



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 15

Aboriginal cultural heritage

15 Aboriginal cultural heritage

This chapter outlines the potential Aboriginal cultural heritage impacts associated with the project and identifies measures which address these impacts. A detailed Aboriginal cultural heritage assessment has been carried out for the project and is included in Appendix L (Technical working paper: Aboriginal cultural heritage assessment report).

The Secretary's environmental assessment requirements as they relate to Aboriginal cultural heritage, and where in the environmental impact statement these have been addressed, are detailed in Table 15-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures.

The proposed environmental management measures relevant to Aboriginal cultural heritage impacts are included in Section 15.5.

Table 15-1 Secretary's environmental assessment requirements – Aboriginal heritage

Secretary's requirement	Where addressed in EIS
1. The Proponent must identify and assess any direct and/or indirect impacts (including cumulative and visual impacts) to the heritage significance of listed (and nominated) heritage items includes of: <ul style="list-style-type: none"> a. Aboriginal places and objects, as defined under the <i>National Parks and Wildlife Act 1974</i> and in accordance with the principles and methods of assessment identified in the current guidelines; 	Section 15.4 identifies and assesses all Aboriginal places and objects. The legislative and policy framework used for this assessment is outlined in Section 15.1 , which includes reference to the guidelines used to consider potential impacts.
<ul style="list-style-type: none"> b. Aboriginal places of heritage significance, as defined in the Standard Instrument – Principal Local Environmental Plan; 	Section 15.3.3 identifies Aboriginal places of heritage significance as defined in the Standard Instrument – Principal Local Environmental Plan.
<ul style="list-style-type: none"> d. items listed on the State, National and World Heritage lists 	Section 15.3.3 identifies search results from relevant Aboriginal heritage databases. Listed non-Aboriginal heritage items are identified in Chapter 14 (Non-Aboriginal heritage).
<ul style="list-style-type: none"> e. heritage items and conservation areas identified in local and regional planning environmental instruments covering the project area; and 	Section 15.3.3 identifies search results relevant Aboriginal heritage databases including relevant local environmental plans.
<ul style="list-style-type: none"> f. marine items of potential heritage significance within Middle Harbour, such as any shipwrecks. 	Section 15.3.4 discusses potential submerged Aboriginal sites. Non-Aboriginal maritime heritage sites are discussed in Chapter 14 (Non-Aboriginal heritage).

Secretary's requirement	Where addressed in EIS
<p>2. Where impacts to State or locally significant heritage items or archaeology are identified, the assessment must:</p> <p>a. include a significance assessment and statement of heritage impact for all heritage items (including any unlisted places that are assessed of heritage value);</p>	<p>Significance assessments are presented in Section 15.3.</p>
<p>b. provide a discussion of alternative locations and design options that have been considered to reduce heritage impacts;</p>	<p>A discussion of alternative locations and design options is provided in Appendix L (Technical working paper: Aboriginal cultural Heritage assessment report) and Section 4.4 and Section 4.5 of Chapter 4 (Project development and alternatives).</p>
<p>c. in areas identified as having potential archaeological significance, undertake a comprehensive archaeological assessment and management plan in line with Heritage Council guidelines which includes a methodology and research design to assess the impact of the works on the potential archaeological resource and to guide physical archaeological test excavations and include the results of these excavations. This is to be carried out by a suitably qualified archaeologist and is to discuss the likelihood of significant historical, maritime and Aboriginal archaeology on the site, how this may be impacted by the project, and includes measures to mitigate any impacts;</p>	<p>Details of test excavations carried out are presented in Section 15.3 and Annexure D of Appendix L (Technical working paper: Aboriginal cultural Heritage assessment report).</p>
<p>d. consider impacts to the item of significance caused by, but not limited to, vibration, demolition, archaeological disturbance, altered historical arrangements and access, increased traffic, visual amenity, landscape and vistas, curtilage, subsidence and architectural noise treatment (as relevant);</p>	<p>Discussion of impacts to items of significance as a result of vibration, demolition, archaeological disturbance, altered historical arrangements and access, increased traffic, visual amenity, landscape and vistas, curtilage, subsidence and architectural noise treatment (as relevant) are provided in Section 15.4 and further discussed in Chapter 10 (Construction noise and vibration)</p>
<p>e. provide a comparative analysis to inform the rarity and representative value of any heritage places proposed for demolition;</p>	<p>No sites are proposed for demolition.</p>
<p>f. outline mitigation measures to avoid and minimise identified impacts in accordance with the current guidelines; and</p>	<p>Mitigation and management measures are presented in Section 15.5.</p>

Secretary's requirement	Where addressed in EIS
<p>g. be undertaken by a suitably qualified heritage consultant(s) (note: where archaeological excavations are proposed the relevant consultant must meet the NSW Heritage Council's Excavation Director criteria).</p>	<p>Appendix L (Technical working paper: Aboriginal cultural heritage assessment report) provides details of qualifications held by archaeologists.</p>
<p>3. Where archaeological investigations of Aboriginal objects are proposed these must be conducted by a suitably qualified archaeologist, meeting the minimum qualification requirements specified in section 1.6 of the <i>Code of Practice for Archaeological Investigation of Aboriginal Objects in NSW</i> (DECCW 2010).</p>	<p>Appendix L (Technical working paper: Aboriginal cultural heritage assessment report) provides details of qualifications held by archaeologists. Section 15.2 provides details of attendance for site surveys.</p>
<p>4. The Proponent must identify and describe the Aboriginal cultural heritage values that exist across the whole area that would be affected by the development and document these in an Aboriginal cultural heritage assessment report (ACHAR). This may include the need for surface survey and test excavation. The identification of cultural heritage values must be conducted in accordance with <i>Code of Practice for Archaeological Investigations of Aboriginal Objects in NSW</i> (OEH 2010), and guided by the <i>Guide to Investigating, Assessing and Reporting on Aboriginal Cultural Heritage in NSW</i> (Office of Environment and Heritage (OEH), 2011a).</p>	<p>Appendix L (Technical working paper: Aboriginal cultural heritage assessment report) documents Aboriginal cultural heritage values and details are summarised in Section 15.3.3 and Section 15.3.7.</p>
<p>5. Consultation with Aboriginal people must be undertaken and documented in accordance with the <i>Aboriginal cultural heritage consultation requirements for proponents 2010</i> (DECCW). The significance of cultural heritage values for Aboriginal people who have a cultural association with the land must be documented in the ACHAR.</p>	<p>Aboriginal stakeholder consultation was carried out in accordance with the <i>Procedure for Aboriginal Cultural Heritage Consultation and Investigation</i> (Roads and Maritime, 2011) and is discussed in Chapter 7 (Stakeholder and community engagement) and Appendix L (Technical working paper: Aboriginal cultural heritage assessment report). Aboriginal cultural significance was assessed through consultation and is summarised in Section 15.3.7.</p>
<p>6. Impacts on Aboriginal cultural heritage values are to be assessed and documented in the ACHAR. The ACHAR must demonstrate attempts to avoid impact upon cultural heritage values and identify any conservation outcomes. Where impacts are unavoidable, the ACHAR must outline measures proposed to mitigate impacts. Any objects recorded as part of the assessment must be documented and notified to the Environment, Energy and Science Group in the Department of Planning, Industry and Environment.</p>	<p>Appendix L (Technical working paper: Aboriginal cultural heritage assessment report) documents potential impacts and management recommendations. These are summarised in Section 15.4 and Section 15.5.</p>

Secretary's requirement	Where addressed in EIS
Note that due diligence is not an appropriate assessment, and an ACHAR is required	Appendix L (Technical working paper: Aboriginal cultural heritage assessment report)

15.1 Legislative and policy framework

The primary legislation relevant to Aboriginal cultural heritage in NSW is the *National Parks and Wildlife Act 1974* (NPW Act) and its supporting regulation, which provides for the management of Aboriginal land, objects and places. Although an Aboriginal heritage impact permit would not be required for the project under section 90 of the NPW Act (refer to Chapter 2 (Assessment process)), an equivalent level of assessment and consultation has been carried out.

The requirement to consider potential impacts on Aboriginal cultural heritage, including objects and places, is given effect through the following guidelines:

- *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales* (DECCW, 2010d)
- *Guide to Investigating, Assessing and Reporting on Aboriginal Cultural Heritage in NSW* (OEH, 2011a)
- *Aboriginal Cultural Heritage Consultation Requirements for Proponents* (DECCW, 2010b)
- *Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW* (DECCW, 2010c).

The *Procedure for Aboriginal Cultural Heritage Consultation and Investigation* (PACHCI) (Roads and Maritime Services, 2011a) specifically tailors and applies the requirements of these guidelines to its road projects.

The *Native Title Act 1993* (Commonwealth) and *Aboriginal Land Rights Act 1983* (NSW) provide a framework for the protection of native title rights on certain Crown lands. There are no Crown lands subject to a native title claim within the footprint of the project.

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Commonwealth) aims to recognise the role of Indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity, and to promote the use of Indigenous peoples' knowledge of biodiversity with the involvement of, and in cooperation with, the owners of the knowledge. The EPBC Act establishes both the National Heritage List, which includes natural, Indigenous and historic places that are of outstanding heritage value to the nation, and the Commonwealth Heritage List, which includes places on Commonwealth lands and waters or under Australian Government control that have Indigenous heritage significance. There are no Aboriginal heritage items in the detailed investigation area that are registered on either the National or Commonwealth lists.

The *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (Commonwealth), provides for the protection of Aboriginal cultural property that are of particular significance to Aboriginals in accordance with Aboriginal tradition and may apply to Aboriginal cultural property as well as ancient sites.

15.2 Assessment methodology

The Aboriginal cultural heritage assessment was carried out in accordance with the PACHCI (Roads and Maritime Services, 2011a). The PACHCI applies the requirements of other relevant guidelines (refer to Section 15.1) to road projects.

The PACHCI provides Aboriginal people with the opportunity to participate in the decision making process regarding the management of their cultural heritage, by providing Transport for NSW with information regarding cultural significance as well as providing input into management options, if required. The PACHCI includes up to four stages of assessment, all of which are relevant and have been applied to the project:

- Stage 1 – a desktop risk assessment was carried out to determine whether the project may potentially impact on Aboriginal cultural heritage and require further assessment or investigation. The desktop risk assessment considered relevant registers and databases, including but not limited to the Aboriginal Heritage Information Management System (AHIMS)
- Stage 2 – because Stage 1 identified a risk of impact on Aboriginal cultural heritage, site surveys of relevant areas were carried out in consultation with the Metropolitan Local Aboriginal Land Council
- Stage 3 – because Stage 2 identified that there may be an impact on Aboriginal cultural heritage, an Aboriginal cultural heritage assessment report (ACHAR) was prepared and formal consultation with Aboriginal stakeholders was carried out
- Stage 4 – the outcomes and recommendations from the ACHAR, including mitigation and management measures, would be implemented during construction and operation of the project.

For the purpose of the Aboriginal cultural heritage assessment, all areas within 300 metres of the project's construction footprint were considered. As project refinements were made during the Stage 3 PACHCI process, this search area was refined to 50 metres (see Figure 15-1). Searches of AHIMS, relevant local environmental plans and State and Commonwealth heritage registers were carried out on 1 May 2017. A further search of AHIMS sites was carried out on 8 April 2020 to determine if any additional sites were apparent. No new AHIMS sites were determined from those identified in the 2017 search.

Site surveys were carried out in May, June and August 2017 by a qualified archaeologist accompanied by a representative of the Metropolitan Local Aboriginal Land Council. Aboriginal site officers were also engaged for archaeological field inspections in January 2018. Additional assessments were carried out with nominated site officers representing the Metro Metropolitan Local Aboriginal Land Council in August 2018, February 2020 and September 2020. During these surveys, site officers were provided an opportunity to comment on the potential for Aboriginal cultural material to be present within the study area, the cultural significance of any Aboriginal cultural heritage sites identified during the survey and proposed management recommendations, including recommendations for further assessment. Feedback from Registered Aboriginal Parties has also been incorporated into the assessment.

Registered Aboriginal Parties were identified in accordance with the DECCW guidelines (2010b) and invited to an Aboriginal focus group (AFG) meeting on the project, held on 28 September 2017. A second AFG was held on 3 November 2020. Through these meetings Registered Aboriginal Parties have been provided an opportunity to review site surveys and assessment methodology. Feedback from Registered Aboriginal Parties has been incorporated into the ACHAR.

Aboriginal stakeholder consultation was carried out in accordance with the PACHCI and is discussed in Chapter 7 (Stakeholder and community engagement) and Appendix L (Technical working paper: Aboriginal cultural heritage assessment report).

In conjunction with the PACHCI process, an assessment of potential submerged Aboriginal sites was carried out within the marine environment of the project area. Where possible, the assessment of potential submerged Aboriginal sites was coordinated with the PACHCI process.

The potential submerged Aboriginal sites assessment included:

- Review of existing information and remote sensing data
- Field survey, carried out as part of the maritime archaeological dive inspections in December 2017 at two locations where rock outcrops indicated the potential for the presence of rock overhangs which could have associations with past human occupation
- Establishing a predictive model of maritime heritage potential to guide the assessment of significance and sensitivity
- Assessing potential impacts and providing appropriate mitigation and management measures.

15.3 Existing environment

15.3.1 Ethnographic and archaeological context

The Sydney area has a rich indigenous heritage. Aboriginal occupation focused on accessing resources from diverse ecological areas, seasons and conditions. Occupation sites, hunting, travel and inter-clan contact would have been associated with coastal areas, smaller rivers, creeks and swamps.

Aboriginal occupation in the Sydney area is known to have extended beyond the Last Glacial Maximum (about 21,000 years ago). Evidence of Aboriginal occupation in NSW dates back to around 50,000 to 60,000 years ago at Lake Mungo, up to 30,000 years ago at Parramatta, and is increasingly identified at other locations in the Sydney Basin.

Until the most recent ice age, about 12,000 years ago, sea levels were about 100 metres below their current level and the eastern coastline of Australia was about 25 to 30 kilometres further east. As the climate grew warmer and the sea level began to rise, these freshwater creeks and rivers were gradually drowned, and the lower-middle slopes of the ancient valleys were slowly inundated. The sea eventually flooded the area that became Port Jackson, and food resources would have changed dramatically. The sea level stabilised about 6000 to 8000 years ago which allowed the development of the foreshore maritime resource economy that then operated until after the arrival of the First Fleet in 1788.

Numerous open and rockshelter sites with shell middens and remains of fish and land mammals dating to the past 4500 years are known around Port Jackson, including Middle Harbour (Attenbrow, 2010). The material culture of Aboriginal people reflected a reliance on organic materials, using an intimate understanding of timber, plant and animal products to make utensils, tools and weapons. Igneous stone suitable for hatchet heads and stone for flaking, cutting and scraping were not naturally available in the area and could be traded from long distances.

Historically, Aboriginal people lived in small family or clan groups that were associated with particular territories or places. The project would be located on land within the boundaries of the Darug linguistic group. The two dialects of *Darug* are suggested to have been used: the coastal dialect (area between Sydney Harbour and Botany Bay, and west to Parramatta), and the hinterland dialect (area to the west of the Cumberland Plain) (Attenbrow, 2010).

Rock shelters appear to have been widely used by Darug-speaking peoples in coastal areas at the time of European contact. Existing data suggests that dominant site types for this region include rock shelters, artefact scatters and isolated artefacts, with middens present in the coastal areas further north. Applied art in rock shelters and engravings on sandstone platforms were common in this part of Sydney, although their fragility means that many have been lost in the past two centuries.

There is evidence of Aboriginal occupation throughout the study area, with areas of plentiful food resources associated with shorelines, riparian zones and adjacent areas including Clive Park, Burnt Bridge Creek and Flat Rock Creek. During urban development, many of these areas have been covered by fill, concealing original formations. Some evidence of Aboriginal occupation may also be present along movement pathways, meeting and camping sites, which were often associated with ridgelines.

