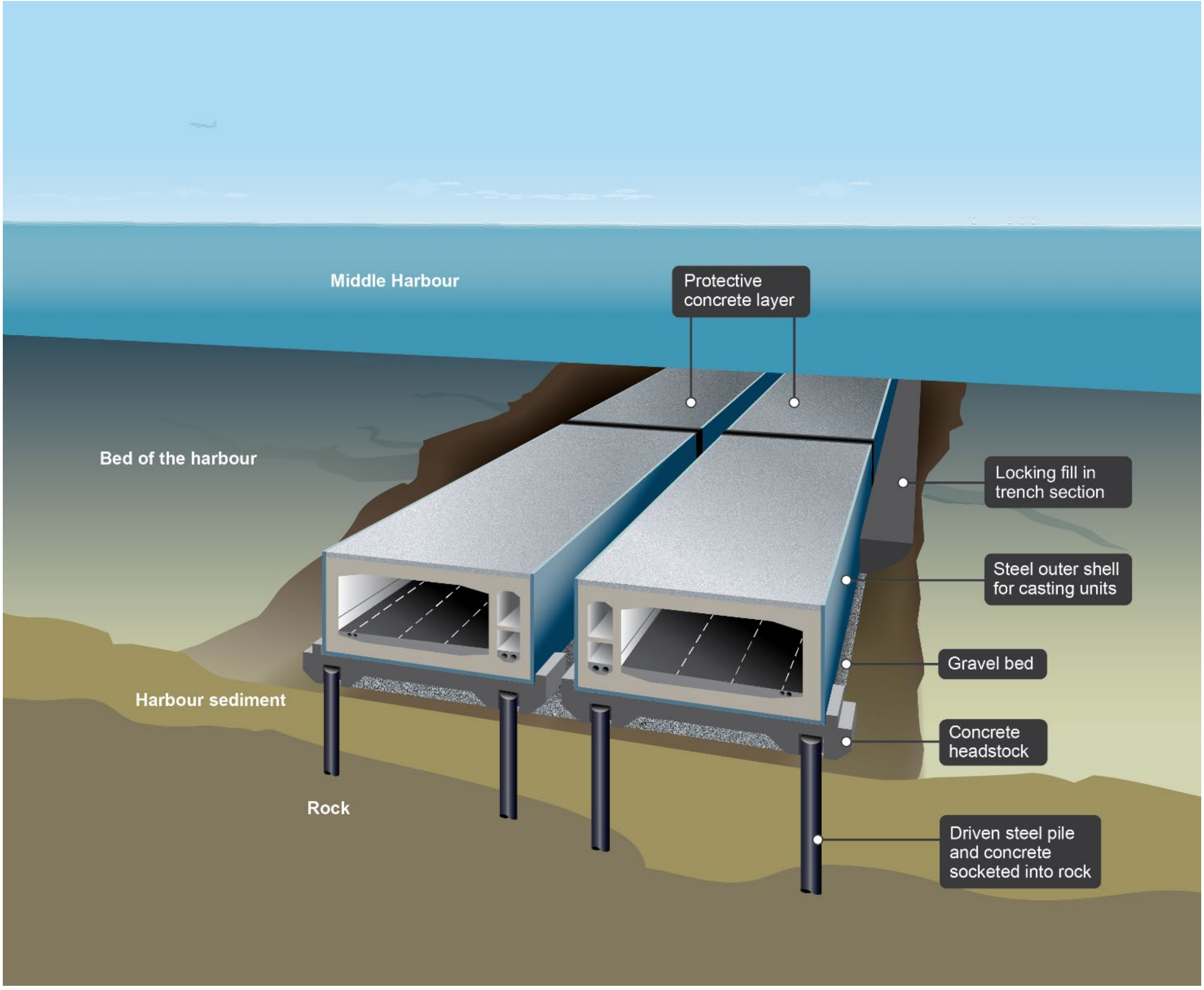


Figure 4-18 Example of an immersed tube tunnel

Figure 4-19 shows the four main options considered for the vertical alignment of the Middle Harbour tunnels:

- A deep driven roadheader tunnel, completely within rock (green)
- A shallower tunnel boring machine tunnel, with parts of the tunnel in softer, weathered rock or sediment (blue and purple)
- An immersed tube tunnel lying on top, or within the top layers, of softer, weathered rock and sediments (grey).

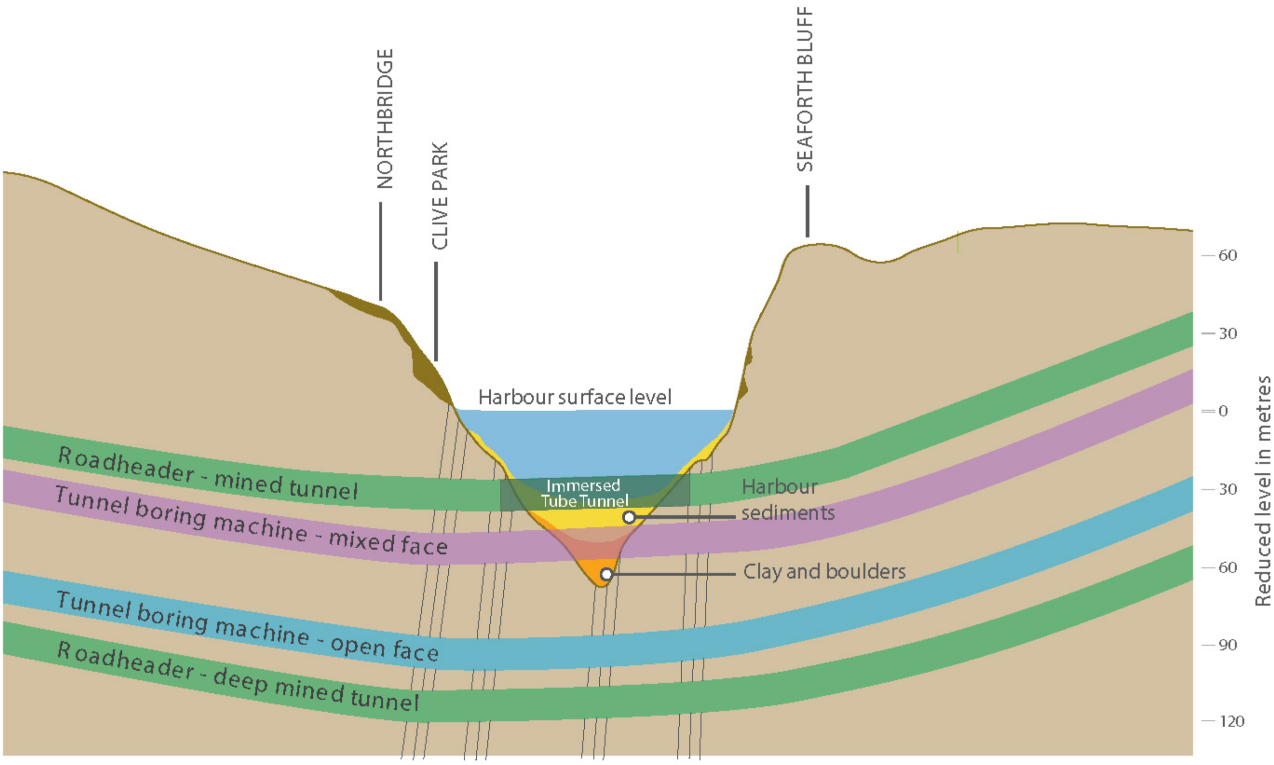


Figure 4-19 Main vertical alignment options for the Middle Harbour tunnels

When considering the performance of each of the potential methodologies against design, constructability, traffic performance, environmental and social criteria, the preferred method for crossing Middle Harbour is via an immersed tube tunnel. The justification for selecting this alternative is summarised in Table 4-4.

Table 4-4 Preferred tunnelling method for the Middle Harbour crossing

Method	Summary of evaluation
Immersed tube tunnel	**Advantages:** • The technology required is proven, having been used on major contemporary infrastructure projects around the world, including the Sydney Harbour Tunnel • Provides the shallowest possible tunnel alignment at the Middle Harbour crossing enabling the best possible gradient and associated performance outcomes (eg safety, vehicle speeds, journey experience, long-term emissions) • Minimises tunnelling risks by reducing exposure to tunnelling through poor geology and reducing the time workers need to spend in high risk tunnelling environments • Lower construction and operational costs when compared to alternative methodologies • Minimises the size of waterside sites when compared to those required to launch, support, and retrieve large diameter tunnel boring machines • Substantially reduces haulage on land when compared to tunnel boring machine solutions • Takes advantage of marine logistics to minimise heavy haulage on roads • The preferred alignment avoids interfaces with substantial sensitive marine ecology at the sand bar at the entrance to Middle Harbour (immersed tube tunnel proposed for the purple corridor alternative). **Disadvantages:**

Method	Summary of evaluation
	• Requires measures to be implemented to prevent migration of material during excavation of sediments, particularly areas with elevated levels of contaminants within the surface layer (about 0.5 metres to one metre) of the bed of Middle Harbour • Interfaces with commercial and recreational maritime traffic during construction.

4.5.2 Warringah Freeway connection alternatives

The Warringah Freeway connection would provide connectivity between Beaches Link, the Western Harbour Tunnel and Gore Hill Freeway. Initially, considerations of possible alternatives for such a connection included an underground interchange option as well as a contemporary surface interchange. Ultimately, the underground interchange was found to be incompatible with the preferred corridor alternative (blue corridor alternative), while also being considered to be cost prohibitive. The underground interchange would require the reconfiguration of the Warringah Freeway corridor for surface infrastructure and portals, given the increase in vehicles that would use the corridor, and some form of connection to the surface for vehicles leaving the Beaches Link tunnel.

As such, a surface connection in the form of a surface interchange, was considered the preferred connection alternative for linking the Beaches Link and Warringah Freeway. However, there were severe limitations for the location for a surface interchange, given the intense land use in the surrounding area and the resulting environmental and community impacts, including property acquisition. Therefore, the preferred alternative for the Warringah Freeway connection has been developed to remain primarily within the existing road corridor.

With this in mind, the consideration of alternatives for the surface connection of Beaches Link and Warringah Freeway included:

- Locations and configurations of ramp connections to and from the Warringah Freeway
- Connections between the Beaches Link and the Western Harbour Tunnel, North Sydney and, more broadly, the Sydney Harbour Bridge (cut and cover or mined-tunnel solutions)
- Minimising environmental, community and property impacts.

Informed by these considerations, it was determined that the preferred connection alternative for the Warringah Freeway would be that the Beaches Link tunnel portals would be located south of the Miller Street overpass within the road corridor. This location would take advantage of the wide road corridor and more sympathetic topography compared to road corridor availability and topography for tunnel portal locations south of Ernest Street. The tunnel portal locations would also enable many of the proposed road connections to largely occur aboveground, thereby avoiding more underground caverns and tunnels. The location would require utilisation of some land currently used by Cammeray Golf Course in order to achieve the optimal staging of the surface connection.

The surface connection would also integrate with the Western Harbour Tunnel and Warringah Freeway Upgrade project, ensuring that the location and extent of ramp connections and portals, as well as the preferred construction methodology, could be optimised between the projects, reducing disruption as much as possible.