15.3.2 Environmental and landscape context

The lower North Shore landscape region is a highly urbanised and developed landscape with only very small pockets of unmodified landscape remaining. The lower North Shore portion of the study area includes several parks and reserves including St Leonards Park, ANZAC Park, Cammeray Golf Course, Artarmon Park and Artarmon Reserve, as well as the Flat Rock Reserve and the surrounding alluvial terraces and exposed sandstone outcrops. These parks and reserves have been subject to less intensive disturbance and may have increased potential for Aboriginal sites.

The Middle Harbour and Balgowlah landscape region is also a highly urbanised landscape with only very small pockets of unmodified landscape remaining. The landscape region is characterised by undulating to rolling low hills on Hawkesbury Sandstone with local reliefs of 20 to 80 metres and slopes of 10 to 25 per cent and rock outcrops of less than 25 per cent. A gentler gradient at Clive Park descends from Northbridge into a shallower portion of Middle Harbour with the Spit Bridge located where a long, narrow sandbar once formed. Middle Harbour is bordered by steep headlands of exposed Hawkesbury Sandstone with some low hills and rises on Triassic and later sediments. The study area traverses the low gradient at Clive Park towards Seaforth and Balgowlah, where Burnt Bridge Creek is situated in Hawkesbury Sandstone bedrock.

At the Wakehurst Parkway landscape region, there are sections of undisturbed remnant landscapes in two locations within or in close proximity to the project (Garigal National Park and Manly Dam Reserve). The Wakehurst Parkway is located within an erosional landscape comprising undulating to rolling low hills on Hawkesbury Sandstone, broad ridges, gently to moderately inclined slopes, wide rock benches with low broken scarps, small hanging valleys and areas of poor drainage. The landscape region is characterised by rugged, rolling to very steep hills on Hawkesbury Sandstone with local reliefs of 40 to 200 metres with rock outcrops and shallow, stony, highly permeable soils. The Wakehurst Parkway landscape region is particularly significant because of the Hawkesbury Sandstone and its association with known Aboriginal rock engravings.

15.3.3 Database search results

AHIMS sites in the region around the project are shown in Figure 15-1. Of these, 11 sites have been identified within 50 metres of the project construction footprint including:

- One artefact scatter
- Four art sites (engraving and pigment)
- Three rock shelters (with middens)
- Three potential archaeological deposits (PADs).

The location and condition of one of the sites (45-6-0662) was unable to be confirmed during field inspection and the Aboriginal Heritage Office has advised that the site was likely covered by gravel/vegetation. As such, a desktop assessment of this site was carried out, basing findings on settlement and vibration modelling.

The site Wakehurst Engraving MAN 104 (45-6-3032) was observed to be significantly damaged during field inspection in September 2020. This resulted in notification to the Department of Premier and Cabinet (Heritage) (also known as Heritage NSW).

A further three additional AHIMS sites, 45-5-2222 (Clive Park 4; Northbridge) 45-6-0994 (Chatswood) and 45-6-1587 (Seaforth) were initially identified within the study area but were later confirmed as being incorrectly mapped and were determined to sit outside the study area. These sites do not form part of the eleven sites identified within the study area and have not been considered further in this assessment.

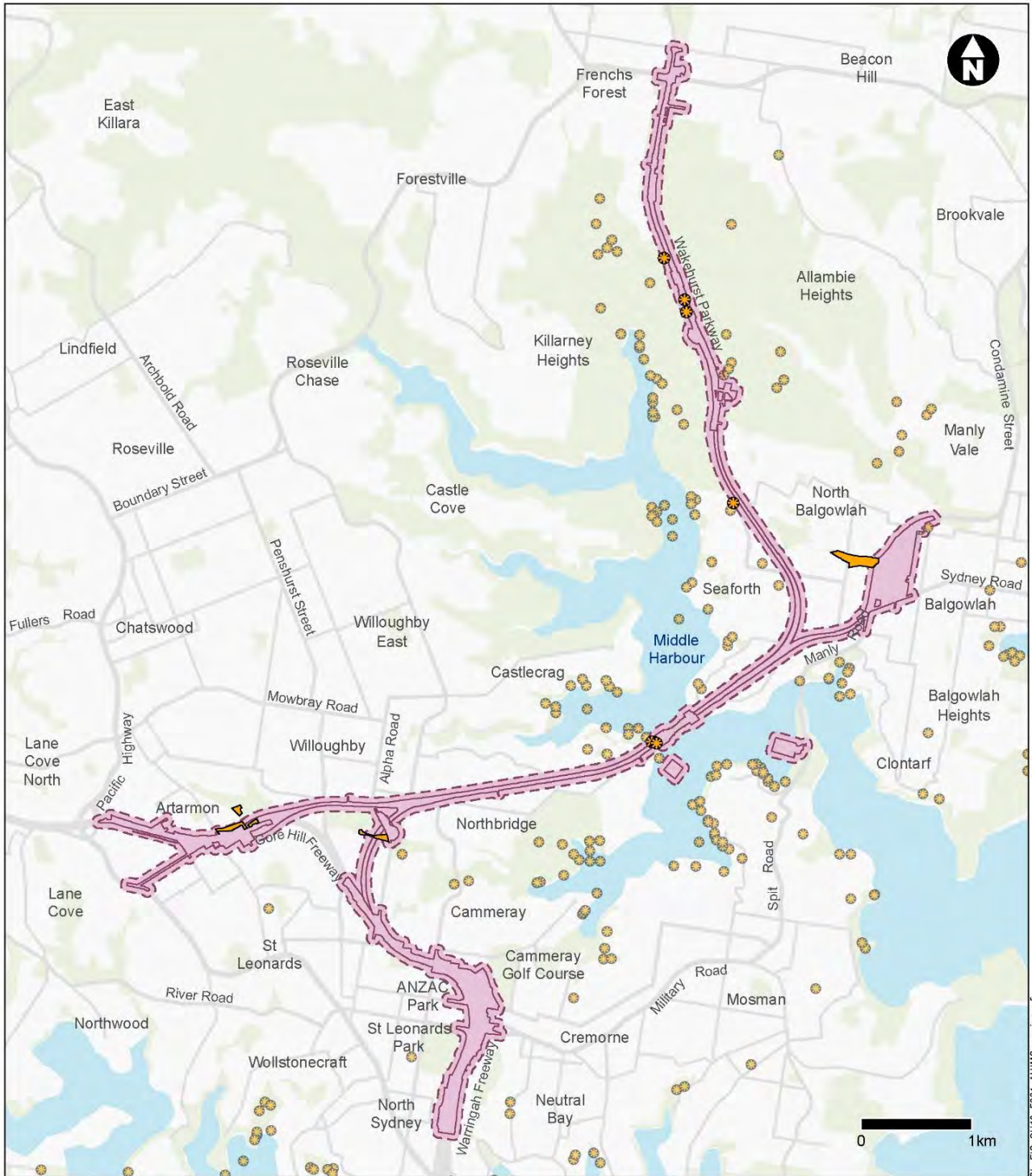
Details of the AHIMS sites, including Aboriginal cultural values identified through consultation with knowledge holders, are summarised in Table 15-2. The proximity of these sites to the construction footprint is shown in Figure 15-2 to Figure 15-5. The location of Aboriginal sites presented in Figure 15-2 to Figure 15-5 is based on the results of extensive AHIMS searches. Where possible, the location of these sites was confirmed during the archaeological survey.

No relevant items were identified in schedule 5 of the *North Sydney Local Environmental Plan 2013*, the *Willoughby Local Environmental Plan 2012* or the *Warringah Local Environment Plan 2011*.

Table 15-2 AHIMS sites within 50 metres of the project construction footprint




AHIMS site ID	Site name	Site type	Proximity to the project	Cultural value description
45-6-3599	Artarmon Park artefact scatter	Sub-surface artefact scatter	Within 50 metres of surface works at the Gore Hill Freeway Connection.	Part of cultural area and occupation site
45-6-3362	Artarmon Park potential archaeological deposit (PAD)	Potential archaeological deposit	Within 50 metres of surface works and the ramp tunnels at the Gore Hill Freeway Connection and Beaches Link on-ramp (portal).	Part of cultural area and occupation site
45-6-3361	Flat Rock Creek PAD	Potential archaeological deposit	Within 50 metres of surface works and above the alignment of the mainline tunnels at Flat Rock Drive construction support site (BL2).	Part of cultural area and occupation site
45-6-3012	Clive Park 8, Shelter and Midden	Shelter and midden (rock shelter is less than 50 m ³ in size)	Located above the mainline tunnels at Clive Park and within 50 metres of the Middle Harbour south cofferdam construction support site (BL7).	Part of cultural area and occupation site
45-6-0654	Clive Park 1; Northbridge	Shelter with midden, art, burial/s and artefact scatter (rock shelter is less than 50 m ³ in size)	Located above the mainline tunnels at Clive Park and within 50 metres of the Middle Harbour south cofferdam construction support site (BL7).	Part of cultural area and occupation site
45-6-0996	Clive Park 2; Taplin's Cicada Pupa Cave	Shelter with art and midden (rock shelter is less than 50 m ³ in size)	Located above the mainline tunnels at Clive Park and within 50 metres of the Middle Harbour south cofferdam construction support site (BL7).	Part of cultural area and occupation site
45-6-3363	Burnt Bridge Creek PAD	Potential archaeological deposit	Within 50 metres of surface works at Balgowlah and the ramp tunnels.	Part of cultural area and occupation site
45-6-3032	Wakehurst Engraving MAN 104	Rock engraving on outcrop	Within 50 metres of the ramp tunnels at Seaforth. Damage to the site was observed during field inspection in September 2020.	Part of cultural area and occupation site
45-6-2940	Rock engraving (Garigal National Park)	Rock engraving	Within 50 metres of surface works on Wakehurst Parkway (Killarney Heights).	Part of cultural area and occupation site

AHIMS site ID	Site name	Site type	Proximity to the project	Cultural value description
45-6-0662	Frenchs Forest; Bantry Bay; Wakehurst Parkway	Rock engraving	Potentially within 50 metres of surface works on Wakehurst Parkway (Killarney Heights). Location and condition of site could not be confirmed during field inspection as site is likely covered by gravel/vegetation.	Part of cultural area and occupation site
45-6-0655	Bantry Bay Aboriginal Engraving Site	Large rock engraving site with multiple engravings	Within 50 metres of surface works on Wakehurst Parkway (Killarney Heights).	Part of cultural area and occupation site



Legend

Construction features

-  50 metre area around construction footprint
-  Construction footprint
-  Tunnel

AHIMS sites




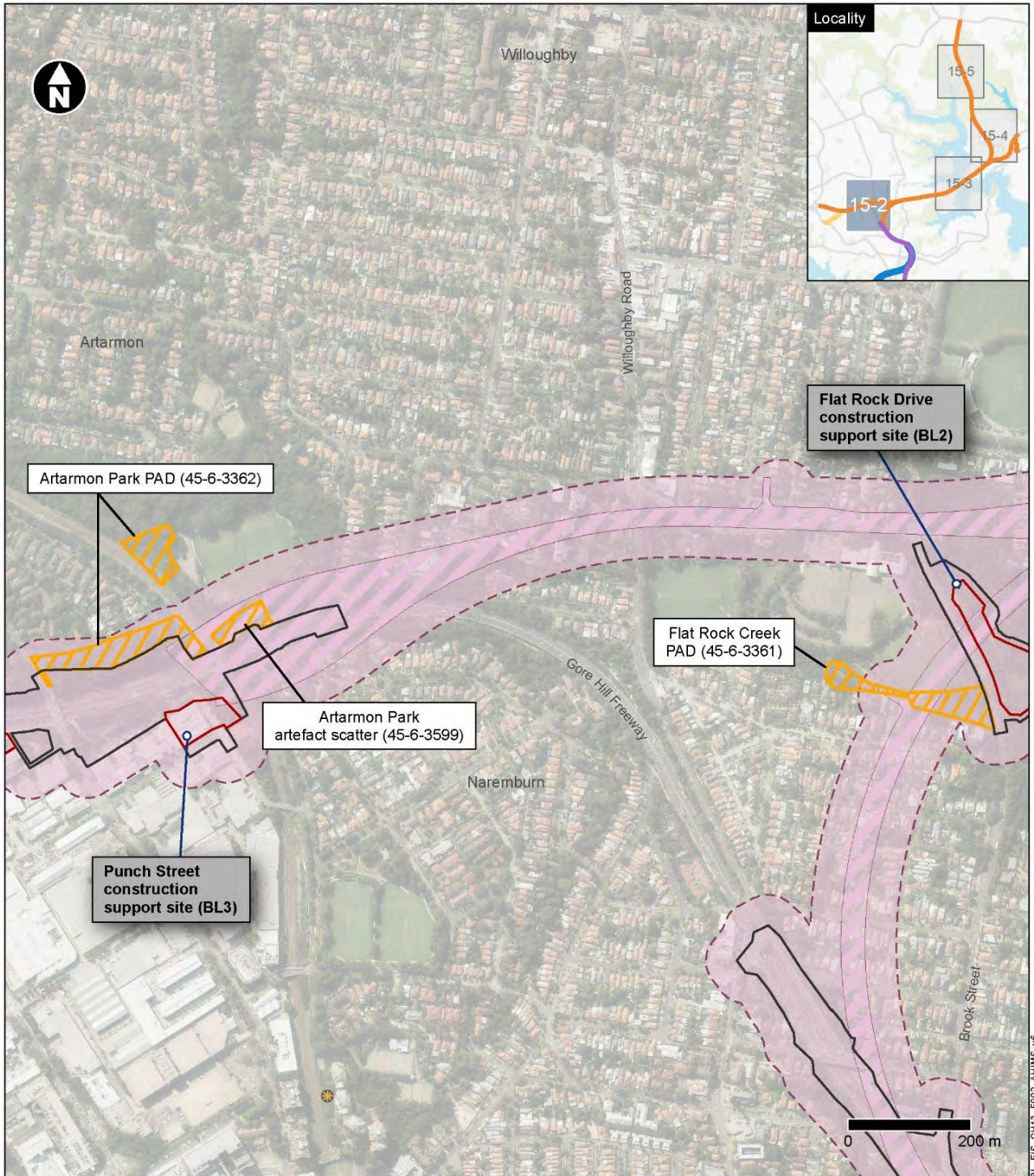




-  AHIMS site within 50 metres of the construction footprint
-  AHIMS site over 50 metres from the construction footprint
-  Potential Archaeological Deposit

Figure 15-1 AHIMS sites in the region around the project



Legend

Construction features

-  50 metre area around construction footprint
-  Construction footprint
-  Construction support site
-  Tunnel

AHIMS sites



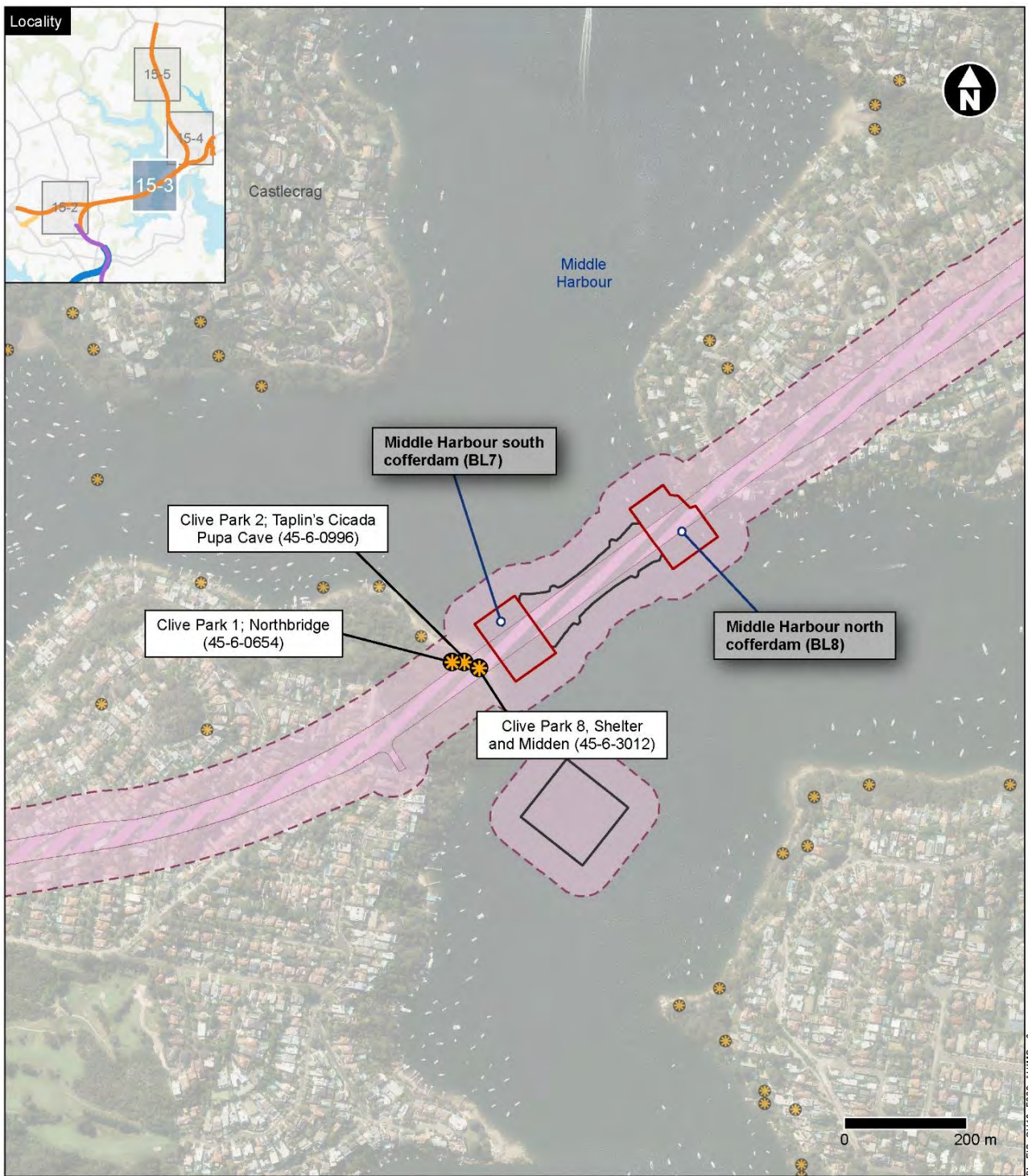




-  AHIMS site over 50 metres from the construction footprint
-  Potential Archaeological Deposit

Figure 15-2 AHIMS sites within 50 metres of the project construction footprint (Gore Hill Freeway and Flat Rock Creek)



Legend

Construction features

-  50 metre area around construction footprint
-  Construction footprint
-  Construction support site
-  Tunnel

AHIMS sites



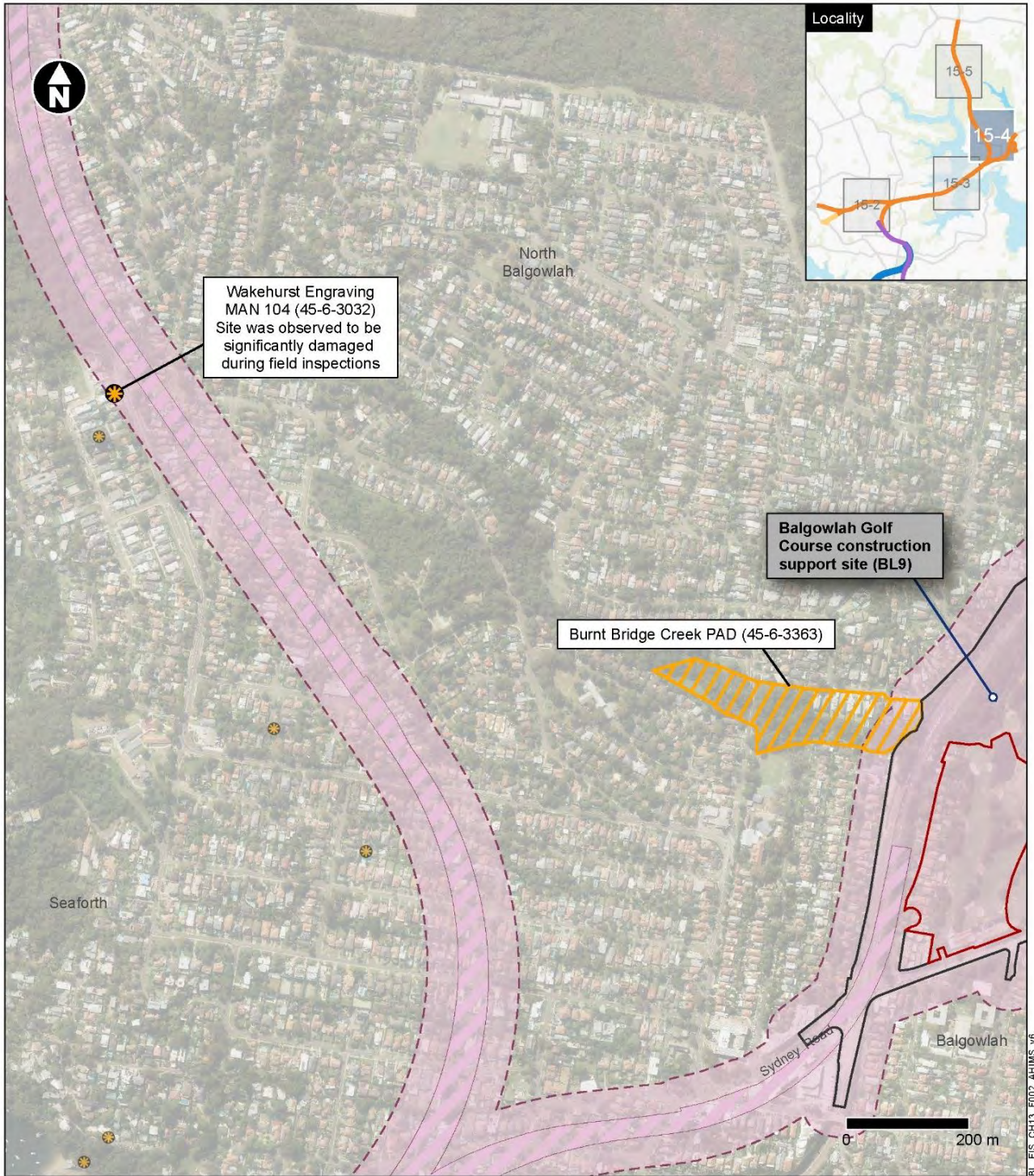
-  AHIMS site within 50 metres of the construction footprint
-  AHIMS site over 50 metres from the construction footprint

Figure 15-3 AHIMS sites within 50 metres of the project construction footprint (Middle Harbour)



Legend

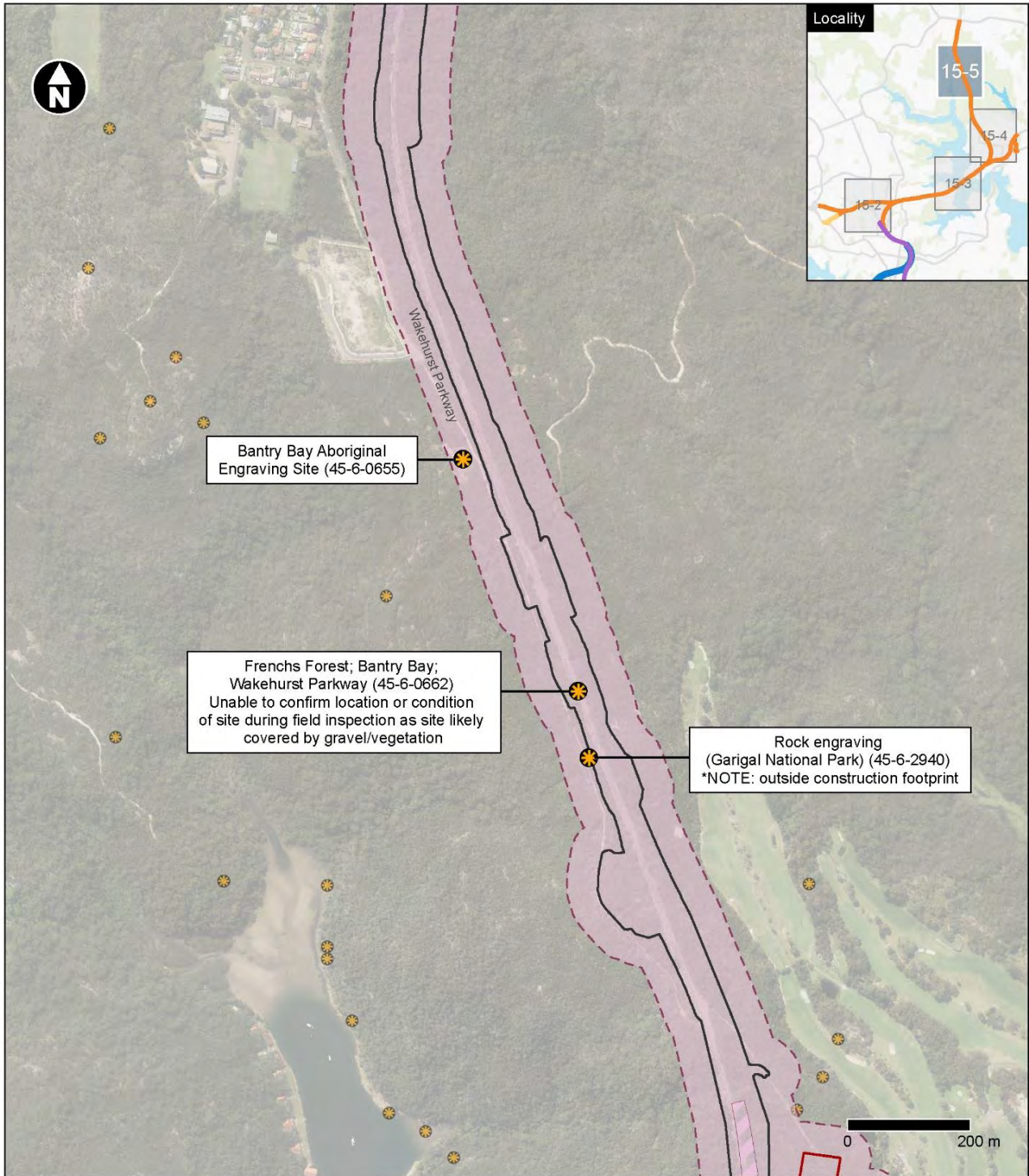
Construction features

- 50 metre area around construction footprint
- Construction footprint
- Construction support site
- Tunnel

AHIMS sites

- AHIMS site within 50 metres of the construction footprint
- AHIMS site over 50 metres from the construction footprint
- Potential Archaeological Deposit

Figure 15-4 AHIMS sites within 50 metres of the project construction footprint (Seaforth to Balgowlah)



Legend

Construction features

- 50 metre area around construction footprint
- Construction footprint
- Construction support site
- Tunnel

AHIMS sites

- AHIMS site within 50 metres of the construction footprint
- AHIMS site over 50 metres from the construction footprint

Figure 15-5 AHIMS sites within 50 metres of the project construction footprint (Wakehurst Parkway)

15.3.4 Potential submerged Aboriginal sites

Potential submerged Aboriginal archaeological sites refers to archaeological sites inundated since around 17,000 years ago, when the sea level began to rise, eventually flooding the river valley and forming a flood tide delta (Sydney Institute of Marine Science 2014). Aboriginal archaeological sites that could occur in inundated areas of the study area include:

- Rock shelters with occupation evidence and deposit
- Art and grinding grooves on sandstone ledges and faces
- Middens and/or stone artefact scatters on sandstone platforms and elevated area
- Fish traps on shallow, wide and gently sloping sandstone platforms.

The probability of these surviving intact, or at all depends on how the sea rose – gradually or as an encroaching active shoreline with wave and tidal action, and the subsequent pattern of tidal flow. The pronounced rock outcrops at about 20 metres depth close to Seaforth Bluff are considered to have moderate to high potential for the presence and survival of inundated rock shelters, more so than smaller rock overhangs closer to Clive Park which have been assessed as having low potential. At 30 metres below the current bed of the harbour, peat deposits present along the ancient watercourse that formed Middle Harbour have the greatest potential to contain well-preserved archaeological objects. There is a moderate to high potential for all identified site types listed above to be present in the Pearl Bay (west of Spit West Reserve) and the area between Clive Park and Beauty Point.

Potential rock overhangs are submerged and concealed by marine sediments, so they cannot be readily accessed and assessed. The assessment of impacts to submerged Aboriginal archaeological sites is therefore based on the potential for such sites to exist, using available geophysical information and an understanding of site formation processes.

Areas where submerged Aboriginal archaeological sites could occur have been considered based on a combination of the likelihood of the site occurring and the likelihood of it surviving inundation. Table 15-3 presents how archaeological potential has been defined, based on the likelihood of a site's presence.

Table 15-3 Defining Aboriginal archaeological potential

Archaeological potential	Likelihood of presence
Moderate to high	50–100 per cent
Low	25–49 per cent
Very Low	2–24 per cent
Remote	Less than 0–1 per cent

Table 15-4 summarises areas of submerged Aboriginal archaeological potential relevant to the project.

Table 15-4 Summary of areas of submerged Aboriginal archaeological potential

Location	Potential Aboriginal site type	Archaeological potential	Predicted potential location within study area
Between Northbridge and Seaforth	Stone artefacts, midden deposits and fish traps	Moderate to high	Formed along the ancient watercourse (as shown from geotechnical investigations).
	Rock shelters	Moderate to high	Along the sloping bed of the harbour on the Seaforth side of Middle Harbour.
	Rock shelters	Low	Along the sloping bed of the harbour on the Clive Park side of Middle Harbour.
	Rock shelters, art, grinding grooves, middens, stone artefact scatters, quarry sites and fish traps	Very low	Across the remainder of the study area.
Pearl Bay (west of Spit West Reserve)	Rock shelters, grinding grooves, middens and/or stone artefact scatters, stone quarry sites, fish traps	Moderate to high	In potential residual soils and/or sandstone overhangs/ledges, creek lines that may occur buried beneath Holocene marine sediments, up to up 30 metres thick below the current surface bed of the harbour.
Between Clive Park and Beauty Point)	Rock shelters, grinding grooves, middens and/or stone artefact scatters, stone quarry sites, fish traps.	Moderate to high	In potential residual soils and/or sandstone overhangs/ledges, creek lines that may occur buried beneath Holocene marine sediments which are assumed to comprise at least the first few metres of the current bed of the harbour.

15.3.5 Archaeological survey results

Targeted archaeological surveys were carried May, June and August 2017 to confirm the location of registered AHIMS sites and to assess areas identified as having potential Aboriginal archaeological sensitivity based on particular landforms. Additional assessments were undertaken with nominated site officers representing the Metropolitan Local Aboriginal Land Council in August 2018, February 2020 and September 2020. During these surveys, site officers were provided an opportunity to comment on the potential for Aboriginal cultural material to be present within the study area, the cultural significance of any Aboriginal cultural heritage sites identified during the survey and proposed management recommendations, including recommendations for further assessment. These areas of potential Aboriginal archaeological sensitivity and archaeological survey results are described in Table 15-5.

The archaeological surveys verified the presence of 10 of the 11 identified AHIMS sites. The location and condition of one of the sites (45-6-0662, Frenchs Forest; Bantry Bay; Wakehurst Parkway) could not be confirmed during field inspection and the Aboriginal Heritage Office has advised that the site was likely covered by gravel and vegetation.

The site Wakehurst Engraving MAN 104 (45-6-3032) was observed to be significantly damaged during field inspection in September 2020. An extensive area of bedrock from the horizontal rock

engraving appeared to have been cut back, with a significant portion missing, exceeding one square metre in extent. Transport for NSW has notified Heritage NSW of the damage.