4.5.3 Gore Hill Freeway Connection alternatives

The Gore Hill Freeway Connection would provide the strategic east–west link for movements between the Northern Beaches and strategic centres accessed via the Gore Hill Freeway/Lane Cove Tunnel and Reserve Road at Artarmon, including Macquarie Park and St Leonards. Three alternatives have been considered for this connection as shown in Figure 4-20.

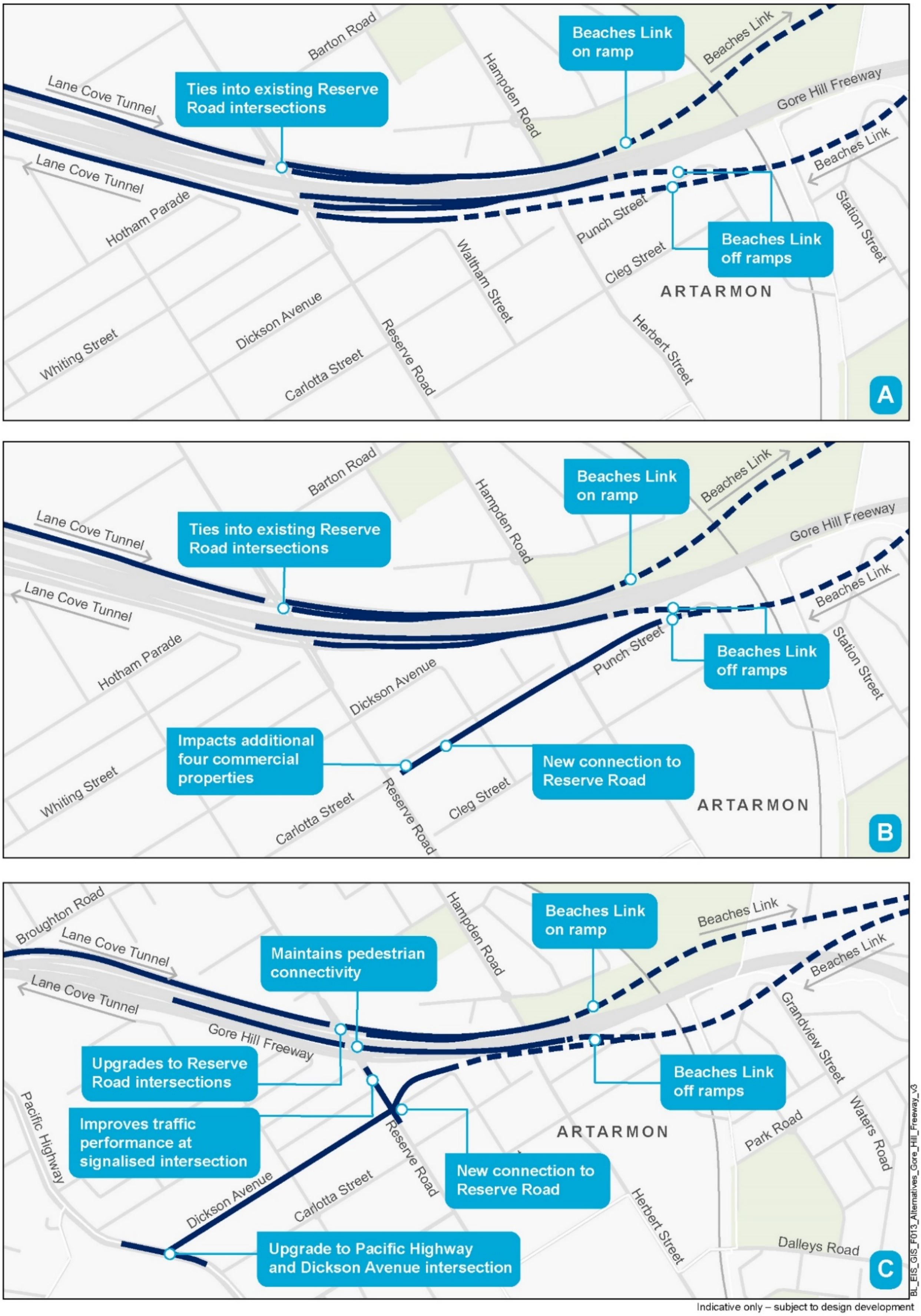


Figure 4-20 Alternatives considered for the Gore Hill Freeway Connection

An overview of the justification for selecting option C (refer to Figure 4-20) as the preferred connection alternative is summarised in Table 4-5.

Table 4-5 Summary of evaluation of Gore Hill Freeway Connection preferred alternative

Evaluation criteria	Reason for preferred alternative (option C)
Connectivity and network performance	• Provides connectivity between Beaches Link and the Gore Hill Freeway/Lane Cove Tunnel, supporting the strategic east–west connectivity to and from the Northern Beaches • Provides connectivity between Beaches Link and Reserve Road, enabling convenient access to and from the Artarmon industrial area, employment centres such as St Leonards and Chatswood, and Royal North Shore Hospital precinct. The direct motorway standard link between Royal North Shore Hospital and the Northern Beaches Hospital Precinct would be an important benefit of Beaches Link • Provides connectivity to Chatswood via Dickson Avenue and the Pacific Highway • Reduces pressure on the Reserve Road interchange compared to options that introduce westbound off ramps into this node.
Constructability and design	• Reduces impacts on the Gore Hill Freeway and Lane Cove Tunnel during construction, given the works would be on both the inside and outside of the existing corridor • Challenges largely relate to the construction of the works under Hampden Road and adjacent to live traffic on the Gore Hill Freeway • Probable maximum flood immunity achieved.
Community and environment	• Minimises impacts on bushland to the north • Minimises impacts to private property, notably residential property acquisition requirements • Major construction sites located to the south of the Gore Hill Freeway in the Artarmon industrial area – reducing exposure to residential receivers.

4.5.4 Wakehurst Parkway connection alternatives

Following the unveiling of the *County of Cumberland Planning Scheme* (1948), it was proposed that the Wakehurst Parkway become the main road between the Sydney CBD and the Northern Beaches via a Warringah Freeway extension to Seaforth. The Wakehurst Parkway's intended function as a motorway receiver is reflected in the fact that it is an arterial, limited access road with an 80 km/h posted speed and is located within a road reservation that is about 80 metres wide. The current Wakehurst Parkway corridor is a key arterial road link for the northern and western areas of the Northern Beaches, including Frenchs Forest, Narrabeen and Mona Vale. However, its current utility is diminished by its southern terminus, which links through the Seaforth town centre before connecting to Manly Road/Spit Road/Military Road.

New tunnelled connections to and from the Wakehurst Parkway would provide a strategic link between the Northern Beaches Hospital Precinct and centres in the upper Northern Beaches, and key centres across Greater Sydney. This would greatly improve connectivity for the northern areas of the Northern Beaches and assist in reducing demand for the Warringah Road, Roseville Bridge and Eastern Valley Way corridors.

A range of alternatives have been considered for this connection, including the location of the tunnel portals along the Wakehurst Parkway. Three alternative locations (portal location option A, portal location option B and portal location option C) were considered, as shown in Figure 4-21.

All portal location alternatives were located within the Wakehurst Parkway road corridor, which is much wider than the current road.

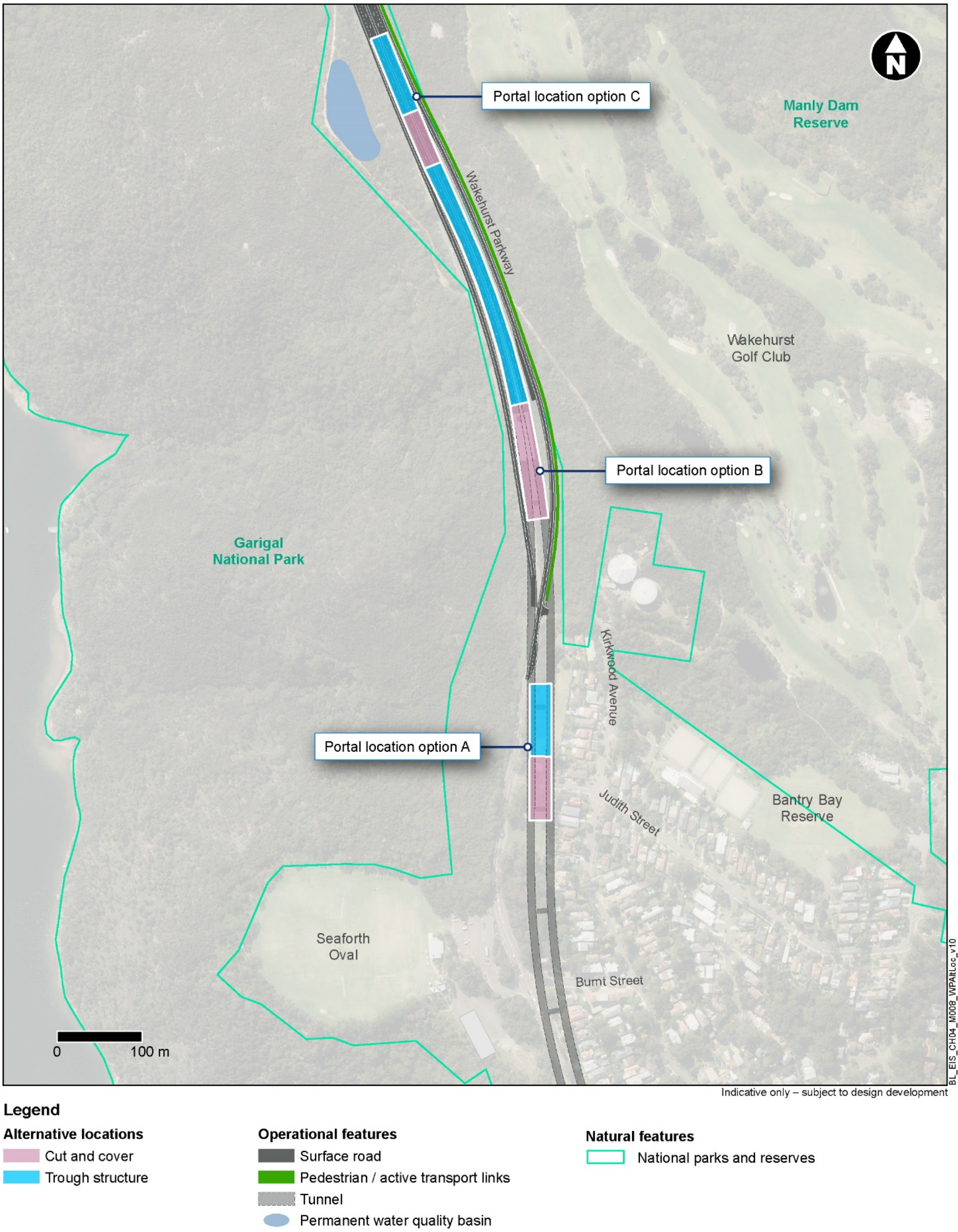


Figure 4-21 Connection alternatives at the Wakehurst Parkway

Following assessment of the options by a multidisciplinary team, portal location option B (refer to Figure 4-21) was selected as the preferred location of the connections to and from the Wakehurst Parkway. The justification for selecting this alternative is summarised in Table 4-6.