No previously unrecorded Aboriginal cultural heritage places or objects were identified during the surveys.

Table 15-5 Outcomes of the archaeological surveys

Survey area	Aboriginal archaeological sensitivity	Archaeological survey results
St Leonards Park, North Sydney	Low	No Aboriginal cultural heritage was identified.
Cammeray Golf Club, Cammeray	Low	No Aboriginal cultural heritage was identified.
ANZAC Park, Cammeray	Low	No Aboriginal cultural heritage was identified.
Artarmon Park, Artarmon	Low	Potential archaeological deposit: several large sandstone outcrop areas and intact deposits: <ul style="list-style-type: none"> • Artarmon Park PAD (45-6-3362) • Artarmon Park artefact scatter (45-6-3599).
Punch Street, Artarmon	Low	No Aboriginal cultural heritage was identified.
Flat Rock Creek, Willoughby	Low	Historically significant area (Henry Lawson Cave) outside study area. One potential archaeological deposit identified near large sandstone outcrop areas with potentially intact deposit: <ul style="list-style-type: none"> • Flat Rock Creek PAD (45-6-3361).
Clive Park, Northbridge	High	Registered AHIMS sites inspected: <ul style="list-style-type: none"> • Clive Park 2; Taplin's Cicada Pupa Cave (45-6-0996) • Clive Park 1; Northbridge (45-6-0654) • Clive Park 8, Shelter and Midden (45-6-3012). No further Aboriginal cultural heritage was identified.
Spit West Reserve, Mosman	Low	No Aboriginal cultural heritage was identified.
Balgowlah Golf Course and Burnt Bridge Creek, Balgowlah	Low	High levels of disturbance across the site. Two recorded AHIMS sites were unable to be located (note these sites have now been documented as being destroyed and Heritage NSW have updated AHIMS to reflect this). Areas of potential archaeological deposit were noted where intact landforms remain adjacent to the creek. There is the potential for grinding grooves and engravings in the sandstone bedrock. Location of Burnt Bridge Creek PAD (45-6-3363). No further Aboriginal cultural heritage was identified.

Survey area	Aboriginal archaeological sensitivity	Archaeological survey results
Wakehurst Parkway, Seaforth to Frenchs Forest	High	Registered AHIMS sites inspected: <ul style="list-style-type: none"> Bantry Bay Aboriginal Engraving Site (45-6-0655) Wakehurst Engraving MAN 104 (45-6-3032) This site was observed to be significantly damaged during field inspection carried out in September 2020 Rock engraving (Garigal National Park) (45-6-2940) The location and condition of Frenchs Forest; Bantry Bay; Wakehurst Parkway (45-6-0662) was not able to be confirmed as the site was likely covered by gravel/vegetation.

15.3.6 Test excavation

During the archaeological survey, three areas of potential archaeological deposit were identified.

Further assessment and impact modelling was carried out to determine whether these sites had the potential to be directly impacted by the project. Based on this impact modelling, only the Artarmon Park potential archaeological deposit required test excavation as it is within the construction footprint that could be directly impacted by construction activities.

Test excavation at Balgowlah and Flat Rock Creek was not required because the areas of potential archaeological deposit are outside the immediate construction footprint. Although they are within the broader 50 metre area from the construction footprint being considered for indirect impacts (vibration and settlement), areas of potential archaeological deposit would not be impacted.

The test excavation at Artarmon Park consisted of:

- 17 shovel test pits (500 millimetres x 500 millimetres)
- One test pit (1000 millimetres x 1000 millimetres).

During the test excavations an artefact scatter consisting of 15 sub-surface stone artefacts (chert, silcrete, quartzite and mudstone material) were identified in association with Artarmon Park PAD (45-6-3362). This has been recorded as Artarmon Park artefact scatter (45-6-3599).

15.3.7 Significance assessment

The significance of those Aboriginal sites within 50 metres of the project construction footprint is summarised in Table 15-6, and has been assessed based on the four values of the Australia ICOMOS (International Council on Monuments and Sites) *Burra Charter* (Australia ICOMOS 2013):

- Social values
- Historical values
- Scientific values
- Aesthetic values.

Aboriginal cultural significance was assessed through consultation with the relevant Registered Aboriginal Parties during the archaeological survey and consultation process.

Potential archaeological deposits do not have a statement of significance below as they have not been extensively excavated and their significance is not able to be determined. It is noted that project refinements have allowed potential archaeological deposits to be avoided, removing the need to excavate in these areas during construction.

Any potential submerged Aboriginal archaeological sites could potentially have very high scientific significance due to the potential to yield information that would contribute to an understanding of New South Wales' natural and cultural history. Submerged Aboriginal archaeological sites and Pleistocene Aboriginal archaeological sites are both, on their own, rare site types within a New South Wales context and the identification of submerged Pleistocene landscapes and associated Aboriginal archaeological resources would be an extremely rare discovery within Australia.

Table 15-6 Significance of Aboriginal sites within 50 metres of the project construction footprint

Name and AHIMS ID	Significance value				Overall significance
	Social	Historical	Scientific	Aesthetic	
Artarmon Park artefact scatter (45-6-3599)	High	N/A	Moderate	Low	Low-moderate
Clive Park 8, Shelter and Midden (45-6-3012)	High	N/A	High	High	High
Clive Park 1; Northbridge (45-6-0654)	High	N/A	Moderate-high	High	High
Clive Park 2; Taplin's Cicada Pupa Cave (45-6-0996)	High	N/A	Moderate-high	Moderate	Moderate-high
Rock engraving (Garigal National Park) (45-6-2940)	High	High	Moderate-high	High	High
Bantry Bay Aboriginal Engraving Site (45-6-0655)	High	High	High	High	High

Name and AHIMS ID	Significance value				Overall significance
	Social	Historical	Scientific	Aesthetic	
Wakehurst Engraving MAN 104 (45-6-3032)	High	N/A	Low	Low	Low The site was observed to be damaged during field inspection in September 2020. Prior to the field inspection, the site had low overall significance. Following the September 2020 inspection, the significance rating of low is retained.
Frenchs Forest; Bantry Bay; Wakehurst Parkway (45-6-0662)	The location and condition of this site could not be confirmed during field inspection as the site was likely covered by gravel/vegetation. As such, a desktop assessment of this site was carried out, and no significance assessment has been carried out. The Aboriginal Heritage Office were the last agency to have conducted a condition assessment of the site.				

15.4 Assessment of potential impacts

15.4.1 Potential impacts to terrestrial Aboriginal heritage sites

Most potential impacts to Aboriginal sites would occur during construction, and may include:

- Direct impacts such as the removal or destruction of an Aboriginal site
- Indirect impacts associated with construction vibration generated by surface works in proximity to Aboriginal sites.

Potential impacts during operation are expected to be limited and may include indirect impacts associated with Aboriginal site setting (visual impacts, changes to vistas/landscapes), changes to ongoing use or environmental association.

The potential for these impacts to occur at known Aboriginal sites is summarised in Table 15-7. Based on the results of this assessment and in consultation with the Registered Aboriginal Parties, it is anticipated that:

- The location and condition of one Aboriginal site Frenchs Forest; Bantry Bay; Wakehurst Parkway (45-6-0662) could not be confirmed during field inspection but is considered likely to be within the construction footprint. This site could have partial/potential direct impact but this would need to be determined through further consultation/inspection
- Five Aboriginal sites (45-6-0655, Bantry Bay Aboriginal Engraving Site; 45-6-2940, Rock engraving (Garigal National Park); 45-6-3362, Artarmon Park PAD; 45-6-3361, Flat Rock Creek PAD and 45-6-3363, Burnt Bridge Creek PAD) are located within 50 metres of surface works including two sites that may be subject to indirect impacts associated with vibration and settlement (45-6-0655, Bantry Bay Aboriginal Engraving Site and 45-6-2940, Rock engraving (Garigal National Park))

- Five Aboriginal sites (45-6-3032, Wakehurst Engraving MAN 104; 45-6-3012, Clive Park 8, Shelter and Midden; 45-6-0654, Clive Park 1; Northbridge; 45-6-0996, Clive Park 2; Taplin's Cicada Pupa Cave and 45-6-3599, Artarmon Park artefact scatter) are located above or within 50 metres of the tunnel alignment and may be subject to indirect impacts associated with vibration and settlement
- Operational impacts are considered to be negligible.

Table 15-7 Assessment of potential impacts to known Aboriginal cultural heritage sites

Site	Site type	Overall site significance	Potential impact and description	Risk of potential impacts
Artarmon Park artefact scatter (45-6-3599)	Sub-surface artefact scatter	Low-moderate	Site is a sub-surface artefact scatter and would not be impacted by the project.	No impact
Artarmon Park PAD (45-6-3362)	Potential archaeological deposit	N/A	Site is a potential archaeological deposit and would not be impacted by the project.	No impact
Flat Rock Creek PAD (45-6-3361)	Potential archaeological deposit	N/A	Site is a potential archaeological deposit and would not be impacted by the project.	No impact
Clive Park 8, Shelter and Midden (45-6-3012)	Shelter and midden	High	Indirect – vibration Vibration impact would be outside the minimum working distance for unsound structures.	Negligible
			Indirect – settlement Settlement is predicted to be between 25-30 millimetres.	Negligible
Clive Park 1; Northbridge (45-6-0654)	Shelter with art, burial/s, shelter with midden, artefact scatter	High	Indirect – vibration Vibration impact would be outside the minimum working distance for unsound structures.	Negligible
			Indirect – settlement Settlement is predicted to be between 20-25 millimetres. Large overhang and high significance of this site increased significance outcome of potential impact.	Minor

Site	Site type	Overall site significance	Potential impact and description	Risk of potential impacts
Clive Park 2; Taplin's Cicada Pupa Cave (45-6-0996)	Shelter with art, shelter with midden	Moderate-high	Indirect – vibration Vibration impact would be outside the minimum working distance for unsound structures.	Negligible
			Indirect – settlement Settlement is predicted to be 10-15 millimetres.	Negligible
Burnt Bridge Creek PAD (45-6-3363)	Potential archaeological deposit	N/A	Site is a potential archaeological deposit and would not be impacted by the project. Rock shelter is less than 50 cubic metres in size.	No impact
Wakehurst Engraving MAN 104 (45-6-3032)	Rock engraving on outcrop	High	Indirect – vibration Vibration impact would be outside the minimum working distance for unsound structures.	Negligible
			Indirect – settlement Settlement at this location is predicted to be 10-15 millimetres, which poses a minor risk, however the existing site is already significantly impacted/damage and risk is therefore considered negligible.	Negligible
Rock engraving (Garigal National Park) (45-6-2940)	Rock engraving	High	Indirect – change to environmental setting and access There is the potential for changes to the visual setting and surrounding landscape due to the removal of mature native trees during construction. There is the potential for changes to the site access during construction works.	Negligible
			Indirect – vibration Vibration impact would be outside the minimum working distance for unsound structures.	Negligible

Site	Site type	Overall site significance	Potential impact and description	Risk of potential impacts
Frenchs Forest; Bantry Bay; Wakehurst Parkway (45-6-0662)	Rock engraving	Not assessed	Direct (partial/potential) Location and condition not confirmed during site inspection as site was likely covered by gravel/vegetation.	Minor
Bantry Bay Aboriginal Engraving Site (45-6-0655)	Large rock engraving site with multiple engravings	High	Indirect – change to environmental setting and access There is the potential for changes to the visual setting and surrounding landscape due to the removal of mature native trees during construction. There is the potential for changes to the site access during construction works.	Negligible
			Indirect – vibration Vibration impact would be outside the minimum working distance for unsound structures.	Negligible

Note: Each AIHMS site has been assessed for indirect impacts associated with settlement. With the exception of Clive Park 8, Shelter and Midden (45-6-3012), Clive Park 1; Northbridge (45-6-0654), Clive Park 2; Taplin's Cicada Pupa Cave (45-6-0996) and Wakehurst Engraving MAN 104 (45-6-3032) all sites within the study area are outside of the zone of potential settlement impacts.

15.4.2 Impacts to potential submerged Aboriginal sites

Potential rock overhangs are submerged and concealed by marine sediments, so they cannot be readily accessed and assessed. The assessment of impacts to submerged Aboriginal archaeological sites is therefore based on the potential for such sites to exist, using available geophysical information and an understanding of site formation processes.

The predictive model provides a basis for assessing potential impacts and identified that there is documented evidence of Aboriginal occupation and land use patterns along the Port Jackson shoreline and the broader Sydney Basin.

The extent to which sites may have survived inundation is dependent on the length and intensity of exposure to water movement and wave action. It is predicted that most submerged sites are likely to be identified in peat deposits which have formed above residual subsoils, some of which may be beneath at least 10 metres of marine sediment.

Construction activities associated with excavation within the cofferdams, dredging and piling may have direct and indirect impacts on potential submerged Aboriginal archaeological sites. The construction of the immersed tube tunnels would require dredging of the bed of the harbour to create a trench for the installation of the immersed tube tunnel. The slopes of the trench would generally be about 14 degrees (25 per cent) to maximise the stability of the trench and minimise the risk of slumping. The tunnel trench would be designed to provide a solid and safe place for the immersed tube tunnel to be placed.

Most of the potential impacts to submerged Aboriginal archaeological sites would likely occur during construction rather than operation, and may include:

- Direct impacts from construction activities such as dredging, piling and excavation within the cofferdams
- Indirect impacts associated with construction vibration generated by construction activities in proximity to Aboriginal sites.

Indirect impacts such as vibration would have a negligible impact, because any submerged Aboriginal archaeological sites would be buried, and movement of individual objects would be minimal.

Further investigation would be required to confirm the presence of sites and their condition. If confirmed, the identification and documentation of such Aboriginal archaeological sites would demonstrate that such sites could be present across Sydney Harbour / Middle Harbour, and the information obtained in this project would be valuable in managing this resource.

A summary of potential impacts to submerged Aboriginal heritage is provided in Table 15-8.

Table 15-8 Assessment of potential impacts to submerged Aboriginal sites

Location	Potential Aboriginal site type	Archaeological potential	Significance of direct impacts	Risk of indirect impacts
Between Northbridge and Seaforth	Stone artefacts, midden deposits and fish traps	Moderate to high	Moderate to major (before mitigation) due to dredging	Negligible
	Rock shelters – Seaforth side of Middle Harbour	Moderate to high	N/A as likely below construction depth	Negligible
	Rock shelters – Clive Park side of Middle Harbour	Low	N/A	Negligible
	Rock shelters, art, grinding grooves, middens, stone artefact scatters, quarry sites and fish traps (across remainder of study area)	Very low	Negligible to moderate (before mitigation) due to dredging and excavation	Negligible
Pearl Bay (west of Spit West Reserve)	All forms identified – rock shelters, grinding grooves, middens and/or stone artefact scatters, stone quarry sites, fish traps	Moderate to high	Potential impacts to submerged Aboriginal sites unlikely in this location as the depth of piling for the temporary wharf would not reach below bed of the harbour strata containing Aboriginal archaeological sites. Potential impacts are therefore considered negligible to minor.	
Between Clive Park and Beauty Point)	All forms identified – rock shelters, grinding grooves, middens and/or stone artefact scatters, stone quarry sites, fish traps	Moderate to high	Potential impacts to submerged Aboriginal sites unlikely in this location as the depth of piling for the temporary wharf would not reach below bed of the harbour containing Aboriginal archaeological sites. Potential impacts are therefore considered negligible.	

15.5 Environmental management measures

Measures to avoid, minimise or manage Aboriginal cultural heritage impacts as a result of the project are detailed in Table 15-9.