Table 4-6 Summary of evaluation of the Wakehurst Parkway connection preferred alternative

Evaluation criteria	Reason for preferred alternative (option B)
Connectivity and network performance	• Portal location option B would provide high-quality connectivity to and from the Wakehurst Parkway within the 80 km/h speed zone, avoiding interfaces between the limited access portion and residential streets • Connectivity to and from the Wakehurst Parkway south of the portals would be maintained but converted to on and off ramps – making the new tunnel connections the main route and downgrading the southern portion of the Wakehurst Parkway which is bypassed • A 'turn around' option was considered to provide access to and from the northern part of Seaforth. This option would involve an underpass near portal location option C and ramps that would allow Seaforth residents to get to and from the tunnels. This option was tested, however the demand was extremely low due to the distance to be travelled combined with the bypass of the southern portion of Wakehurst Parkway and its connection at Balgowlah, making portal location option B more attractive from a travel time perspective.
Constructability and design	• Portal location option B would enable traffic to be diverted around the outside of a central work zone • Portal location option B would result in a reduction of about 450 metres of surface works compared to portal location option A • Portal location option B would include a tunnelling length of 200 metres at a maximum grade of six per cent compared to 750 metres at a maximum grade of six per cent at portal location option A • Portal location option B would require about 450 metres less tunnelling than portal location option C.
Community and environment	• There would be a reduced impact on Duffys Forest endangered ecological community compared to portal location option A • The community impact would be less than at portal location option A, as the tunnel portal would be located further from residential properties • Option B would still require the Option A site area for a temporary construction support site • Access to Seaforth Oval would no longer be impacted during construction • Reduced visual impact and landscape impacts compared to portal location option A • Avoided impacts on Garigal National Park and Manly Dam Reserve.
Economic factors	• Offers economic efficiencies due to reducing the length of tunnel at maximum grade, thus lowering associated costs. These economic efficiencies offset the additional capital cost of increased driven tunnelling for option B.

4.5.5 Balgowlah connection alternatives

The Balgowlah connections would link the Beaches Link tunnels and the eastern area of the Northern Beaches peninsula, including Seaforth, Manly and Brookvale. These suburbs are accessed via Condamine Street and Sydney Road, which both connect to Burnt Bridge Creek Deviation where the Balgowlah connection alternatives have been explored, based on:

- Tunnelled connections to both Burnt Bridge Creek Deviation and Sydney Road (alternatives 1 and 2)
- Tunnelled connections to Burnt Bridge Creek Deviation with a surface connection to Sydney Road via a new access road (alternatives 4a, 4b and 4c)
- Tunnelled connections to Burnt Bridge Creek Deviation with a surface connection via an upgraded Burnt Bridge Creek Deviation to Sydney Road (alternatives 3, 6 and 7)
- Tunnelled connections to Burnt Bridge Creek Deviation with a surface connection to Sydney Road via an upgraded Condamine Street (alternatives 5, 8 and 9).

A summary of the assessment of each of the connection alternatives against the key objectives of the project for the Balgowlah area (as shown in Table 4-7) are outlined below.

Table 4-7 Key objectives of the project for the Balgowlah area

Category	Consideration
Traffic and transport	• Improve key travel times for the region • Improve local traffic performance • Meet predicted strategic demand with connectivity and gradients to deliver a high-quality transport product • Integrate with existing bus lanes to provide for express bus services via Beaches Link • Integrate with the local road network to minimise impacts and optimise performance • Minimise traffic impact to Burnt Bridge Creek Deviation, Condamine Street and Sydney Road during construction • Minimise impacts to existing active transport corridors and identify opportunities for improvements.
Environment and heritage	• Minimise impacts to existing vegetation, particularly intact portions of the Burnt Bridge Creek corridor west of the Burnt Bridge Creek Deviation and east of Kitchener Street • Minimise impacts on Burnt Bridge Creek • Minimise impacts to grey-headed flying fox habitat north of Kitchener Street • Ventilation design and effectiveness to meet Department of Planning, Industry and Environment and NSW Environment Protection Authority requirements.
Community	• Minimise impacts to existing recreation areas • Minimise direct and indirect impacts on sensitive receivers, for example, schools, childcare centres, aged care facilities, etc. • Identify opportunities for amenity improvements both during and after completion (active transport, open space and recreation areas, etc.)

Category	Consideration
	• Minimise direct private property impacts • Minimise indirect private property impacts • Ensure pedestrian safety during construction and operation.
Flooding	• Maintain flood immunity of Beaches Link ramps • Avoid potential increases to flooding in surrounding properties associated with location of Beaches Link infrastructure.
Constructability and engineering	• Designs to meet Australian Standards and Transport for NSW design and safety standards • Access to suitable temporary construction support sites • Minimise construction staging works in busy road corridors • Ensure solution can be constructed and maintained safely and efficiently • Minimise program duration • Minimise haulage via local roads • Minimise interfaces with pedestrians during construction • Minimise exposure to poor geology • Minimise impacts on existing utilities.
Cost	• Ensure a value for money solution, considering both construction and operational costs and risks.

Each alternative was assigned a ranking for each category to identify whether it aligns with the project development considerations, as per the colour coding shown below:

Aligns with project development considerations

Mostly aligns with project development considerations

Partially aligns with project development considerations

Does not align with project development considerations

The proposed reference design (New Access Road option) is used as the base for comparison of alternatives in the following text.

Alternative 1 - Ramps emerging in Sydney Road

Alternative 1 would comprise tunnel ramps emerging within Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Single lane ramps to Sydney Road would provide connectivity for traffic travelling to and from the Manly area.

Figure 4-22 Alternative 1 – Ramps emerging in Sydney Road

Table 4-8 Evaluation summary of 'Alternative 1 - Ramps emerging in Sydney Road'

Category	Consideration	Assessment
Traffic and transport	• Poor connectivity to Seaforth/North Balgowlah as east-facing ramps to Sydney Road do not service the catchment west of Burnt Bridge Creek Deviation • Direct tunnel connection to Sydney Road reduces pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection • Reduced traffic signal controls for southbound traffic on Burnt Bridge Creek Deviation • Challenging to integrate tunnel ramps into Sydney Road • Impacts to local access at Pickworth Avenue and Maretimo Street due to emerging tunnel ramps • Lanes from tunnel not able to fully integrate ahead of Wanganella Street intersection. Existing right turn to Wanganalla Street (south) would need to be removed • Existing eastbound queuing capacity at this intersection reduced – likely to impact performance • Major construction staging works within Sydney Road corridor.	● (orange)

Category	Consideration	Assessment
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and Balgowlah Golf Course construction works.	

Community	• Increased property impacts – 12 residences and businesses impacted along Sydney Road between Burnt Bridge Creek Deviation and Wanganella Street
	• Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for:
	  – Burnt Bridge Creek Deviation and Sydney Road staging and widening works
	  – Tunnel and surface works temporary construction support site
	  – Motorway facilities
	• Reduced permanent impacts to golf course; motorway facilities still located on golf course land
	• Impact to Balgowlah Oval due to widening of Sydney Road
	• Permanent road infrastructure further away from residents on eastern side of golf course; but closer to residents and schools on Sydney Road
	• Impact to existing pedestrian bridge over Sydney Road due to road widening and construction of cut and cover ramps in Sydney Road
	• Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works.	

Flooding	• Increased risk of flooding impacts during construction.	

Constructability and engineering	• Large increase in tunnelling (2.9 kilometres) due to:
	  – Additional tunnel ramps to Sydney Road not included in the proposed reference design. The length of these ramps is driven by the substantial level difference between Sydney Road and where the Burnt Bridge Creek Deviation ramps dive underground
	  – Additional tunnelling would also be required to provide ventilation tunnels from the Sydney Road ramps to the Burnt Bridge Creek Deviation motorway facility/ventilation outlet
	• Increase in tunnelling quantities would necessitate an increased number of roadheaders, increased spoil volumes, and hence increased heavy haulage from this site - over 40,000 truck movements for spoil haulage alone Increased construction complexity and disruptions to local traffic, including major staging within Sydney Road corridor	

Category	Consideration	Assessment
	• Additional impacts to utilities on Sydney Road. This may result in temporary impacts to local utilities in the area during relocation works.	
Cost	• Increased construction and operational costs due to additional: – Infrastructure and fans required to move air through longer ventilation tunnels, with increased maintenance costs – Major construction staging works within Sydney Road.	● (orange)

Alternative 2 - Tunnel loop ramps to Sydney Road

Alternative 2 would comprise tunnel ramps emerging within Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Single lane ramps to Sydney Road would use an underground loop within the Balgowlah Golf Course to connect to a signalised intersection on Sydney Road near Maretimo Street.

Figure 4-23 Alternative 2 - Tunnel loop ramps to Sydney Road

Table 4-9 Evaluation summary of 'Alternative 2 - Tunnel loop ramps to Sydney Road'

Category	Consideration	Assessment
Traffic and transport	• Local network performance as per proposed reference design alternative 4c • Traffic signals for an access road no longer required at Burnt Bridge Creek Deviation.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Direct private property impacts as per proposed reference design alternative 4c • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation and Sydney Road staging and widening works – Tunnel and surface works temporary construction support site – Tunnel loop construction works – Motorway facilities • Permanent impacts to the golf course for the loop ramps and motorway facilities • Increased residual land for community use post construction • Balgowlah Oval closed during construction due to loop ramp construction • Permanent road infrastructure further from residents on eastern side of golf course • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works.	
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Large increase in tunnelling (additional 3.3 kilometres) due to: – Additional tunnel ramps to Sydney Road not included in the proposed reference design alternative 4c. The length of these ramps is determined by the substantial level difference between Sydney Road and the location where the Burnt Bridge Creek Deviation ramps dive underground – Additional tunnelling to provide ventilation tunnels from the Sydney Road ramps to the Burnt Bridge Creek Deviation motorway facility/ventilation outlet	

Category	Consideration	Assessment
	• Increase in tunnelling quantities would necessitate an increased number of roadheaders, increased spoil volumes, and hence increased heavy haulage from this site - over 40,000 truck movements for spoil haulage alone.	
Cost	• Increased construction and operational costs due to additional infrastructure and fans required to move air through longer ventilation tunnels, with higher maintenance costs.	●

Alternative 3 - Connection partially controlled by traffic signals at Burnt Bridge Creek Deviation

Alternative 3 would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging near Serpentine Crescent. This would provide free-flow connection to and from the tunnel for traffic travelling to and from the Pittwater Road/Condamine Street corridor.

Figure 4-24 Alternative 3 - Connection partially controlled by traffic signals at Burnt Bridge Creek Deviation

Table 4-10 Evaluation summary of 'Alternative 3 - Connection partially controlled by traffic signals at Burnt Bridge Creek Deviation'

Category	Consideration	Assessment
Traffic and transport	• Reduced traffic signal phases for southbound traffic from Burnt Bridge Creek Deviation to the tunnel • Traffic signals for the access road no longer required at the Maretimo Street/Sydney Road intersection • Increased risk of queuing into tunnel due to additional conflicting signalised movements • Poorer local network performance as a result of: – Additional traffic signal phasing to the Sydney Road/Burnt Bridge Creek Deviation/Manly Road intersection to allow for right turn for westbound traffic to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection – New traffic signals for northbound surface traffic on Burnt Bridge Creek Deviation (not signalised in proposed reference design alternative 4c).	
Environment and heritage	• Major impacts to the section of Burnt Bridge Creek west of Burnt Bridge Creek Deviation – likely to be redirected into culverts • Additional 13,000 square metres of vegetation clearing along the Burnt Bridge Creek corridor to the west of Burnt Bridge Creek Deviation • Increased tunnel infrastructure in Burnt Bridge Creek floodplain.	
Community	• Permanent road infrastructure located further from residents on eastern side of golf course • Increased property impacts: – 17 additional properties impacted for tunnel ramp construction and intersection upgrade at Sydney Road – Permanent road infrastructure closer to residents on Serpentine Crescent, Hope Street and Kempbridge Avenue and closer to Seaforth Public School • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation staging and widening works – Tunnel and surface works temporary construction support site • Permanent impacts to Balgowlah Golf Course for the Burnt Bridge Creek Deviation widening • Longer construction program.	

Category	Consideration	Assessment
Flooding	• Increased tunnel infrastructure in Burnt Bridge Creek floodplain to ensure the tunnels are not flooded during major flood events. These measures would be likely to impact flow-path and flood levels on nearby properties • Additional risk of flooding during construction.	
Constructability and engineering	• Complex construction staging resulting in: – Slow productivities due to constrained cut and cover site and tunnel construction access in creek valley – Major disruption to Burnt Bridge Creek Deviation during construction of intersection and cut and cover structure – Risk of flooding during construction due to portal location in creek valley.	
Cost	• Considerably increased construction cost due to: – Increased staging in busy Burnt Bridge Creek Deviation corridor – Increased exposure to flooding risk – Highly constrained construction site.	

Alternative 4a - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road to distribute traffic and provide connection to new open space and recreation facilities

Alternative 4a would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Connectivity between the tunnel and Sydney Road corridor would be provided via a surface access road aligned to the eastern boundary of the golf course to distribute traffic across the network. The access road would also provide connection to the new and improved open space and recreation facilities.

Figure 4-25 Alternative 4a - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road to distribute traffic and provide connection to new and improved open space and recreation facilities

Table 4-11 Evaluation summary of 'Alternative 4a - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road to distribute traffic and provide connection to new and improved open space and recreation facilities'

Category	Consideration	Assessment
Traffic and transport	• Access road connection to Sydney Road along eastern boundary improves long-term network performance by: – Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road – Eliminating traffic weaving inherent in many other options – Improving traffic performance and road safety outcomes • Minimises staging and construction works in Sydney Road corridor • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation • Provides connection to the new and improved open space and recreation facilities.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously	

Category	Consideration	Assessment
	realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Small number (six) of private property acquisitions. Acquisitions on Sydney Road and Serpentine Crescent not required as for several other alternatives • Balgowlah Oval and the pedestrian bridge over Sydney Road remain open during construction • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation widening works – Tunnel and surface works temporary construction support site – Motorway facilities and access road construction • Opportunity to re-purpose Balgowlah Golf Course as new and improved open space and recreation facilities in a staged manner both during and after construction • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Permanent road infrastructure closer to residents near the eastern boundary of the golf course • Permanent noise and visual impacts would require mitigation during operation.	
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system • Less tunnelling and haulage of spoil compared to other alternatives • Minimises construction in the Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Relatively low cover tunnelling required under residential properties in Hope Street, increasing settlement risk.	
Cost	• Reduced construction staging in the Sydney Road corridor, reducing construction costs • Reduced scope of local road works required to integrate the project, reducing construction costs.	

Alternative 4b - North facing tunnel ramps to Burnt Bridge Creek Deviation with access road aligned to the golf course's western boundary to distribute traffic and provide connection to the new and improved open space and recreation facilities

Alternative 4b would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to and from the Pittwater Road/Condamine Street corridor. Connectivity between the tunnel and Sydney Road corridor would be provided via a surface access road to distribute traffic, similar to that outlined for 'Alternative 4a', however differing in alignment as the access road would run parallel to the western boundary of the golf course. The access road would also provide connection to the new and improved open space and recreation facilities.

Compared to alternative 4a, an additional 29 residential properties would be acquired on Dudley Street to facilitate:

- Locating of the temporary construction support site partially near Dudley Street and partially on golf course land
- The opportunity for a staged hand over of new and improved open space and recreation facilities on the eastern side of the new access road
- Additional new open space and recreation facilities on residual land near Dudley Street after construction works are completed.

Figure 4-26 Alternative 4b – North facing tunnel ramps to Burnt Bridge Creek Deviation with access road aligned to the golf course's western boundary to distribute traffic and provide connection to the new and improved open space and recreation facilities

Table 4-12 Evaluation summary of 'Alternative 4b – North facing tunnel ramps to Burnt Bridge Creek Deviation with access road aligned to the golf course's western boundary to distribute traffic and provide connection to the new and improved open space and recreation facilities'

Category	Consideration	Assessment
Traffic and transport	• Access road connection to Sydney Road along eastern boundary improves long-term network performance by: – Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road – Eliminating traffic weaving inherent in many other options – Improving traffic performance and road safety outcomes • Minimises staging and construction works in Sydney Road corridor • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation • Provides connection to the new and improved open space and recreation facilities.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Additional 29 private property acquisitions compared to alternative 4a • Balgowlah Oval and the pedestrian bridge over Sydney Road remain open during construction • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation widening works – Tunnel and surface works temporary construction support site – Motorway facilities and access road construction • Opportunity to re-purpose Balgowlah Golf Course as new and improved open space and recreation facilities in a staged manner both during and after construction • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Permanent road infrastructure further from residents near the eastern boundary of the golf course • Permanent noise and visual impacts would less require mitigation during operation.	

Category	Consideration	Assessment
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system • Less tunnelling and haulage of spoil compared to other alternatives • Minimises construction in the Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Relatively low cover tunnelling required under residential properties in Hope Street, increasing settlement risk.	
Cost	• Reduced construction staging in Sydney Road, reducing construction costs • Reduced scope of local road works required to integrate the project, reducing construction costs.	

Alternative 4c - North facing tunnel ramps to Burnt Bridge Creek Deviation with shortened, centralised access road to distribute traffic and provide connection to the new and improved open space and recreation facilities

Alternative 4c is similar in design and arrangement as alternatives 4a and 4b. Alternative 4c would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation that would emerge south of Burnt Bridge Creek, rather than further north as in alternatives 4a and 4b. Connectivity to and from Pittwater Road/Condamine Street is maintained. Given the positioning of the tunnel ramps south of Burnt Bridge Creek there would be no requirement to alter the current alignment of the Kitchener Street bridge. Connectivity between the tunnel and the Sydney Road corridor would be provided via a surface access road through the existing Balgowlah Golf Course to distribute traffic demand across the local network and provide connection to the new and improved open space and recreation facilities. The alignment of this surface access road would differ and be notably shorter to alternatives 4a and 4b.

Figure 4-27 Alternative 4c - North facing tunnel ramps to Burnt Bridge Creek Deviation with shortened, centralised access road to distribute traffic and provide connection to the new and improved open space and recreation facilities

Table 4-13 Evaluation summary of 'Alternative 4c – North facing tunnel ramps to Burnt Bridge Creek Deviation with shortened, centralised access road to distribute traffic and provide connection to the new and improved open space and recreation facilities'

Category	Consideration	Assessment
Traffic and transport	• Access road connection to Sydney Road along eastern boundary improves long-term network performance by: – Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road – Eliminating traffic weaving inherent in many other options – Improving traffic performance and road safety outcomes – Access road is shorter than for alternatives 4a and 4b • Minimises staging and construction works in Sydney Road corridor • Tunnel portal is moved to the south • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation • Provides connection to the new and improved open space	● (green)

Category	Consideration	Assessment
	and recreation facilities • Longer two lane ramp tunnels to Balgowlah and Wakehurst Parkway connections. Shorter three lane mainline tunnels • Existing Kitchener Street/Myrtle Street traffic arrangements no longer impacted with bridge replacement works eliminated • Extensive utility works and associated local traffic interruptions eliminated in streets west of Burnt Bridge Creek Deviation.	
Environment and heritage	• Requires only minor works to Burnt Bridge Creek and eliminates extensive diversion works within the existing creek, reducing impacts on flora and fauna, including potentially reduced impact on mature trees in the golf course compared to alternatives 4a and 4b • Scope of staged construction within the Burnt Bridge Creek Deviation reduced • Reduced impact likely on grey-headed flying fox habitat north of Kitchener Street bridge compared to alternatives 4a and 4b • Reduced risk of potential impact to Aboriginal heritage due to reduced creek diversion works.	
Community	• Additional 29 private property acquisitions compared to alternative 4a • Balgowlah Oval and the pedestrian bridge over Sydney Road remain open during construction • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation widening works – Tunnel and surface works temporary construction support site – Motorway facilities and access road construction • Opportunity to re-purpose Balgowlah Golf Course as new and improved open space and recreation facilities in a staged manner both during and after construction • Permanent road infrastructure more centrally aligned within the golf course site, reducing potential amenity, noise and vibration impacts when compared to alternatives 4a and 4b • Permanent noise and visual impacts would less require mitigation during operation.	
Flooding	• Location of tunnel portal reduces risk of flooding impacts during construction and operation.	
Constructability and	• Overall construction footprint reduced in comparison to alternatives 4a and 4b due to elimination of Kitchener Street	

Category	Consideration	Assessment
engineering	bridge works • Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system • Less tunnelling and haulage of spoil compared to other alternatives • Minimises construction in the Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Elimination of impacts on multiple utilities required for alternatives 4a and 4b • Relatively low cover tunnelling eliminated under residential properties in Hope Street eliminating settlement and ground–borne noise impacts • Scope of staged construction within the Burnt Bridge Creek Deviation reduced with cut and cover staging works now located close and adjacent to the temporary construction support site at Dudley Street.	
Cost	• Reduced construction staging in Sydney Road corridor, reducing construction costs • Reduced scope of local road works required to integrate the project, reducing construction costs.	

Alternative 5 - North facing tunnel ramps to Burnt Bridge Creek Deviation including Condamine Street upgrade

Alternative 5 would comprise a single set of tunnel ramps to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to the area. Surface road upgrades to Condamine Street at intersections with Sydney Road and Balgowlah Road would provide surface road access to the tunnel.