Table 15-9 Environmental management measures – Aboriginal cultural heritage

Ref	Phase	Impact	Environmental management measure	Location
Terrestrial Aboriginal heritage				
AH1	Pre-construction and construction	Aboriginal heritage – vibration, and settlement impacts	<p>Before the start of construction, further consultation with Heritage NSW, the Metropolitan Local Aboriginal Land Council, the Aboriginal Heritage Office and the Registered Aboriginal Parties will be carried out to decide an appropriate course of action for the Aboriginal site 45-6-0662 on Wakehurst Parkway, as the location of this site could not be confirmed during field inspection (site is likely covered by gravel/vegetation).</p> <p>If considered appropriate, an archaeological investigation may be carried out at the possible site location to carefully remove the gravel/vegetation, to confirm its presence and record the underlying site condition.</p> <p>If new information regarding site condition is identified during consultation suggesting the site may be subject to impacts due to vibration and settlement, environmental management measures AH2, AH3 and AH4 will apply.</p> <p>In the absence of confirming the site, if during construction works a site is located, the unexpected finds protocol prescribed in AH5 would apply. Further, Heritage NSW, an appropriately qualified archaeologist and the Metropolitan Local Aboriginal Land Council will be contacted and the site will be re-recorded in situ.</p>	Frenchs Forest; Bantry Bay; Wakehurst Parkway (45-6-0662)
AH2	Pre-construction and construction	Aboriginal heritage – vibration impacts	<p>The following process will be carried out to confirm where vibration monitoring at those terrestrial sites within 50 metres of the project corridor will be required:</p> <ol style="list-style-type: none"> Terrestrial Aboriginal site condition surveys of sites will be completed by an appropriately qualified person using those techniques appropriate in determining which sites are considered to be structurally unsound Where this determination cannot be made, as a precaution the site will be considered to be structurally unsound A screening of vibration intensive activities within 50 metres of structurally unsound sites will be carried out to identify activities 	All registered AHIMS sites subject to vibration intensive activities determined to be structurally unsound (see AH2).

Ref	Phase	Impact	Environmental management measure	Location
			<p>that have the potential to exceed vibration levels of 2.5 millimetres per second</p> <p>d) Sites identified as being both structurally unsound and having potential for exceedance in vibration levels of 2.5 millimetres per second will be identified as requiring vibration monitoring where this cannot be reduced at the source.</p>	
AH3	Construction	Aboriginal heritage – vibration impacts	<p>Vibration monitoring will be carried out at sites that have been identified as requiring monitoring in accordance with the process outlined in environmental management measure AH2. The monitoring process will:</p> <ul style="list-style-type: none"> • Be developed by a suitably qualified person • Be risk-based • Include appropriate frequency and duration of monitoring including adequate benchmark recording before works commence • Include appropriate management protocols for any exceedances. <p>Where possible, project works will be conducted in a manner to minimise vibration levels, to less than 2.5 millimetres per second at all structurally unsound AHIMS sites.</p>	All registered AHIMS sites located subject to vibration intensive activities determined to be structurally unsound (see AH2).
AH4	Construction	Aboriginal heritage – vibration impacts	<p>Where monitoring identifies that vibration levels exceed 2.5 millimetres per second, or following vibration intensive activities, subsequent condition survey of sites that are subject to monitoring in AH3 will be carried out.</p> <p>The subsequent condition surveys will record any changes to the integrity of the site that may have resulted from construction vibration. Additional surveys must be carried out by a suitably qualified person and include a Metropolitan Local Aboriginal Land Council representative. AHIMS site cards will be updated accordingly where any changes are observed. Condition surveys may include further photogrammetry and 3D-capture techniques, in which case comparison against the baseline will be carried out.</p>	All registered AHIMS sites subject to vibration monitoring (see AH3)

Ref	Phase	Impact	Environmental management measure	Location
AH5	Construction	Unexpected discovery of historical heritage materials, features, or deposits	If at any time during construction of the project, any items of potential Aboriginal archaeological or cultural heritage conservation significance or Ancestral remains are discovered they will be managed in accordance, the <i>Standard Management Procedure: Unexpected Heritage Items</i> (Roads and Maritime Services, 2015d).	BL/GHF
AH6	Construction	Aboriginal heritage – impacts	Cultural and historic heritage awareness training will be carried out for personnel engaged in work that may impact heritage items before commencing works for the project.	BL/GHF
AH7	Pre-construction and construction	Aboriginal heritage – impacts	As part of the project urban design and landscape plan, an Aboriginal heritage interpretation strategy will be developed for the project in consultation with Registered Aboriginal Parties and other relevant Stakeholders. Appropriate Aboriginal heritage interpretation will be incorporated into the project urban design and landscape plan in accordance with the interpretation strategy.	BL/GHF
Maritime Aboriginal heritage				
AH8	Pre-construction	Potential Aboriginal submerged sites heritage impacts	<p>The effectiveness of using high resolution geophysical survey to identify rock overhangs concealed by marine sediments will be assessed. If it is determined that a high resolution geophysical survey could produce the desired results, then the survey will be carried out.</p> <p>If the geophysical survey conclusively shows that there are no rock overhangs measuring at least 1.5 metres in height (from the rock base to the rock ceiling), there would be no further archaeological work carried out and any residual risk will be managed through an unexpected finds procedure. However, if the geophysical survey is inconclusive or distinct rock overhangs are identified, then an archaeological dive investigation will be implemented. Much of the diving will be done in near zero visibility and will therefore be limited to what a diver can feasibly and safely do.</p>	Potential rock shelter(s) at Seaforth located outside of Middle Harbour north construction support site (BL8) cofferdam footprint but within the dredge footprint

Ref	Phase	Impact	Environmental management measure	Location
AH9	Pre-construction and construction	Potential Aboriginal submerged sites heritage impacts	<p>The effectiveness of using high resolution geophysical survey to identify rock overhangs concealed by marine sediments will be assessed. If it is determined that a high resolution geophysical survey could produce the desired results, then the survey will be carried out.</p> <p>If the geophysical survey conclusively shows that there are no rock overhangs measuring at least 1.5 metres in height (from the rock base to the rock ceiling), there would be no further archaeological work carried out and any residual risk will be managed through an unexpected finds procedure. However, if the geophysical survey is inconclusive or distinct rock overhangs are identified, then onsite visual monitoring within the cofferdam will be carried out during the construction period, after the cofferdam has been de-watered. The aim of the monitoring will be to identify voids within the bedrock close to the interface with marine sediments.</p> <p>In the event that a void in the bedrock appears that displays the characteristics of a potential rock shelter, then the marine sediments will be removed by pump. Should the marine sediments bottom out onto the rock no further action would be taken. If the characteristics of the marine sediments change or if fissures are evident, then samples of the sediments will be taken, preferably as an intact core sample.</p> <p>In consultation with a suitably experienced geomorphologist a set of criteria will be established for the identification of pre-inundation soil deposits (peat, charcoal, roots, etc). If pre-inundation soil deposits are evident within samples, a controlled archaeological investigation to recover any artefacts will take place. However, the extent of the archaeological investigation and method of recovery will be determined by the constraints of the bed rock conditions and workplace health and safety protocols and constraints within the cofferdams, including safety protocols for handling of potentially contaminated sediment.</p> <p>Environmental, engineering and workplace health and safety factors such as operating space within an overhang, viscosity of the pre-inundation soil and elevated contamination levels will have an influence on the method of archaeological investigation, which will nonetheless aim to retain spatial and stratigraphic control if at all feasible.</p>	Within the footprint of Middle Harbour south and north cofferdams construction support sites (BL7 and BL8)

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 16

Geology, soils and groundwater

16 Geology, soils and groundwater

This chapter outlines the potential geology, soils and groundwater impacts associated with the project and identifies measures which address these impacts. The impacts associated with the discharge of treated groundwater are detailed in Chapter 17 (Hydrodynamics and water quality).

Assessment of contamination and groundwater impacts have been carried out for the project and are included in Appendix M (Technical working paper: Contamination) and Appendix N (Technical working paper: Groundwater). These assessments have also been informed by geotechnical investigations carried out for the project.

The Secretary's environmental assessment requirements as they relate to the geology, soils and groundwater, and where in the environmental impact statement these have been addressed, are detailed in Table 16-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to geology, soils and groundwater are included in Section 16.7.

Table 16-1 Secretary's environmental assessment requirements – Geology, soils and groundwater

Secretary's requirement	Where addressed in the EIS
Soils and contamination	
1. The Proponent must verify the risk of acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Risk Map) within, and in the area likely to be impacted by, the project.	Details with respect to the risk of acid sulfate soils are presented within Section 16.3.3 , Appendix M (Technical working paper: Contamination), Appendix N (Technical working paper: Groundwater) and Appendix O (Technical working paper: Surface water).
2. The Proponent must assess the impact of the project on acid sulfate soils (including impacts of acidic runoff offsite) in accordance with the current guidelines and detail the mitigation measures proposed to minimise potential impacts.	An assessment of the impact of the project on acid sulfate soils is provided in Sections 16.4.1 and Section 16.5.2 . Management measures to minimise these impacts are outlined in Section 16.7 . More specific details with respect to acid sulfate soil risk are provided in Appendix M (Technical working paper: Contamination) and risk of acid sulfate soil activation due to groundwater drawdown in Appendix N (Technical working paper: Groundwater).

Secretary's requirement	Where addressed in the EIS
<p>3. The Proponent must assess whether the land and harbour sediment are likely to be contaminated and identify if remediation of the land is required, having regard to the ecological and human health risks posed by the contamination in the context of past, existing and future land uses.</p>	<p>Qualitative assessment of the potential contamination risks, and the need for land remediation, is provided in Section 16.4. Requirements for future remediation activities are identified Section 16.7. Human health and ecological risks posed by contamination are assessed in Chapter 13 (Human health) and Chapter 19 (Biodiversity).</p> <p>Further details of the assessment of contamination risk and the management of contamination are provided in Appendix M (Technical working paper: Contamination).</p>
<p>4. Where assessment and/or remediation is required, the Proponent must document how the assessment and/or remediation would be undertaken in accordance with current guidelines.</p>	<p>Section 16.4.3 provides an outline of the risk of contamination identified in the assessment and an assessment of potential contamination risk. Section 16.7 documents the assessment and remediation process that would be followed for the management of potential contamination risk.</p> <p>Further details of the assessment of contamination risk and the management of contamination are provided in Appendix M (Technical working paper: Contamination).</p>
<p>5. Where contaminated spoil and/or sediments are to be handled, the Proponent must provide details of contamination characteristics and measures to manage this spoil to avoid adverse impacts to land and water quality.</p>	<p>Chapter 6 (Construction works) details the proposed construction method which has considered measures from Appendix Q (Technical working paper: Marine water quality) to avoid adverse impacts to land and water quality during contaminated spoil handling. Appendix P (Technical working paper: Hydrodynamics and dredge plume modelling) outlines the proposed dredge methodology.</p> <p>Section 16.3.5, Section 16.4.3 and Chapter 24 (Resource use and waste management) provide details on the likely contamination characteristics of spoil and how contaminated spoil will likely be managed.</p> <p>Section 16.7 and Chapter 24 (Resource use and waste management) provides the environmental management measures proposed to manage the spoil to avoid adverse impacts to land and water quality.</p>
<p>6. The Proponent must assess whether salinity is likely to be an issue and if so, determine the presence, extent and severity of soil salinity within the project area.</p>	<p>An assessment of the potential for salinity to be present and its severity is provided in Section 16.3.</p>
<p>7. The Proponent must assess the impacts of the project on soil salinity and how it may affect groundwater resources and hydrology.</p>	<p>An assessment of the project's impact on soil salinity is provided in Section 16.3.3 and Section 16.4.1.</p>

Secretary's requirement	Where addressed in the EIS
8. The Proponent must assess the impacts on soil and land resources (including erosion risk or hazard). Particular attention must be given to soil erosion and sediment transport consistent with the practices and principles in the current guidelines.	An assessment of the project's impact on soil and land resources, with particular emphasis on soil erosion and sediment transport, is provided in Section 16.3.3 and Section 16.4.1 .
9. The Proponent must assess the impact of any disturbance of contaminated groundwater and the tunnels should be designed so as to not exacerbate mobilisation of contaminated groundwater and/or prevent contaminated groundwater flow.	An assessment of contaminated groundwater impacts and a description of how the tunnel has been designed so as to not exacerbate mobilisation of contaminated groundwater and/or prevent contaminated groundwater flow is provided in Chapter 5 (Project description) and Sections 16.4 and Section 16.5.2 .
Water – Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) and groundwater dependent ecosystems likely to be impacted by the project, including rivers, streams, wetlands and estuaries as described in Appendix 2 of the <i>Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects</i> (Office of Environment and Heritage, 2014).	<p>Section 16.3.4 and Figure 16-6 present the hydrological regime for groundwater.</p> <p>Chapter 17 (Hydrodynamics and water quality), details surface water resources likely to be impacted by the project is presented in Section 17.3.</p> <p>Sections 16.3.4, 16.4.5 and 16.5.2 discuss groundwater dependent ecosystems that are to be potentially impacted by the project.</p> <p>Chapter 19 (Biodiversity) provides consideration of relevant biodiversity matters.</p>
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations (including mapping of these locations), volume, frequency and duration for both the construction and operational phases of the project.	<p>Refer to Section 16.4.5 and Section 16.5.2 for groundwater inflow predictions during construction and operation.</p> <p>Chapter 17 (Hydrodynamics and water quality) provides a water balance for construction and operation.</p>
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: <ul style="list-style-type: none"> a. natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), 	<p>Section 16.4 describes potential construction impacts to groundwater and Section 16.5 describes potential operational impacts to groundwater. Details of the modelling undertaken to assess impacts to groundwater are presented in Annexure F of Appendix N (Technical working paper: Groundwater).</p> <p>Chapter 17 (Hydrodynamics and water quality) includes detail on surface water hydrological impacts and impacts on natural processes.</p> <p>Potential hydrological impacts and impacts on natural processes are included in Chapter 18 (Flooding).</p>

Secretary's requirement	Where addressed in the EIS
aquatic connectivity, water dependent fauna and flora and access to habitat for spawning and refuge;	Chapter 19 (Biodiversity) assesses potential surface water and groundwater hydrological impacts on the health of the fluvial, riparian, estuarine or marine system, aquatic connectivity, fauna and flora, and access to habitat for spawning and refuge.
b. impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Potential groundwater hydrological impacts are included in Section 16.4 and Section 16.5 . The potential for settlement is discussed in Section 16.4.2 . Potential impacts from any permanent and temporary interruption of ground water flow for ecosystems and species and for groundwater users is discussed in Chapter 19 (Biodiversity).
c. changes to environmental water availability and flows, both regulated/licensed and unregulated/rules based sources including the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course;	Potential changes to environmental water availability and flows, including to the storage dam at Cammeray Golf Course, is provided in Chapter 17 (Hydrodynamics and water quality).
d. direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Chapter 17 (Hydrodynamics and water quality) assesses the potential impacts on surface water with regard to erosion, siltation, and bank stability. Impacts from scour and erosion on geomorphology and the effects of proposed stormwater and wastewater management on surface water quality are also assessed in this chapter.
e. minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Minimising the effects of proposed stormwater and wastewater management on natural hydrological attributes and on the existing capacity of stormwater systems is described in Chapter 17 (Hydrodynamics and water quality).
f. measures to mitigate the impacts of the proposal and manage the disposal of produced and incidental water.	Chapter 17 (Hydrodynamics and water quality), details environmental management measures relating to surface water. Water drainage and management infrastructure is detailed in Chapter 5 (Project description) and Chapter 6 (Construction work).