Figure 4-28 Alternative 5 - North facing tunnel ramps to Burnt Bridge Creek Deviation including Condamine Street upgrade

Table 4-14 Evaluation summary of 'Alternative 5 - North facing tunnel ramps to Burnt Bridge Creek Deviation including Condamine Street upgrade'

Category	Consideration	Assessment
Traffic and transport	• Widening of Burnt Bridge Creek Deviation into the golf course allows traffic flow to be maintained during construction, as per the proposed reference design alternative 4c • Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Local network impacts and poorer long-term traffic performance, including: – Local traffic impacts concentrated on Kenneth Road and Condamine Street as they become primary access roads for the tunnel – Kitchener Street/Balgowlah Road would be used by traffic attempting to access the tunnel from Seaforth – Potential rat run on local streets, such as Wanganella Street and West Street for traffic accessing Kitchener Street and Balgowlah Road – Existing residential accesses, multiple intersections with	(orange circle)

Category	Consideration	Assessment
	traffic signals and bus stops along the Condamine Street corridor mean capacity of existing lanes would not be realised even with parking removed – Increased demand on these roads is likely to result in poor long-term performance, eroding travel time benefits • Considerably increased traffic volumes on Kitchener Street, Balgowlah Road and Condamine Street would increase impacts on residents and businesses along these corridors.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact would be limited to the portion of the creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works.	
Community	• Minimises permanent impacts to Balgowlah Golf Course by eliminating 18,000 square metres of impact associated with access road • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation widening works – Tunnel and surface works temporary construction support site – Motorway facilities construction • Reduced indirect impacts on residents on eastern side of golf course • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Increased private property impacts: – Increased demand on Condamine Street would require a road upgrade. This would likely result in removal of parking and property impacts along Condamine Street and Sydney Road to provide turning movements – Properties impacted along Condamine Street and Sydney Road due to intersection upgrades and associated widening in this area.	
Flooding	• Increased risk of flooding impacts during construction.	
Constructability and engineering	• Minimises construction in Sydney Road corridor • Minimises construction within the Burnt Bridge Creek Deviation corridor • Traffic staging for road upgrades on Condamine Street in narrow existing busy road corridor • Less tunnelling and haulage of spoil compared to other	

Category	Consideration	Assessment
	longer driven tunnel options • Motorway facilities close to the tunnel ramps reduces the length of ventilation tunnels and maximises the efficiency of the system.	
Cost	• Additional property and road upgrade costs on Condamine Street and Sydney Road exceed savings of not constructing access road.	● (orange)

Alternative 6 - Burnt Bridge Creek Deviation loop interchange

Alternative 6 would comprise two sets of tunnel ramps to Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor and Sydney Road east and west. The south facing ramps would be in a loop arrangement to transition to and from the tunnel within the Balgowlah Golf Course site.

Figure 4-29 Alternative 6 - Burnt Bridge Creek Deviation loop interchange

Table 4-15 Evaluation summary of 'Alternative 6 - Burnt Bridge Creek Deviation loop interchange'

Category	Consideration	Assessment
Traffic and transport	• Undesirable road geometry: – Tight radius tunnel loops (potentially a major road safety hazard) at the exit and entry from an 80 km/h road (Burnt Bridge Creek Deviation and Beaches Link tunnels) – Road design and safety standards generally suggest this design should be avoided as it increases the risk of accidents, including heavy vehicle rollovers – Northbound tunnel includes a decision point for drivers very close to the exit of the tight radius curve (east or west on Sydney Road) • Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Poorer local network performance: – The proximity of southern ramp to the Sydney Road intersection would create a weave – degrading the performance of this intersection – Requires additional phase for traffic signals to the Sydney Road intersection to allow for right turn to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection.	
Environment and heritage	• Requires realignment of Burnt Bridge Creek but this impact is limited to portion of creek previously realigned during original Burnt Bridge Creek Deviation construction and golf course construction works • Increased tunnel infrastructure in Burnt Bridge Creek floodplain.	
Community	• Permanent road infrastructure located further from residents living near the golf course, however the main access ramp would be closer to some residents on the eastern boundary • Increased property impacts, with 13 properties impacted to facilitate south-facing ramps and upgrade of Sydney Road intersection • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation staging – Tunnel and surface works temporary construction support site – Motorway facilities • Permanent impacts to the golf course site, including: – Burnt Bridge Creek Deviation widening	

Category	Consideration	Assessment
	– Trough structures for loop ramps – Motorway facilities. • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works	
Flooding	• Increased risk of flooding during construction and operation.	
Constructability and engineering	• Substantial increase in tunnelling (additional 635 metres and two additional caverns) for the additional south-facing tunnel ramps not included in the proposed reference design alternative 4c • Increased volumes of heavy haulage from tunnelling • Increased staging in Burnt Bridge Creek Deviation corridor for the additional set of tunnel ramps and bridge structure • Surface works in Burnt Bridge Creek Deviation corridor would be increased to bring multiple ramps to surface • Increased tunnel infrastructure in Burnt Bridge Creek floodplain to ensure the tunnels are not flooded in major flood events. These measures would be likely to impact flow-paths and flood levels on nearby properties during operational phase • Additional risk of flooding during construction.	
Cost	• Considerably higher construction cost due to increased: – Tunnelling complexity – Staging in busy Burnt Bridge Creek Deviation corridor – Exposure to flooding risk.	

Alternative 7 - North and south facing tunnel ramps to Burnt Bridge Creek Deviation

Alternative 7 was suggested as an alternative through community consultation. This alternative would comprises two sets of tunnel ramps to Burnt Bridge Creek Deviation to connect to and from the Pittwater Road/Condamine Street corridor and Sydney Road.

Figure 4-30 Alternative 7 - North and south facing tunnel ramps to Burnt Bridge Creek Deviation

Table 4-16 Evaluation summary of 'Alternative 7 - North and south facing tunnel ramps to Burnt Bridge Creek Deviation'

Category	Consideration	Assessment
Traffic and transport	• Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Poor local network performance due to: – Proximity of northern ramps to Condamine Street intersection creating weave issues and removal of the right-turn movement to Condamine Street south. This would likely place additional pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection to allow for right turn for westbound traffic to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection – Increased risk of queuing into tunnel compared to the proposed reference design alternative 4c, which avoids access road signals and is about one kilometre from Condamine Street intersection • Increased heavy haulage due to increased number of roadheaders, spoil volumes and tunnelling.	

Category	Consideration	Assessment
Environment and heritage	• Increased impacts to Burnt Bridge Creek with an additional 300 metres of Burnt Bridge Creek to be realigned • Large increase in vegetation clearing required. Additional 13,000 square metres of vegetation clearing, including in the area behind Kitchener Street identified as grey-headed flying-fox habitat.	●
Community	• Permanent road infrastructure further from residents near the eastern boundary of golf course • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation staging – Tunnel and surface works construction • Permanent impacts to the golf course site due to Burnt Bridge Creek Deviation widening • Reduced permanent impacts to the existing open space at Balgowlah Golf Course by 18,000 square metres due to removal of access road and motorway facilities • Greater private property impacts, with the acquisition of an additional 20 properties: – At Burnt Bridge Creek Deviation/Sydney Road intersection and Dudley Street to allow for intersection augmentation – Along Kitchener Street and Balgowlah Road to allow for creek realignment and construction of north-facing tunnel ramps.	●
Flooding	• North-facing tunnel ramps in Burnt Bridge Creek floodplain: – Places tunnels and surface widening in worst affected area of Burnt Bridge Creek floodplain – Would require substantial infrastructure to ensure the tunnels are not flooded during major flood events. These measures are likely to impact flow-paths and flood levels on nearby properties • Additional risk of inundation during construction.	●
Constructability and engineering	• Substantial increase in tunnelling (additional 1.9 kilometres, three additional caverns and 400 metres of ventilation tunnel) due to: – Additional tunnel south-facing ramps not included in the proposed reference design alternative 4c – Additional tunnelling to provide ventilation tunnels from the north-facing ramps to the Burnt Bridge Creek Deviation motorway facility – Increased truck haulage due to increased tunnelling and spoil – over 23,000 truck movements for spoil haulage	●

Category	Consideration	Assessment
	alone. • Increased staging in Burnt Bridge Creek Deviation corridor for the: – Additional set of tunnel ramps – Cut and cover structures across Burnt Bridge Creek Deviation which are complex to build north of Kitchener Street in a significant flood zone with limited area for staging creek diversion works • Length of surface works in Burnt Bridge Creek Deviation corridor greatly increased.	
Cost	• Considerably greater construction cost due to increased: – Tunnelling – Increased staging in the busy Burnt Bridge Creek Deviation corridor – Exposure to flooding risk in the most affected area of the floodplain during construction and operational phases.	

Alternative 8 - North facing tunnel ramps and surface ramps to Kitchener Street

Alternative 8 was suggested as an alternative through community consultation and would comprise a single tunnel ramp to Burnt Bridge Creek Deviation, emerging south of Kitchener Street to provide connectivity to and from the Pittwater Road/Condamine Street corridor. A separate set of ramps to the Kitchener Street bridge would provide access to North Balgowlah, Seaforth and Balgowlah Road/Condamine Street for access to Sydney Road.

Figure 4-31 Alternative 8 - North facing tunnel ramps and surface ramps to Kitchener Street

Table 4-17 Evaluation summary of 'Alternative 8 - North facing tunnel ramps and surface ramps to Kitchener Street'

Category	Consideration	Assessment
Traffic and transport	• Traffic signals for the access road no longer required on Burnt Bridge Creek Deviation or the Maretimo Street/Sydney Road intersection • Poor local network performance due to: – Proximity of northern ramps to Condamine Street intersection creating weave issues and removal of the right-turn movement to Condamine Street south. This would likely place additional pressure on Sydney Road and Kenneth Road intersections – Requires additional traffic signal phasing for the Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection to allow for right turn westbound traffic to Burnt Bridge Creek Deviation (currently not permitted). This would place additional pressure on the performance of this intersection • Local traffic impacts would be concentrated on Kitchener Street, and Balgowlah Road would become a sub arterial road with increased demand on Kitchener Street, Balgowlah Road and Condamine Street, reducing travel time benefits	(orange circle)

Category	Consideration	Assessment
	and impacting residents and businesses • Increased risk of queuing into tunnel compared to the proposed reference design alternative 4c, which avoids access road signals and is about one kilometre from Condamine Street.	
Environment and heritage	• Additional 350 metres of Burnt Bridge Creek to be realigned north of Kitchener Street • Additional 13,000 square metres of vegetation clearing, including in the area behind Kitchener Street identified as grey-headed flying-fox habitat.	
Community	• Motorway ramps to Kitchener Street would result in increased traffic noise being generated at a higher elevation in this area • Kitchener Street bridge would require replacement to facilitate changed lane arrangements on Burnt Bridge Creek Deviation resulting in disruption impacts to local traffic during staging works • Permanent road infrastructure further from residents near to the eastern boundary of golf course • Reduced permanent impacts to the existing open space at the golf course by 18,000 square metres due to removal of access road and motorway facilities • Greater private property impacts, with the acquisition of more than 20 additional properties: – At Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Dudley Street to allow for intersection upgrade – Along Kitchener Street and Balgowlah Road to allow for creek realignment and construction of north-facing tunnel ramps • Kitchener Street, Balgowlah Road and Condamine Street would need to be upgraded resulting in the removal of parking and property impacts • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation staging – Tunnel and surface works temporary construction support site – Motorway facilities • Permanent impacts to the golf course site due to Burnt Bridge Creek Deviation widening.	
Flooding	• North-facing tunnel ramps in Burnt Bridge Creek floodplain: – Places tunnels and surface widening in worst affected areas of the floodplain	

Category	Consideration	Assessment
	– Would require substantial infrastructure to ensure the tunnels are not flooded during major flood events. These measures are likely to impact flow-paths and flood levels on nearby properties • Additional risk of inundation during construction.	
Constructability and engineering	• Motorway facilities close to tunnel ramps • Increased staging in Burnt Bridge Creek Deviation corridor for the: – Additional set of surface ramps to the new Kitchener Street Bridge – Complex cut and cover structures across the Burnt Bridge Creek Deviation • Length of surface works in Burnt Bridge Creek Deviation corridor substantially increased.	
Cost	• Greater construction cost due to increased: – Staging in busy Burnt Bridge Creek Deviation corridor – Exposure to flooding risk.	

Alternative 9 - North facing tunnel ramps to Burnt Bridge Creek Deviation with dual U-turn overpass facility

Alternative 9 was suggested as an alternative through community consultation. This alternative would comprise tunnel ramps emerging within Burnt Bridge Creek Deviation to provide connectivity to and from the Pittwater Road/Condamine Street corridor, with a U-turn overpass over Burnt Bridge Creek Deviation, north of Kitchener Street. The U-turn overpass would provide movements to and from the tunnel portal and the suburbs of Seaforth, North Balgowlah and Balgowlah.

Figure 4-32 Alternative 9 - North facing tunnel ramps to Burnt Bridge Creek Deviation with dual U-turn overpass facility

Table 4-18 Evaluation summary of 'Alternative 9 - North facing tunnel ramps to Burnt Bridge Creek Deviation with dual U-turn overpass facility'

Category	Consideration	Assessment
Traffic and transport	• Traffic signals for an access road no longer required on Burnt Bridge Creek Deviation or at the Maretimo Street/Sydney Road intersection • Poor local network performance: – Condamine Street would be a much shorter route for traffic coming from Manly via Sydney Road under this option (1780 metres compared to 3200 metres via the proposed U-turn) – This would increase traffic pressure on Condamine Street, triggering the need for substantial surface works to integrate into the local network • Increased traffic impacts during construction due to additional staging and temporary works within the Burnt Bridge Creek Deviation corridor for the new U-turn facility and upgraded Burnt Bridge Creek Deviation/Condamine Street intersection.	(orange circle)
Environment and heritage	• Increase in vegetation clearing. Additional 13,000 square metres of vegetation clearing, including in the area behind	(orange circle)

Category	Consideration	Assessment
	Kitchener Street identified as grey-headed flying-fox habitat • Increased visual impact associated with two elevated structures • Noise and light generation from traffic on elevated structures.	
Community	• Reduces permanent impacts to the existing open space at the golf course • Increased property impacts: – Alternative places substantial additional pressure on Condamine Street. Large number of additional private property acquisitions, including multiple large commercial properties, would be required to facilitate the upgrade of Condamine Street to accommodate additional Manly-bound traffic – Additional permanent project footprint north of Kitchener Street • Temporary impact to the majority of Balgowlah Golf Course (excluding Balgowlah Oval and scout hall) during construction for: – Burnt Bridge Creek Deviation widening – Tunnel and surface works temporary construction support site – Motorway facilities.	
Flooding	• Tunnel portals constructed clear of the worst affected flood zone, but large ramp structure in flood plain would impact flows and require mitigation.	
Constructability and engineering	• Substantial additional construction within Burnt Bridge Creek Deviation corridor to build multiple ramps and overpasses.	
Cost	• Considerably greater construction cost due to: – Substantial additional upgrades at Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection for additional turn lanes, the Burnt Bridge Creek Deviation/Condamine Street new overpass and Sydney Road/Condamine Street turning lanes – Increased staging within the busy Burnt Bridge Creek Deviation corridor.	

Preferred alternative

An overall summary table comparing the connection alternatives to Balgowlah described above is presented in Figure 4-33.

Project development considerations	Ramps emerging in Sydney Road (1)	Tunnel loop ramps to Sydney Road (2)	Connection partially controlled by traffic signals at BBCD (3)	North facing tunnel ramps to BBCD with east access road to distribute traffic (4a)	North facing tunnel ramps to BBCD with west access road to distribute traffic (4b)	North facing tunnel ramps to BBCD with shorter access road to distribute traffic (4c)	North facing tunnel ramps to BBCD including Condamine Street upgrade (5)	BBCD loop interchange (6)	North and south facing ramps to BBCD (7)	North facing tunnel ramps and surface ramps to Kitchener Street (8)	North facing tunnel ramps to BBCD with dual U-turn overpass facility (9)
	Balgowlah connection alternatives										
Traffic and transport	Partially aligns	Aligns	Mostly aligns	Aligns	Aligns	Aligns	Partially aligns	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns
Environment and heritage	Mostly aligns	Mostly aligns	Partially aligns	Mostly aligns	Mostly aligns	Aligns	Aligns	Mostly aligns	Partially aligns	Mostly aligns	Partially aligns
Community	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns	Partially aligns	Mostly aligns	Partially aligns	Partially aligns	Partially aligns	Partially aligns	Partially aligns
Flooding	Mostly aligns	Mostly aligns	Partially aligns	Mostly aligns	Mostly aligns	Aligns	Mostly aligns	Mostly aligns	Partially aligns	Mostly aligns	Partially aligns
Constructability and engineering	Partially aligns	Partially aligns	Mostly aligns	Mostly aligns	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns	Partially aligns	Mostly aligns	Partially aligns
Cost	Partially aligns	Partially aligns	Partially aligns	Mostly aligns	Mostly aligns	Mostly aligns	Partially aligns	Partially aligns	Does not align	Partially aligns	Partially aligns

Note: BBCD = Burnt Bridge Creek Deviation

- Aligns with project development considerations
- Mostly aligns with project development considerations
- Partially aligns with project development considerations
- Does not align with project development considerations

Figure 4-33 Balgowlah connection alternatives – project development considerations

Based on the assigned ratings and overall scores, the preferred alternative for the Balgowlah connection is the access road alternative 4c. The justification for selecting this alternative is summarised in Table 4-19.

Table 4-19 Summary of evaluation of Balgowlah connection preferred alternative

Evaluation criteria	Reason for preferred alternative
Traffic and transport	• Access road connection to Sydney Road improves long-term network performance by: – Reducing pressure on Burnt Bridge Creek Deviation/Sydney Road/Manly Road intersection and Condamine Street between Burnt Bridge Creek Deviation and Sydney Road – Eliminating traffic weaving inherent in many other options – Improving traffic performance and road safety outcomes – Access road is shorter than for alternatives 4a and 4b • Provides connection to the new open space and recreation facilities • Minimises construction in Sydney Road corridor • Requires traffic lights for southbound traffic on Burnt Bridge Creek Deviation and new access road/Sydney Road/Maretimo Street intersection • Shorter operational access road compared to alternatives 4a and 4b • Longer two lane ramp tunnels to Balgowlah and Wakehurst Parkway connections. Shorter three lane mainline tunnels compared to alternatives 4a and 4b • Extensive utility works and associated local traffic interruptions greatly reduced in streets west of Burnt Bridge Creek Deviation.
Environment and heritage	• Requires only localised adjustment to Burnt Bridge Creek and eliminates extensive diversion works within the existing creek, reducing impacts on flora and fauna, including potentially reduced impact on mature trees in the golf course precinct compared to alternatives 4a and 4b • Scope of staged construction within the Burnt Bridge Creek Deviation reduced • Reduced impact likely on grey-headed flying fox habitat north of Kitchener Street bridge compared to alternatives 4a and 4b • Reduced risk of potential impact to Aboriginal heritage with reduced creek diversion works.
Community	• Substantial increase to private property impacts compared to alternative 4a. Large portion of Dudley Street subject to property acquisitions (same as for alternative 4b) • Acquisitions on Sydney Road and Serpentine Crescent not required as for several other alternatives • Reduced substratum acquisitions under residential properties in Seaforth compared to alternatives 4a and 4b • Existing Kitchener Street/Myrtle Street local traffic arrangements no longer impacted with bridge replacement works eliminated • New and improved open space and recreation facilities, including (subject to

Evaluation criteria	Reason for preferred alternative
	further consultation): – Land not required for the construction or operation of the project would be progressively re-purposed and handed over to Northern Beaches Council for the community – Potential for new and improved open space and recreation facilities in residual land primarily to the east and north of the new access road, to be available for use earlier than alternative 4a • Along with a shorter access road, permanent road infrastructure is more centrally aligned within the golf course site, reducing potential amenity, noise and vibration impacts when compared to alternatives 4a and 4b.
Flooding	• Location of cut and cover tunnel portal moved to the south away from floodplain therefore reducing potential flooding impacts during construction and operation.
Construction and engineering	• Overall construction footprint reduced in comparison to alternatives 4a and 4b due to elimination of Kitchener Street bridge works • Less tunnelling and haulage of spoil compared to several other options with direct tunnel access to Sydney Road or additional south facing ramps on Burnt Bridge Creek Deviation • Appropriately sized temporary construction support site with arterial road access, allowing the project to be delivered efficiently, reducing construction duration along with allowing repurposed new and improved open space and recreation facilities to be available earlier than for alternatives 4a and 4b • Minimises construction in the Sydney Road corridor • Scope of staged construction works within the Burnt Bridge Creek Deviation reduced with cut and cover portal moved to the south and now located close and adjacent to the temporary construction support site at Dudley Street/Balgowlah Golf Course • Greatly reduces impacts on multiple utilities required for alternatives 4a and 4b • Relatively low cover tunnelling eliminated under residential properties in Hope Street, eliminating settlement risk and ground-borne noise risk.
Cost	• Reduced construction staging in busy road corridors, reducing construction costs • Reduced scope of local road works required to integrate project, reducing construction costs.

4.5.6 Ventilation alternatives

Ventilation system design

Tunnel ventilation systems must continuously, reliably and efficiently provide a safe environment for tunnel users and communities surrounding the infrastructure. The basic objectives of tunnel ventilation systems are to:

- Maintain in-tunnel air quality
- Avoid portal emissions
- Manage smoke during fire incidents.

Most 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.

On an open roadway, vehicle emissions are diluted and dispersed by natural surface air flows. However, in a tunnel, mechanical ventilation can be required to ensure that air quality standards are maintained. This is achieved by providing fresh air to, and removing exhaust air from, the tunnel. The requirements for tunnel ventilation are determined by the vehicle emissions in the tunnel and the limits of pollutant levels set by regulatory authorities. Air quality is managed by ensuring that the volume of fresh air coming into the tunnel adequately dilutes emissions.

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 about one kilometre long, air flow resulting from the piston effect of the vehicles may be adequate to manage in-tunnel air quality.

In longer tunnels, the flow of fresh air can be supplemented by ventilation facilities which remove exhaust air and/or supply additional fresh air. The need for these features is dependent on tunnel size and length, and the number and mix of vehicles using the tunnel. Fans may also be required when the piston effect is insufficient to maintain adequate air flow, such as during periods of low traffic or congested traffic conditions.

Elevated ventilation outlets are used for longer tunnels in urban areas in Australia to disperse tunnel air at a height that ensures compliance with ambient air quality criteria.

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 alternatives for design of the ventilation system were considered. The advantages and disadvantages of the various systems are described below and shown in Figure 4-34.

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 (that is less than one kilometre). This is because, without the assistance of mechanical ventilation, vehicle emissions can build up within the tunnels leading to unacceptable in-tunnel air quality under some traffic scenarios. Emergency smoke management considerations may also dictate a mechanical solution. Natural ventilation would not achieve acceptable in-tunnel air quality under low vehicle speed conditions or during emergencies and is therefore not a viable ventilation design for the project.

Longitudinal ventilation

The simplest form of ventilation for road tunnels 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, during normal operating conditions, most air would be forced through the tunnels by the movement of vehicles (the piston effect) and jet fans would be used to assist with the movement of tunnel air, to maintain acceptable in-tunnel air quality. The air pressure inside the exit portals would be maintained below atmospheric pressure to avoid the release of tunnel air from the portals. This air is then exhausted through an elevated ventilation outlet to maximise dispersion. All road tunnels longer than one kilometre built in Australia in the last 20 years have been designed and operated with longitudinal ventilation systems. This includes the recently completed NorthConnex, New M4 and M8 tunnels and the M4-M5 Link tunnels currently under construction.