Secretary's requirement	Where addressed in the EIS
4. The assessment must provide details of the final landform of the sites to be excavated or modified (e.g. portals), including final void management and rehabilitation measures.	<p>The details of the final landform, including management and rehabilitation measures, are provided in Chapter 22 (Urban design and visual amenity).</p> <p>Landscape treatments for the project are detailed in Chapter 5 (Project description).</p> <p>The management of voids (shafts and access declines) is detailed in Chapter 6 (Construction work), Section 6.4.1.</p>
5. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	<p>The requirements for baseline groundwater monitoring is provided in Section 16.6.</p> <p>Chapter 17 (Hydrodynamics and water quality) provides a description of surface water monitoring carried out to inform this environmental impact statement, and requirements for construction and operational monitoring.</p>
6. The assessment must include details of proposed surface and groundwater monitoring.	<p>Details relating to the proposed surface and groundwater monitoring are provided in Chapter 17 (Hydrodynamics and water quality) and Section 16.6 and Section 16.7, respectively.</p>
7. The Proponent must identify design approaches to minimise or prevent drainage of alluvium in the paleochannels.	<p>Palaeochannels near the project are described in Section 16.3.4.</p> <p>Details of tunnel design are provided in Chapter 5 (Project description) and Chapter 6 (Construction work).</p>

16.1 Legislative and policy framework

The impact assessment of the project on soils has been prepared in accordance with the following key guidelines and policies:

- *Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom, 2004) and Volume 2 (DECC, 2008)*
- *Soil and Landscape Issues in Environmental Impact Assessment (DLWC, 2000)*
- *Site Investigations for Urban Salinity (DLWC, 2002)*
- *Landslide risk management guidelines (Australian Geomechanics Society, 2007)*
- *Framework for Biodiversity Assessment – Appendix 2 (Office of Environment and Heritage, 2014a).*

The impact assessment of the project on contamination has been prepared in accordance with and/or consideration of the following contamination legislation, policies and guidelines:

- *Contaminated Land Management Act 1997*
- *Acid Sulfate Soils Assessment Guidelines (Ahern, Stone and Blunden, 1998)*
- *Acid Sulfate Soils Manual (Acid Sulfate Soils Management Advisory Committee (ASSMAC), 1998)*
- *PFAS National Environmental Management Plan Version 2.0 (Heads of EPAs Australia and New Zealand (HEPA), 2020)*

- *Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land* (Department of Urban Affairs and Planning and Environmental Protection Authority, 1998)
- *Guidelines for Consultants Reporting on Contaminated Sites* (Office of Environment and Heritage, reprinted 2011b)
- *Guidelines for the NSW Site Auditor Scheme* (NSW EPA, 2017b)
- *Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997* (NSW EPA, 2015a)
- *NSW Aquifer Interference Policy* (NSW DPI, 2012a)
- *NSW Sustainable Design Guidelines Version 4.0* (Transport for NSW, 2017)
- *Risk assessment guidelines for groundwater dependent ecosystems* (Office of Water, 2012b)
- *Guidelines for controlled activities on waterfront land – Riparian corridors* (NSW Department of Industry, 2018)
- Other guidelines made or approved under section 105 of the *Contaminated Land Management Act 1997*
- *High and Low Interim Sediment Quality Guidelines* (ISQG), that form a part of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)
- *National Assessment Guidelines for Dredging* (NAGD) (Department of Environment, Water, Heritage and the Arts, 2009).

The impact assessment of the project on groundwater has been prepared in accordance with the following groundwater legislation and policy documents:

- *Water Act 1912* and *Water Management Act 2000*
- Minimal harm criteria presented in the *NSW Aquifer Interference Policy* (NSW DPI, 2012a)
- *Rules of the Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* (NSW DPI, 2011a).

16.2 Assessment methodology

The methodology for the assessment included:

- A review of the geological context, soil landscapes, salinity and acid sulfate soils
- A review of similar assessments and previous tunnelling projects in the Sydney region, including Sydney Metro City & Southwest (Chatswood to Sydenham) (Jacobs, 2016), North West Rail Link (Transport for NSW, 2012b), M4-M5 Link (AECOM, 2017a), M4 East (GHD, 2015) and the New M5 (now M8) (AECOM, 2015)
- Field investigations including drilling, permeability testing, monitoring bore installation, and water level and quality monitoring
- Preparation of a Stage 1 Contamination Investigation including a review of background and historical information, site inspections, and sampling
- Development of a conceptual model of the hydrogeological environment and groundwater numerical modelling to predict groundwater inflows and drawdown propagation
- Technical review by a suitably qualified independent expert to confirm the groundwater modelling methodology and outputs
- Identification and assessment of potential construction and operational impacts associated with soils, contamination and groundwater
- Identification of environmental management and monitoring measures required to mitigate impacts and manage tunnel inflows.

16.3 Existing environment

16.3.1 Topography

The terrain along the project alignment rises from an elevation of about 65 metres Australian Height Datum (AHD) at the southern extent of the project at Cammeray and undulates towards Middle Harbour. The depth of the harbour in the vicinity of the crossing is approximately 32 metres below sea level. Once the project crosses Middle Harbour the topography has a steep incline up to the ridge line at North Balgowlah, before resuming a moderate incline towards Frenchs Forest, reaching an elevation of about 150 metres AHD at Warringah Road at the northern extent of the project.

Middle Harbour is a sub catchment of Sydney Harbour. The Sydney Harbour estuary is a drowned river valley (palaeovalley), characterised by steep sided banks carved into Hawkesbury Sandstone between 25 and 29 million years ago. Around 17,000 years ago, the sea level rose, flooding the river valley and forming a flood tide delta (Hedge et al., 2013). The Middle Harbour crossing would occur in areas underlain by estuarine, marine and alluvial sediments overlying Hawkesbury Sandstone. The deepest sediments along the alignment are anticipated along a buried palaeovalley where they are predicted to be about 32 metres deep between Northbridge and Seaforth.

16.3.2 Geology

The Sydney 1:100,000 Geological Series Sheet 9130 (NSW Department of Mineral Resources, 1983) indicated that the majority of the project area is underlain by geological units associated with the Wianamatta Group. Hawkesbury Sandstone (Rh) underlies the majority of the project area, with isolated occurrences of Ashfield Shale (Rwa) present in the southern and western portion of the project area, around Cammeray, Naremburn, Artarmon, Willoughby and Northbridge. An intermediate formation between the Hawkesbury Sandstone and the Ashfield Shale, the Mittagong Formation, is sometimes identified but is not mapped along the project alignment. In addition, areas of disturbed ground (manmade fill (mf)) are mapped within Bicentennial Reserve Baseball Diamond and Flat Rock Reserve.

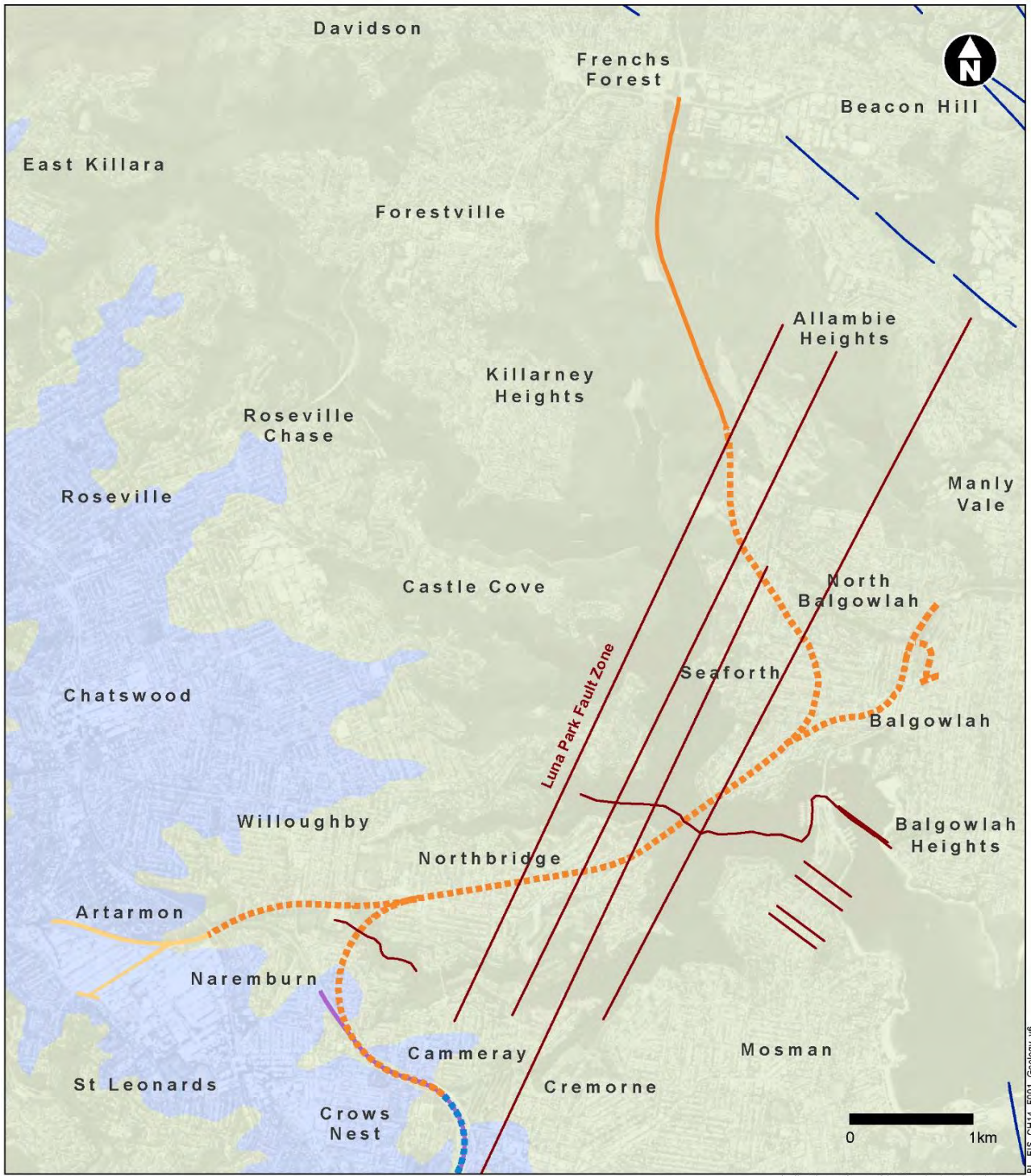
A description of the geological formations are presented in Table 16-2 and shown in Figure 16-1.

Table 16-2 Geological units underlying the project area

Unit	Description
Hawkesbury Sandstone (Rh)	Medium to coarse grained, quartzose sandstone. A combination of highly cross bedded and massive sandstone units with interbedded siltstone.
Ashfield Shale (Rwa)	Consists of four variable thickness sub units of siltstone and laminate.
Mittagong Formation (Rm)	Consists of fine grained sandstone and inter-bedded sandstone/siltstone.
Manmade fill (mf)	Typically comprising waste, emplaced material and engineered fill.

Geological structural features

The solid geology within the study area is cross cut by a number of volcanic structural features that may impact groundwater flow. This includes geological faults (a fracture within rock where displacement may have occurred), which are typically found within the Hawkesbury Sandstone. The presence of geological faults is associated with increased groundwater inflows. The nearest major fault zone to the project is the Luna Park Fault zone which, along with an associated parallel trending joint swarm mapped at Willoughby Creek, is inferred to intersect the alignment at Middle Harbour.



Legend

Operational features

- Beaches Link
- Gore Hill Freeway Connection

Geology

- Hawkesbury sandstone
- Ashfield shale

Geological structural features

- Inferred fault
- Mapped dyke

Connecting projects

- Western Harbour Tunnel
- Warringah Freeway

Figure 16-1 Regional geological context

16.3.3 Soils

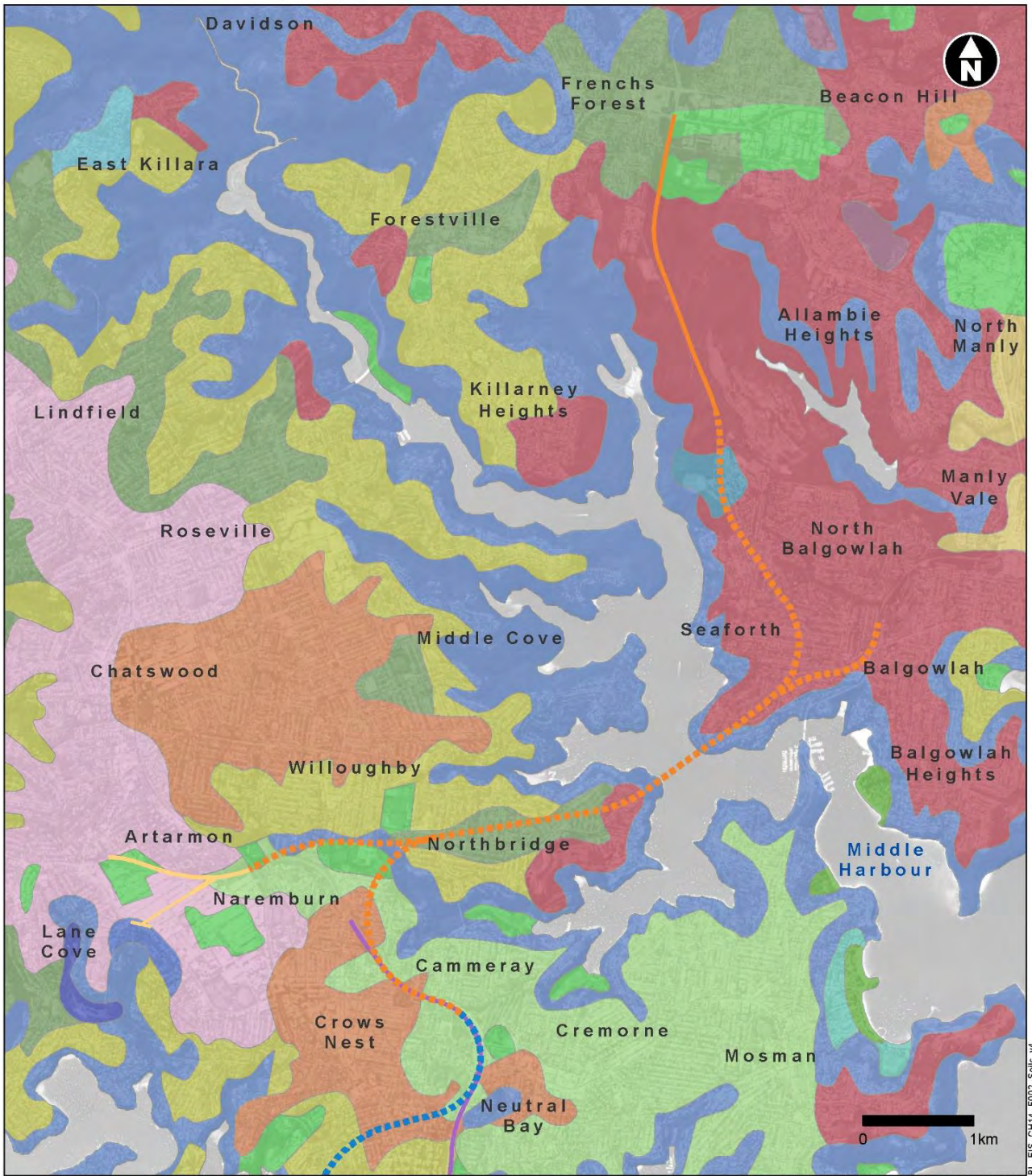
Soil groups and erosion potential

The Sydney 1:100,000 Soil Landscape Series Sheet 9130 (Chapman and Murphy, 1989) indicates that the residual soils within the project area includes the Blacktown (bt), Disturbed (xx), Hawkesbury (ha), Gymea (gy), Lucas Heights (lh), Lambert (la), Somersby (so) and Glenorie (gn) landscape groups. The majority of the project area is underlain by the Gymea landscape group with the Hawkesbury landscape group surrounding the shorelines. A description of the soil landscape groups is presented in Table 16-3 and shown in Figure 16-2.