Transverse ventilation

Another way to ensure adequate dilution of emissions is to provide fresh air inlets along the length of the tunnel along one side, with outlets on the opposite side. This system requires two ducts to be constructed along the length of the tunnel: one for the fresh air supply and one for the exhaust air. Transverse ventilation has been used in the past when vehicle emissions produced greater levels of pollutants than they do today. 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 for controlling smoke in the tunnel in case of a fire. It is also more energy intensive as more power is consumed to manage air flows.

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.

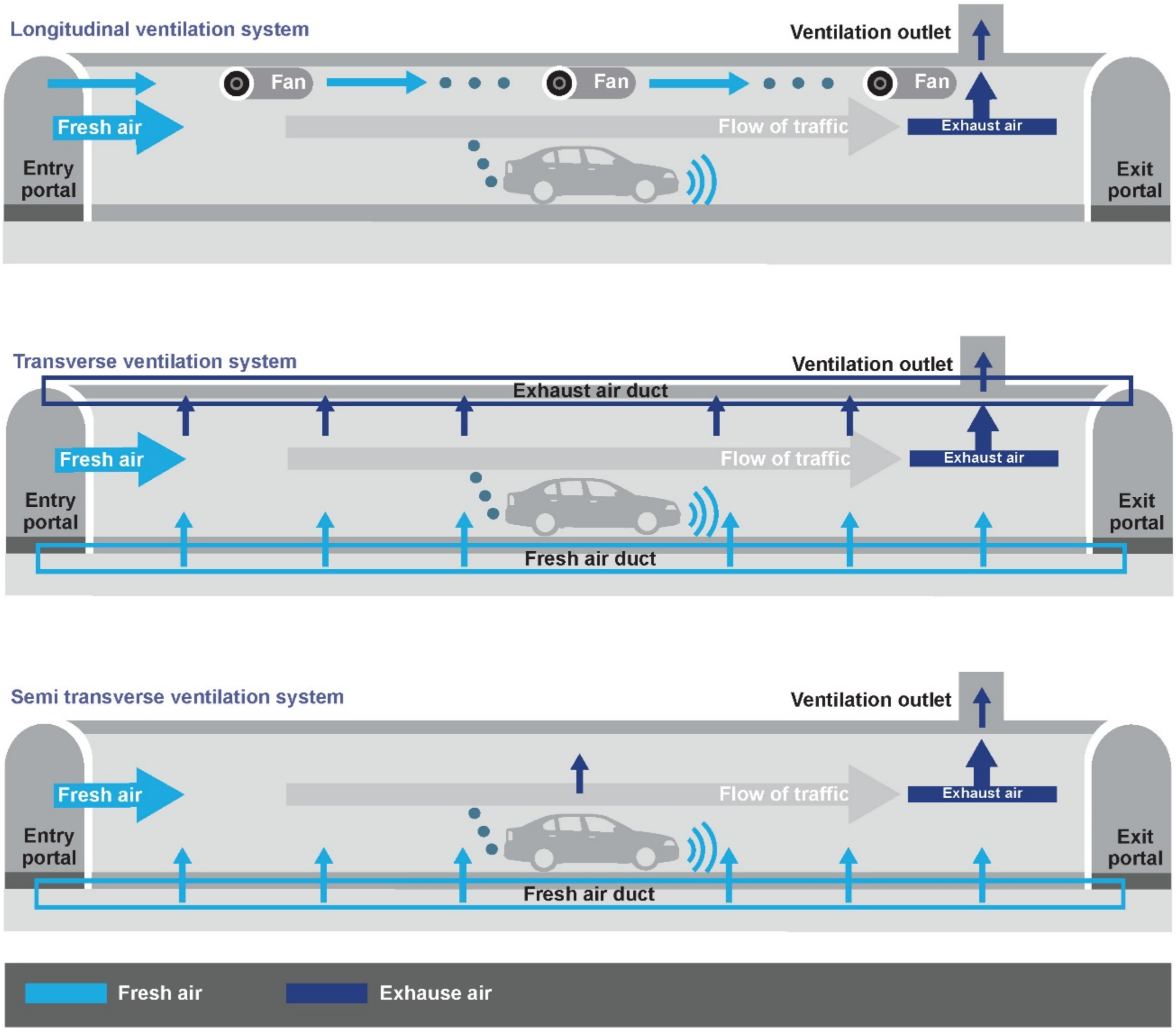


Figure 4-34 Ventilation system design alternatives

Preferred alternative

The development of cleaner vehicles in response to cleaner fuel and emissions standards has led to a substantial reduction in vehicle emissions over the past 20 years. Where longitudinal ventilation was once not 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 maintain acceptable air quality in long tunnels and is considered the most efficient and effective tunnel ventilation system (Advisory Committee on Tunnel Air Quality (ACTAQ), 2019).

Although all three mechanical ventilation systems described above could be designed to meet in-tunnel air quality criteria, a longitudinal system with elevated ventilation outlets has been selected as the preferred option for the project as it is:

- Able to ensure emissions are dispersed and diluted so that there is minimal or no effect on ambient air quality
- Considered to be more effective for the management of smoke in the tunnel in the event of a fire
- Able to meet the requirement to avoid portal emissions
- Less costly to construct and operate than transverse systems.

The effectiveness of elevated ventilation outlets in dispersing emissions is well established. Chapter 12 (Air quality) presents the air quality assessments for both in-tunnel and external air quality. An overview of the ventilation system design and operation is provided in Chapter 5 (Project description).

Consideration of air filtration at the ventilation outlets

Only a small proportion of road tunnels around the world are fitted with air treatment systems. It has been shown that control of pollutants at the source is significantly more effective in improving local and regional air quality (ACTAQ, 2019; NHMRC, 2008a). Control measures include minimising road gradients, increasing tunnel height and providing a large tunnel cross-sectional area. The tunnel ventilation system for the project would be designed with appropriate levels of conservatism and redundancy to ensure compliance with air quality goals and limits.

No in-tunnel filtration system is proposed for the project because the modelling carried out demonstrates that the ventilation system would be effective in ensuring compliance with the in-tunnel air quality criteria. The inclusion of tunnel filtration was evaluated and found not to provide any material benefit to air quality or community health, as discussed in Chapter 12 (Air quality).

The inclusion of filtration would result in no material change in air quality in the surrounding community when compared to the current project ventilation system and outlet design. Any predicted changes in the concentration of pollutants would be largely driven by changes in the surface road traffic.

The independent NSW Chief Scientist and Engineer also released a report in relation to road tunnel air quality. The report found that emissions from well-designed road tunnels cause a negligible change to surrounding air quality, and as such, there is little to no health benefit for surrounding communities in installing filtration and air-treatment systems in such tunnels. Further information is available at www.chiefscientist.nsw.gov.au.

Ventilation outlet locations

The contribution of the ventilation outlets is negligible for the expected traffic scenarios. This outcome can be achieved at nearly any location through appropriate outlet design. Therefore, the main factors when considering the location of the ventilation facilities and outlets were maintaining in-tunnel air quality, maximising operational efficiency and minimising surface disturbance.

Vehicles travelling through the tunnels create a piston effect which draws air in the direction of travel. As a result, the most efficient location for a ventilation outlet is above or adjacent to tunnel portal locations (that is, near the exit portals of the tunnel in Cammeray, Artarmon, Balgowlah and Killarney Heights). This minimises the length of tunnel where the air flow must be forced, by jet fans within the tunnels against traffic flow back to the ventilation point. The reduced use of tunnel ventilation fans also increases the performance of the tunnels and reduces operational power consumption, thereby reducing the operational costs of the project and enhancing the sustainability outcomes.

The proposed ventilation outlets for the project would be located at Warringah Freeway at Cammeray, Gore Hill Freeway at Artarmon, Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights. The ventilation outlet locations at Artarmon, Balgowlah and Killarney Heights were driven by the locations of the tunnel portals and the motorway facilities. For the ventilation outlet at Cammeray, the Warringah Freeway corridor was identified as the preferred location for the ventilation outlet. This location would provide the following key advantages:

- It would minimise the total project footprint, noting alternatives would require additional property acquisition external to the existing road corridor
- It would be immediately above the tunnel, with associated efficiencies.

Refer to Chapter 5 (Project description) for an overview of the key features of the project, including the location of the ventilation outlets, which are shown in Figure 5-1 to Figure 5-7.

4.5.7 Temporary construction support site location alternatives

In addition to the surface disturbance areas required for the operation of the project, a number of temporary construction support sites would be required along the project corridor. The temporary construction support sites would be needed to support both tunnelling and surface works.

Temporary construction support sites would accommodate construction activities such as construction material and equipment storage and staging areas, spoil handling, component casting facilities, worker amenities and car parking.

In addition to the construction requirements, environmental investigations and community and stakeholder feedback were used to inform the identification and configurations of appropriate temporary construction support sites. The primary driver for the location of these sites was the objective of minimising environmental and community impacts, while being suitably located to facilitate the construction activities of the project.

Key factors applied to identification of potential temporary construction support sites included:

- Locating the temporary construction support sites as close as possible to project construction areas
- Avoiding sensitive environments and community locations where possible
- Avoiding material impacts on heritage sites or items
- Maximising opportunities for direct access to motorways and arterial roads or water transport opportunities for construction traffic, and avoiding the need to use local residential streets if possible
- Minimising direct and indirect property impacts and acquisition requirements, particularly in residential areas.

Where the identified temporary construction support sites could not meet the criteria listed above, additional specific mitigation measures were identified to manage impacts associated with their use. Details of temporary construction support sites are provided in Chapter 6 (Construction work) of this environmental impact statement.

Two temporary construction support sites in particular have been subject to more detailed alternative evaluation. These are the:

- Wakehurst Parkway tunnel temporary construction support site at Seaforth/Killarney Heights
- Flat Rock Drive tunnel temporary construction support site at Willoughby/Northbridge.

Wakehurst Parkway tunnel temporary construction support site

Initial planning for this temporary construction support site was associated with the initial preferred connection to and from the Wakehurst Parkway at portal location option A (refer to Section 4.5.4) with the temporary construction support site located at Seaforth Oval overflow carpark area on the western side of the Wakehurst Parkway.

Further community consultation and design development determined the selection of portal location option B as the preferred location of the tunnel portal and connections to and from the Wakehurst Parkway (refer to Section 4.5.4). A preferred temporary construction support site location was then selected on Sydney Water property on Kirkwood Street on the eastern side of the Wakehurst Parkway.

The eastern option was identified as the preferred location for this temporary construction support site, as it:

- Avoids impact to the operation of Seaforth Oval
- Minimises potential impacts on the nearby community precinct
- Uses land owned by the NSW Government

- Allows tunnelling to occur in both a northerly and southerly direction (reducing construction duration).

This site is referred to in Chapter 6 (Construction work) as the Wakehurst Parkway east construction support site (BL13).