Table 16-3 Soil landscape groups across the project area

Soil landscape	Description
Blacktown (bt)	<p>Landscape – found on gently undulating rises on Wianamatta Group shales with local reliefs of up to 30 metres and slopes of less than five per cent.</p> <p>Soils – soils are shallow to moderately deep, with hard-setting mottled texture contrast soils. Red and brown podzolic soils found on crests grading to yellow podzolic soils on lower slopes and in drainage lines.</p> <p>Limitations – Blacktown soils are moderately reactive, with a highly plastic subsoil, and low fertility and poor drainage.</p>
Disturbed (xx)	<p>Landscape – the topography varies from level plans to undulating terrain and has been disturbed by human activity to a depth of at least 100 centimetres.</p> <p>Soils – the original soil has been removed, greatly disturbed or buried. Most of these areas have been levelled to slopes of less than five per cent. Manmade fill includes soil, rock, building and waste material. The original vegetation has been completely cleared.</p> <p>Limitations – the soils are dependent on the nature of fill material with subsidence resulting in a mass movement hazard. Soil impermeability may lead to poor drainage and low fertility. Care must be taken when these sites are developed.</p>
Hawkesbury (ha)	<p>Landscape – found on rugged, rolling to very steep hills on Hawkesbury Sandstone with local reliefs of 40 to 200 metres and slopes of more than 25 per cent and rock outcrops of more than 50 per cent.</p> <p>Soils – soils are typically shallow (less than 50 centimetres), with discontinuous lithosols/siliceous sands associated with rock outcrops, earthy sands, yellow earths and some yellow podzolic soils on the inside of benches and along joints and fractures.</p> <p>Limitations – Hawkesbury soils pose an extreme soil erosion hazard, with mass movement (rockfall) on steep slopes. The soils are shallow, stony, highly permeable and have low fertility.</p>
Glenorie (gn)	<p>Landscape – low rolling and steep hills. Local relief 50 to 120 metres, slopes five to 20 per cent. Convex narrow (20 to 300 metres) ridges and hillcrests grade into moderately inclined side slopes with narrow concave drainage lines. Moderately inclined slopes of 10 to 15 per cent are the dominant landform elements.</p> <p>Soils – shallow to moderately deep (less than 100 centimetres) red, brown and yellow podzolic soils on crests and slopes. Siliceous sands, leached sands and humic gleys on shale lenses and along drainage lines.</p> <p>Limitations – high soil erosion hazard, localised impermeable highly plastic, moderately reactive.</p>

Soil landscape	Description
GyMEA (gy)	<p>Landscape – found on undulating to rolling low hills on Hawkesbury Sandstone with local reliefs of 20 to 80 metres and slopes of 10 to 25 per cent and rock outcrops of less than 25 per cent.</p> <p>Soils – shallow to moderately deep yellow earths and earthy sands on crests and on the inside of benches.</p> <p>Limitations – GyMEA soils have a high soil erosion potential. Soils are shallow, highly permeable with low soil fertility.</p>
Lucas Heights (lh)	<p>Landscape – characterised by gently undulating crests and ridges on plateau surfaces of the Mittagong formation (alternating bands of shale and fine grained sandstones). Local relief to 30 metres, slopes less than 10 per cent. Rock outcrops are absent. Extensively or completely cleared, with dry sclerophyll low forest and woodland.</p> <p>Soils – soils are moderately deep (50 to 150 centimetres), hardsetting yellow podzolic soils and yellow solochs, yellow earths on the outer edges.</p> <p>Limitations – stony soil, with low soil fertility and low available water capacity.</p>
Lambert (la)	<p>Landscape – characterised by undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20 to 120 metres, with slopes around 20 per cent. Other landscape features include rock outcrops with grades of greater than 50 per cent, broad ridges with gently to moderately inclined slopes, wide rock benches with low broken scarps, and small hanging valleys and areas of poor drainage. Vegetation includes open and closed heathland, scrub and occasional low eucalypt open woodland.</p> <p>Soils – soils are generally shallow (less than 50 centimetres) discontinuous earthy sands and yellow earths on crests and the insides of benches; shallow (less than 20 centimetres) siliceous sands/lithosols on leading edges; shallow to moderately deep (less than 150 centimetres) leached sands; grey earths and gleyed podzolic soils in poorly drained areas; and localised yellow podzolic soils associated with shale lenses.</p> <p>Limitations – soils have a very high soil erosion potential, with seasonally perched water tables. The soil is generally shallow, highly permeable and has very low soil fertility.</p>
Somersby (so)	<p>Landscape – characterised by gently undulating to rolling rises on deeply weathered Hawkesbury Sandstone plateau. Local relief up to 40 metres with slopes below 15 per cent grade. Rock outcrops are absent. Crests are broad and convex, and valleys are narrow and concave. Vegetation includes extensively cleared low open woodland and scrubland.</p> <p>Soils – soils are moderately deep to deep (100 to 300 centimetres), with red earths and yellow earths overlying laterite gravels and clays on crests and upper slopes; yellow earths and earthy sands occur on mid slopes; grey earths, leached sands and siliceous sands on lower slopes and drainage lines; gleyed podzolic soils in low lying poorly drained areas.</p> <p>Limitations – Somersby soils have localised, permanently high water tables, areas of laterite, and stony soil. The soils have very low soil fertility and are highly permeable.</p>



BL_EIS_CH14_F002_Soils_v4

Indicative only – subject to design development

Legend

Operational features

- - - Beaches Link
- Gore Hill Freeway Connection

Connecting projects

- - - Western Harbour Tunnel
- Warringah Freeway

Soil landscape

- | | | |
|--|---|--|
| ■ Blacktown | ■ Gymea | ■ Oxford Falls |
| ■ Deep Creek | ■ Gymea/Lambert | ■ Somersby |
| ■ Disturbed terrain | ■ Hawkesbury | ■ Warriewood |
| ■ Faulconbridge | ■ Lambert | ■ West Pennant Hills |
| ■ Glenorie | ■ Lucas Heights | ■ Woy Woy |
| | ■ Newport | |

Figure 16-2 Soil landscapes

Marine sediments

Sediments infilling Middle Harbour comprise Pleistocene and Holocene age alluvial, colluvial, estuarine and marine deposits to about 30 metres thick. Palaeovalley sediments are comprised of silty and peaty sands, silts and clays with shell layers.

The surface sediments which form the present seafloor and cover the underlying sediments across the alignment, typically consist of interbedded soft silty clay and loose sand. A cross section of the marine sediment profile in Middle Harbour along the proposed harbour crossing is shown in Figure 16-3.

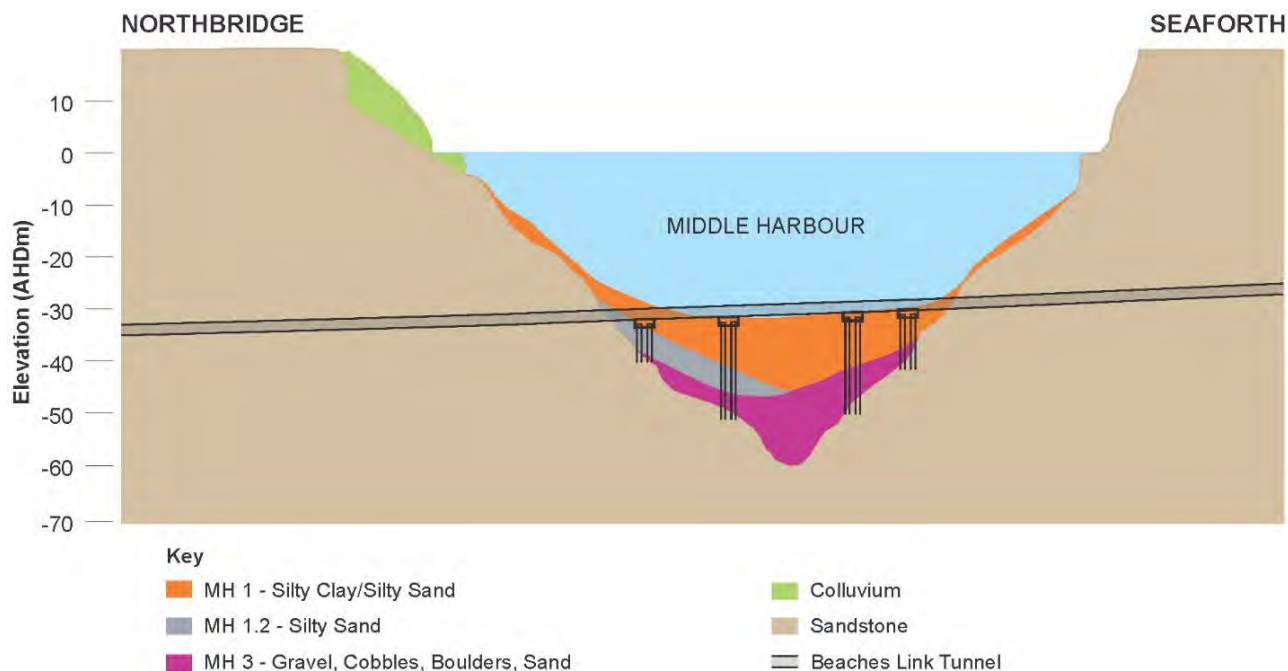


Figure 16-3 Middle Harbour marine sediment and geology profile

Acid sulfate soils

Acid sulfate soils are the common name given to naturally occurring soils, commonly associated with low lying areas of fine grained sediments and typically occur in lacustrine, estuarine, or swamp type environments, that contain iron sulfides (principally iron sulphide or iron disulphide or their precursors) which, on exposure to air, oxidise and create sulfuric acid.

Acid sulfate soil risk maps from the Australian Soil Resource Information System (ASRIS) database were reviewed to ascertain the probability of acid sulfate soil being present across the project area. Based on this information, the generalised acid sulfate soil probability across the project area has been assessed as follows:

- Cammeray to Naremburn – (B4) low probability/very low confidence
- Naremburn to Northbridge – (C4) extremely low probability/very low confidence
- Middle Harbour – (A4) high probability/confidence unknown
- Seaforth to Balgowlah – (C4) extremely low probability/very low confidence
- North Balgowlah to Frenchs Forest – (C4) extremely low probability/very low confidence
- Artarmon to Naremburn – (B4) low probability/very low confidence

A review of the acid sulfate soil risk maps from *the Willoughby Local Environmental Plan 2012* (NSW Government, 2012a) and the *Manly Local Environmental Plan 2013* (NSW Government, 2013b) indicate that the project would be located within areas of Class 5 acid sulfate risk or areas with no probable acid sulfate risk (unclassified). The *Mosman Local Environmental Plan 2012* (NSW Government, 2012b) identified areas underlying The Spit as an acid sulfate soil area (land

up to 5 metres AHD) but did not provide an acid sulfate soil class for this area. The acid sulfate soil risk maps from the *Warringah Local Environmental Plan 2011* (NSW Government, 2011) did not classify the project area as an acid sulfate risk. The *North Sydney Local Environmental Plan 2013* (NSW Government, 2013a) does not contain acid sulfate risk maps. The respective local environmental plans do not cover acid sulfate soil risk within Middle Harbour and associated bays.

The local environmental plans state that development consent is required for the carrying out of work which may disturb, expose or drain acid sulfate soils and cause environmental damage, within the respective risk classes as follows:

- Class 5 – Work within 500 metres of nearby Class 1, 2, 3 or 4 land that is below five metres AHD and by which the water table is likely to be lowered below one metre AHD on nearby Class 1, 2, 3 or 4 land.

Areas with a high probability of acid sulfate soil occurrence along the project alignment for marine environments are illustrated in Figure 16-5.

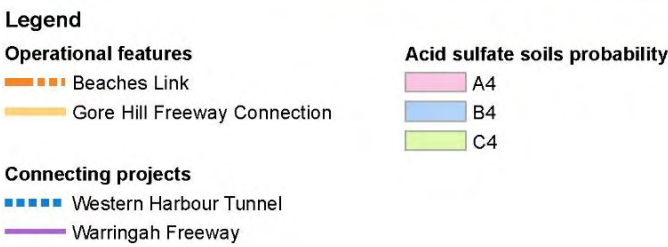


Figure 16-4 Landform acid sulfate soil risk classification



Indicative only – subject to design development

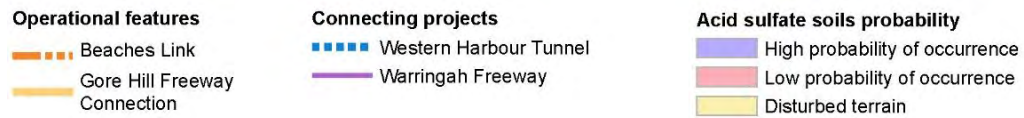


Figure 16-5 Marine environment acid sulfate soil risk classification

Soil salinity

With reference to the *Salinity Potential in Western Sydney 2002* map sheet, (Department of Infrastructure, Planning and Natural Resources (DIPNR)) (2002), higher salinity risk in western Sydney is generally associated with residual soils overlying Wianamatta Group Bringelly Shales. Residual soils from this geological unit near drainage lines pose a higher salinity risk potential.

Notably however, none of the soil landscapes within the project area document salinity as a limitation to the landscape type. Further to this, based on available geological maps, Bringelly Shales are not present within the project area, and none of the local council environmental plans within the project contain salinity risk maps.

As such, naturally occurring soil salinity is not expected to be encountered within the project footprint.

Although not mapped, Ashfield Shale may contain marine salts which would result in saline groundwater (discussed in more detail in Section 16.3.4).

16.3.4 Groundwater

Groundwater flow

Across the study area, the groundwater levels are typically deeper beneath hills and shallowest beneath creeks and gullies. Groundwater within the project footprint is recharged by rainfall runoff and infiltration. Groundwater is present within the following hydrogeological units:

- Quaternary alluvium
- Hawkesbury Sandstone
- Ashfield Shale
- Manmade fill.

Quaternary alluvium

Quaternary alluvium occurs locally around watercourses and generally exhibits good water quality and high flows. Quaternary sediments associated with the palaeochannels (old river or stream channels which have been filled or buried by younger sediment) of Middle Harbour have highly variable hydraulic conductivities (water flow), exhibiting very high flows in water bearing zones dominated by sand and gravel, and very low conductivities in water bearing zones with high clay content. Groundwater within the palaeochannels is typically saline, due to recharge from the Ashfield Shale and leakage from tidally flushed rivers and tributaries.

Other than within the palaeochannels of Middle Harbour, there are only limited occurrences of mapped Quaternary sediments along the alignment. Key occurrences of mapped Quaternary sediments that might influence or be influenced by the project are near Flat Rock Creek.

Overall, the hydraulic conductivity (ie the level of permeability within soils and other materials) in the study area is likely to be low due to the predominance of silty clays and would generally behave as an aquitard (a zone within the earth that restricts groundwater flow from one aquifer to another).

Hawkesbury sandstone aquifer

The most extensive aquifer in the project area is the Hawkesbury Sandstone, which is up to 250 metres thick in the Sydney region and outcrops over most of the Beaches Link project area. Hawkesbury Sandstone has a highly variable hydraulic conductivity. It ranges from unconfined to semi confined and locally confined, with the degree of confinement resulting from stratification (bedding layers), which generally increases with depth. The highly stratified nature of the sandstone and the presence of interbedded shales also results in multiple aquifer zones within the sandstone.

The primary porosity of Hawkesbury Sandstone strata is generally low, leading to very low hydraulic conductivities (low water flow) within the sandstone where there is minimal fracturing. However, the flow of groundwater is usually dominated by secondary porosity, and as such is highly variable and dependent on the distribution of structural defects including fractures, joints and bedding planes.

Groundwater quality within the Hawkesbury Sandstone is generally slightly acidic but of low salinity. The salinity of the upper part of the aquifer, however, can be elevated due to leakage from the Ashfield Shale. Elevated concentrations of dissolved iron and manganese naturally occur within the Hawkesbury Sandstone. In tunnels, groundwater ingress becomes oxidised, causing the dissolved iron and manganese to form sludge in drainage lines.

Ashfield shale aquifer

The clay rich Ashfield Shale behaves as an aquitard as it has a very low vertical hydraulic conductivity (low water flow) which reduces groundwater transfer within and between the strata above and below. Therefore, the Ashfield Shale formations are not considered to form a significant groundwater system within the project area.

Ashfield Shale is only present along the alignment at ridgelines and outcrops in the area from Willoughby to Neutral Bay Junction. The Warringah Freeway cuts through the Ashfield Shale, exposing the underlying Hawkesbury Sandstone at Naremburn, Cammeray, and the Warringah Freeway.