Flat Rock Drive tunnel temporary construction support site

For tunnelling in the area from Naremburn to Middle Harbour, two tunnelling sites would be the preferred strategy for tunnelling logistics. This would be the preference for the safety of construction workers, to maximise the efficiency of tunnelling and to limit project costs. Due to the highly urbanised nature of the suburbs between Naremburn and Middle Harbour, and the depth of the tunnel through this area, limited viable intermediate tunnelling sites were considered to be suitable for the project. Due to these limiting factors, although not ideal for tunnelling construction efficiencies, only one tunnelling site has been proposed between Naremburn and Middle Harbour.. With no intermediate tunnelling site be provided between Naremburn and Middle Harbour, all tunnelling for this area is proposed to be completed from Flat Rock Drive. This would result in the longest one-way drive carried out for a motorway tunnel in Hawkesbury Sandstone, additional cost and an increase in the intensity and duration of construction activities.

Multiple sites were considered, and two sites were shortlisted as options to support tunnel construction from Flat Rock Drive:

- On the Flat Rock baseball diamond located on the western side of Flat Rock Drive
- Within part of Flat Rock Reserve on the eastern side of Flat Rock Drive in land that was revegetated post 1998.

Other alternative sites as well as potential additional intermediate tunnelling sites to improve tunnelling efficiency were considered unfavourable as they would have required haulage of spoil on local streets (some of which are narrow), caused local amenity impacts and resulted in the acquisition of a substantial number of private residential and/or commercial properties.

The Flat Rock Reserve option was identified as the preferred location for this tunnel temporary construction support site, primarily because it avoids direct impacts to the local operational recreation facilities of Willoughby Recreation Centre, netball courts, the baseball diamond and other recreation spaces on the western side of Flat Rock Drive, which are in high demand for local community use.

Additionally, the preferred site would provide direct arterial road access, avoiding haulage through local streets and town centres and direct impacts to private properties. The size of the preferred site would allow the construction of an access decline and the ability to tunnel in three different directions, reducing the number of required intermediate tunnelling sites.

The Flat Rock Reserve site includes native vegetation which will be impacted, however the majority of this vegetation has been established relatively recently as part of the progressive rehabilitation of a former landfill over the last twenty years. This site is referred to in Chapter 6 (Construction work) as the Flat Rock Drive construction support site (BL2).

4.5.8 Spoil transport alternatives

Most of the spoil generated by major transport infrastructure projects currently under delivery and development would be Virgin Excavated Natural Material (VENM). VENM is considered a desirable material for clean fill in development sites and major earthworks projects across Greater Sydney.

Securing spoil disposal sites to meet production throughout construction and during bad weather is critical to the delivery program of tunnelling projects. Most reuse arrangements are directly negotiated between construction contractors and councils or private developers – with major projects often using many sites to optimise haulage and cost.

Tunnel spoil generated from major projects in Sydney is generally transported via road due to the majority of reuse sites being within the Sydney basin and the desire to minimise double handling of material.

Options to reduce impacts of spoil haulage on the surface road network were considered during development of the project. The spoil transportation strategy for the project includes road haulage from all sites.

In addition to the mitigation measures adopted within the proposed construction strategy, additional options to reduce spoil haulage impacts have been considered, including rail or barge as outlined below.

Rail

Freight rail was considered as a mode of spoil transport that may offer the opportunity to move large volumes of material and reduce the number of heavy vehicle movements on the Greater Sydney road network. However, when considering the location of the project and associated temporary construction support sites, this method presents the following issues:

- The material would need to be at least double and, most likely, triple handled. Trucks would be required to move material from temporary construction support sites to a suitable train loading facility, and from the rail terminus to the final disposal location. This would greatly undermine the benefits of any such arrangement, as heavy vehicles are typically on the motorway network shortly after leaving the proposed tunnelling temporary construction support sites. Analysis of haulage to potential train loading facilities concluded that heavy haulage distances on non-motorways would actually increase if this option was adopted
- There are few spare timeslots for freight trains on the Sydney rail network, which presents a considerable construction risk. If the material cannot be reliably moved, large spoil storage facilities would be required to ensure tunnelling operations are not interrupted
- Infrastructure upgrades would be necessary to develop an appropriate train loading facility to receive the material.

Barge

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 on the wider road network.

Barges would be used for the transport of material excavated from Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8), and for deliveries and staff transport to the cofferdam sites. Barges would also be used for the transport of dredge material from the Middle Harbour crossing to the offshore disposal site (further detailed in Section 4.5.10).

However, beyond this, use of barges for handling spoil presents a number of issues, including:

- As none of the Beaches Link tunnelling sites are located adjacent to the harbour or a navigable waterway, the use of barges would require tunnel spoil to be trucked to a harbourside transfer site where it would need to be transferred to barges
- The material would need to be double (or possibly triple) handled, as trucks would be required to move material to a harbourside barge loading facility, possibly through local streets and from the barge to its final disposal location
- Infrastructure upgrades would potentially be required to allow the barge loading facility to receive the material
- Given the requirement to haul material from tunnelling sites to the harbour and from the final barge point to the disposal site, this option is unlikely to materially decrease heavy haulage impacts.

Truck

Spoil removal using trucks would involve transporting material from the construction sites directly to its final destination and would occur primarily via the arterial road network. However, as trucks would be limited to transporting relatively small volumes of spoil (about 25 to 30 tonnes per truck), a large number of truck movements would be required. The use of trucks would streamline the handling of spoil as minimal double or triple handling would be required, but would result in a higher number of trucks on the road. Transport by other transport options (rail and barge) would still require trucks to move material to or from the loading facility and, potentially, to the final destination.

Preferred alternative

A combination of mostly trucks and some barging for Middle Harbour dredging operations is the preferred spoil transport option for the project. With the major temporary construction support sites for Beaches Link all located close to the arterial road network, this solution minimises impacts on the local road network while delivering an efficient and value for money spoil transport solution.

Chapter 6 (Construction work) provides a summary of heavy vehicle movements, including spoil related haulage.

4.5.9 Tunnelling spoil reuse and disposal alternatives

As described in Chapter 24 (Resource use and waste management), spoil would be beneficially reused as part of the project before alternative spoil disposal options, such as other infrastructure or development projects, would be pursued.

Most of the spoil generated by the project would be VENM, which is considered a desirable material for clean fill in development sites and major earthworks projects across Greater Sydney. Generally, VENM is not disposed of at licenced landfills, primarily due to the high cost of doing so in comparison to reuse at development sites. It is proposed that such material generated from the construction works at Balgowlah Golf Course would partly remain on site and be reused to create a landform to support its re-purposing as new and improved open space and recreation facilities.

Residual spoil waste which cannot be reused or recycled would be disposed of at a suitably licensed landfill or waste management facility. Potential opportunities for reuse of spoil within the project include use for the formation of embankments and earth mound noise barriers, site rehabilitation and landscaping, road upgrades and infill for temporary tunnel access declines.

Alternative and/or additional spoil reuse options may be identified by the construction contractor as the project progresses.

Determination of the final destination(s) for spoil from construction of the project would be made during further design development and may include more than one disposal site.

4.5.10 Dredged and excavated harbour bed material management alternative

The project would require material to be dredged and excavated from Middle Harbour to allow for the construction of the immersed tube tunnel crossing between Northbridge and Seaforth. A number of options for the disposal and reuse of these dredged and excavated materials have been considered as part of the development of the project, including:

- Land disposal at a licensed waste management facility
- Offshore disposal.

A summary of the alternatives considered for the disposal and reuse of these materials is provided below.

Land disposal at a licenced waste management facility

Disposal of all dredged and excavated materials from Middle Harbour only to a licensed waste management facility would require:

- Dewatering to a spadable condition prior to disposal, potentially requiring mixing of the material with additives to alter the consistency of the material, enabling it to be transferred to land. Dewatering may require large areas of land, depending on the quantity of material, which may result in additional property acquisition, large and noisy machinery and potential impacts to nearby receivers
- Large volumes of marine vessel movements to transfer dredged and excavated materials to a loadout facility for treatment
- Large volumes of heavy vehicle movements to transfer material (once spadable) to a licensed waste management facility.

Disposal of this material at a licensed waste management facility would likely be at a landfill and would therefore require the use of landfill space. Given the potential environmental impacts associated with the disposal off all dredged and excavated material to a licensed waste management facility, this option was not considered feasible.

However, it is expected that a relatively small amount of material dredged and excavated from Middle Harbour as part of the project may not be suitable for offshore disposal. The reuse of this material is not an option and, given the small amount of material, disposal at a licensed waste management facility is considered an appropriate option.

Offshore disposal

Transport for NSW will submit an application for offshore disposal of suitable dredged and excavated materials from Middle Harbour to the Australian Government Department of Agriculture, Water and the Environment. Offshore disposal is regularly used by marine excavation projects in NSW, with licenced disposal grounds in operation off Sydney Harbour and Newcastle. These sites have been carefully selected by the Australian Government to provide suitable disposal grounds for dredge and marine excavation material and minimise impacts on sensitive marine ecology. The proposed designated offshore disposal site is located about 10 to 15 kilometres offshore of Sydney Heads. The site is over 20 square-kilometres in area and is a non-dispersive ground, meaning that material placed within the area generally does not migrate from that area.

Material disposed of at the designated offshore disposal site (in accordance with legislative requirements) would comprise sediments and rock removed from Middle Harbour during the construction of the Middle Harbour south (BL7) and Middle Harbour north (BL8) cofferdams, and dredged sediment and rock material removed from Middle Harbour as part of the construction of the immersed tube tunnels.

Disposal of suitable dredged and excavated materials at the designated offshore disposal site would:

- Avoid disposal of spoil to land-based sites
- Avoid additional heavy vehicle movements on the road network
- Minimise some environmental impacts such as noise, odour and dust at sensitive receivers, by avoiding the need to carry out treatment, dewatering and land-based transport of all dredged and excavated material
- Avoid the creation of a sizeable waste stream on land.

Material would be required to satisfy the requirements of the *National Assessment Guidelines for Dredging* (Department of Environment, Water, Heritage and the Arts, 2009) before being considered suitable for disposal at the designated offshore disposal site.

Preferred dredged and excavated materials management option

The preferred option for the disposal and/or reuse of dredged and excavated materials is a combination of mostly offshore disposal and some disposal at a licensed land based waste facility. To minimise the potential environmental impacts associated with the disposal and reuse of dredged material, where dredged material complies with the *Environment Protection (Sea Dumping) Act 1981*, it would be disposed of at the designated offshore disposal site. Where material is not suitable for offshore disposal, it would be barged to a loadout facility for treatment to be made spadable and then loaded onto trucks and disposed of at a suitably licensed land-based facility (at a location yet to be determined), and classified according to the NSW Environment Protection Authority's *Waste Classification Guidelines.*

Chapter 6 (Construction work) provides a summary of heavy vehicle and vessel movements relating to the transport of dredged and excavated materials to land for disposal at a licensed waste management facility. Chapter 24 (Resource use and waste management) details the indicative quantities of material requiring disposal at a licensed waste management facility and suitable for disposal at the designated offshore disposal site.

Offshore disposal of dredged and excavated materials would be conducted outside NSW and is therefore not regulated under the *Environmental Planning and Assessment Act 1979* or considered further in this environmental impact statement. Daily maximum construction maritime traffic volumes and routes to navigational channels that lead to Sydney Heads, including barge movements for offshore disposal of suitable dredged and excavated materials, are summarised in Chapter 6 (Construction work) and considered in Chapter 8 (Construction traffic and transport) and Section 5.5 of Appendix F (Technical working paper: Traffic and transport). Noise impacts related to the use of barges at water-based temporary construction support sites have been considered in Chapter 10 (Construction noise and vibration) and Appendix G (Technical working paper: Noise and vibration).