Groundwater quality within the shale is highly variable but is typically brackish or saline, due to the marine salts contained within it. The shale aquifer is characterised by low yields, limited storage and poor groundwater quality. Due to elevated salinity, low pH and the presence of sulfides, the groundwater can be corrosive to tunnel and infrastructure building materials.

Manmade fill

Manmade fill can act as a water bearing unit supporting perched aquifers (aquifers occurring above the regional water table) but with very high variability and unpredictability. The hydraulic properties of the fill are determined by the materials used for the fill as well as how it was laid. The fill material may behave as an unconfined aquifer or aquitard.

At Flat Rock Creek there is a known history of dumping industrial and domestic waste in both whole and incinerated form. Interpretation of historical records indicate that up to 40 metres of fill have been placed along Flat Rock Creek while the landscaped area on the east side of Flat Rock Drive is situated on about 30 metres of fill. The existing creek in the area has been placed in a box culvert which is now at depth and was covered with waste over time. The surface water in the area flows along a manmade creek line before re-joining the original creek to the east of the proposed Flat Rock Drive construction support site (BL2).

Groundwater levels and movement

The regional water table across the study area typically mimics topography and flows from areas of high topographic relief to areas of low topographic relief, ultimately discharging to the surface drainage features and the harbour. The depth of the water table is highly variable and can range from close to ground surface in low lying areas to 100 metres below ground level beneath elevated ridgelines. Localised water tables may also occur due to the highly stratified nature of the Hawkesbury Sandstone.

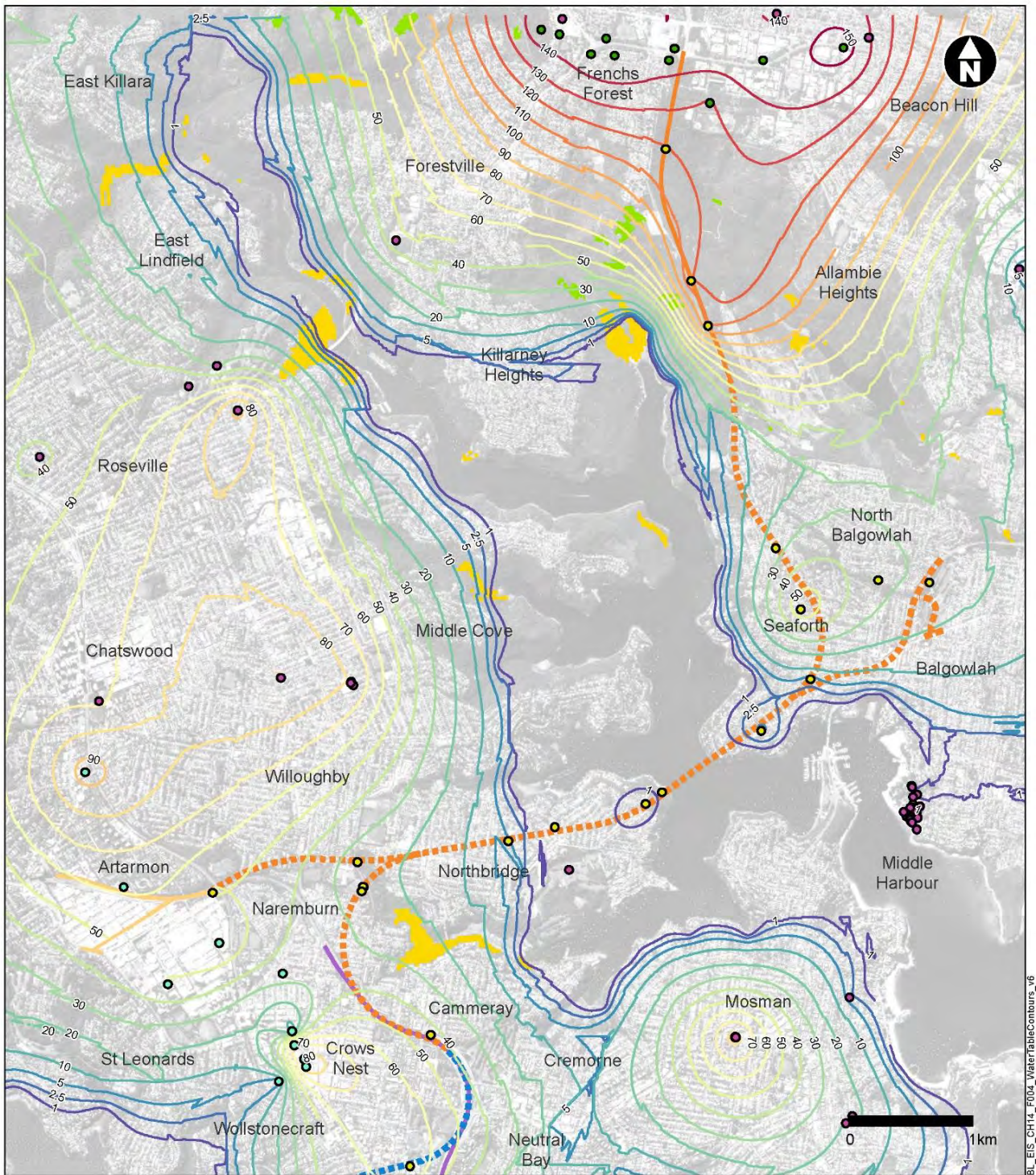
A composite water table contour map for the study area is presented in Figure 16-6. These contours were created using baseline groundwater data from the groundwater monitoring network installed for the project, as well as water levels from the Department of Planning, Industry and Environment (Water) Pinneena database, and water levels obtained from other nearby projects, including Northern Beaches Hospital Road Upgrade (Roads and Maritime Services, 2014a) and Sydney Metro City & Southwest (Chatswood to Sydenham) (Jacobs, 2016). The contours provide a general overview of key groundwater flow directions and trends along the alignment.

The water level contours shown in Figure 16-6 confirm the general trend of the water table following topography, with groundwater flow from elevated areas (recharge) toward the harbours and major drainage lines (discharge).

Deeper groundwater flow would be less controlled by topography and more influenced by the regional structure and stratigraphy (layering) of the Sydney Basin. Regional groundwater flow is predicted to be in an east to south-easterly direction towards Port Jackson and the Tasman Sea.

Hydraulic conductivity is one of the key parameters that controls drawdown in response to tunnel inflows. Hydraulic conductivity testing was conducted during the field investigation program to provide parameters to support the groundwater modelling.

Packer testing (a technique in which inflatable bladders, or packers, are used to isolate different regions of a borehole for hydraulic testing) was also used to determine hydraulic conductivity cross the study area. The majority of boreholes drilled were either in Hawkesbury Sandstone, or overlying sediments (including fill). Permeability results from the marine based testing are typically 1 to 1.5 orders of magnitude greater than the land based permeability values. This reflects the increased occurrence and concentration of structures associated with the harbour areas. The average hydraulic conductivity for the land based Hawkesbury Sandstone was generally in agreement with the range of values from previous investigations. For a detailed analysis of the testing and results refer to Appendix N (Technical working paper: Groundwater).



Legend

Operational features

- Beaches Link
- Gore Hill Freeway Connection

Connecting projects

- Western Harbour Tunnel
- Warringah Freeway

Groundwater monitoring bores

- Sydney Metro & Southwest (Chatswood to Sydenham)
- Western Harbour Tunnel and Beaches Link
- Northern Beaches Hospital Road Upgrade
- Public works

Groundwater dependent ecosystems

- Ecosystem that relies on subsurface presence of groundwater
- Coastal Upland Swamp - mapped by OEH (2016) with some additional ground truthing

Water table contour (mAHd)

- 150 m
- 1 m

Indicative only – subject to design development

Figure 16-6 Water table contour map and groundwater monitoring network

Groundwater inflow in existing Sydney tunnels

Rates of water inflows have been monitored in recent years from several unlined tunnels in the Sydney area with similar geology, hydrogeology and construction to that of the proposed Beaches Link tunnel. These average drainage inflow rates are considered long term flow rates throughout the operational life of the infrastructure and are summarised in Table 16-4.

Table 16-4 Measured and predicted drainage rates in other Sydney tunnels

Tunnel	Opened	Type	Width (metres)	Length (kilometres)	Reported/ predicted inflow (L/sec/km)
Existing tunnels – reported inflow					
Eastern Distributor	1999	Twin three lane road	12 (double deck)	1.7	1
M5 East Motorway	2001	Twin two lane road	8	3.8	0.9
Epping to Chatswood	2009	Twin rail	7.2	13	0.9
Lane Cove Tunnel	2007	Twin three lane road	9	3.6	0.6/1.7 ¹
Cross City Tunnel	2005	Twin two lane road	8	2.1	<3
Recently completed tunnels – predicted inflow					
M4 East	2019	Twin three lane road		5.5	1.5
M8	2020	Twin three lane road	14 to 21	9	0.67

Note 1: Measured inflow in Lane Cove Tunnel varied from 1.7 L/s/km (2001 – mid 2004) to 0.6 L/s/km (2011).

Groundwater quality

The groundwater assessment for the Sydney Metro Chatswood to Sydenham environmental impact statement (Jacobs, 2016) reported on general water quality information from previous tunnelling projects in the Sydney area using information provided by Transport for NSW. Groundwater that flows into existing underground structures in Sydney is generally high in iron, may contain manganese and other contaminants, relatively high salinity (as total dissolved salts) and is slightly acidic. Typical characteristics from existing tunnel projects in Sydney include:

- Energy Australia cable tunnel – iron 110 milligrams per litre; total dissolved solids 10,000 milligrams per litre; pH 5.9
- Sydney Harbour Tunnel – iron 40 milligrams per litre
- Epping to Chatswood Railway – iron 90 milligrams per litre; total dissolved solids 1300 milligrams per litre average to 6000 milligrams per litre; pH 5.9
- Cross City Tunnel – iron 50 milligrams per litre.

Groundwater is expected to be brackish within Ashfield Shale with neutral pH. Groundwater within Mittagong Formation and Hawkesbury Sandstone is expected to be fresh to brackish with neutral to slightly acidic pH and slightly elevated levels of iron and manganese. The concentration of dissolved metals and nutrients in the Ashfield Shale, Mittagong Formation and Hawkesbury Sandstone, including residual soils, is expected to be naturally very low. Organic compounds are not naturally associated with Ashfield Shale, Mittagong Formation or Hawkesbury Sandstone.

Contaminants identified during groundwater monitoring are discussed in Section 16.3.5.

Groundwater dependent ecosystems

A search of the National Atlas of Groundwater Dependent Ecosystems (Bureau of Meteorology, 2020) did not identify any groundwater dependent ecosystems within the construction footprint (refer to Chapter 19 (Biodiversity)). However, three areas of groundwater dependent ecosystems with potential reliance on subsurface groundwater associated with local waterways were identified within or close to the construction footprint as identified in Table 16-5.

Table 16-5 Groundwater dependent ecosystems

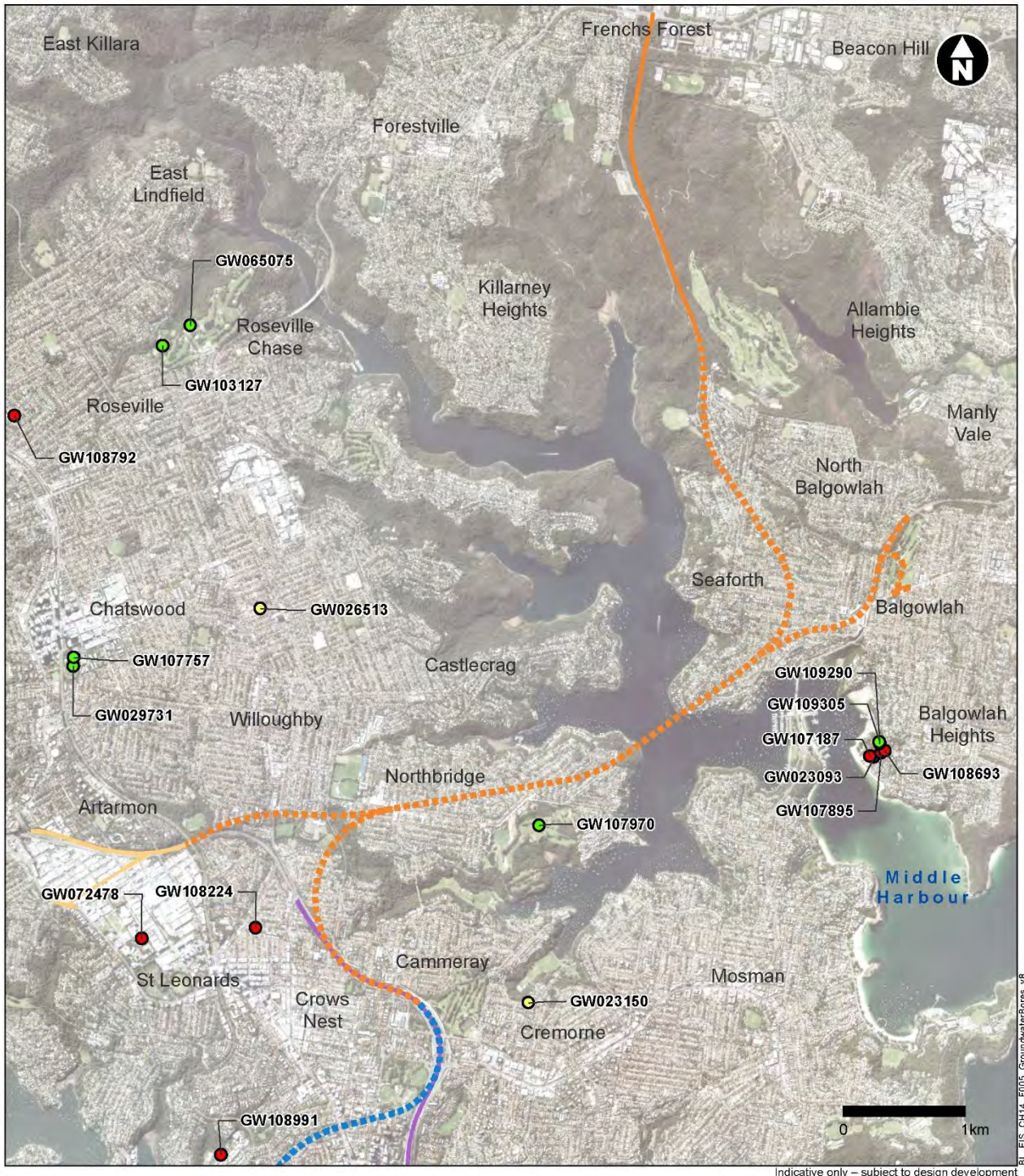
Ecosystems mapped	Location and type of potential groundwater dependent ecosystem	Receptor	Distance from construction footprint
Coastal Sandstone Gully Forest Sandstone Riparian Scrub Coastal Sand Forest	Upper reaches of Flat Rock Creek at Munro Park, Cammeray/Northbridge – Moderate to high potential for terrestrial groundwater dependent ecosystem	Vegetation at Flat Rock and Quarry Creeks	About 280 metres southeast of the tunnel alignment and the Flat Rock Drive construction support site (BL2)
Estuarine Mangrove Forest Seagrass Meadow Coastal Sandstone Gully Forest	Bates Creek, Killarney Heights – Moderate to high potential for terrestrial groundwater dependent ecosystem	Vegetation at Bates Creek Coastal Upland Swamp at Bates Reserve/Garigal National Park	About 550 metres west of the Wakehurst Parkway surface works
Coastal Sandstone Gully Forest Coastal Sandstone Plateau Heath	Manly Dam Reserve, Allambie Heights – Moderate potential for terrestrial groundwater dependent ecosystem	Vegetation at Manly Dam Reserve	About 650 metres east of the Wakehurst Parkway surface works

Groundwater users and extraction

Hawkesbury sandstone has been historically used as a water supply in the Sydney area with useful yields when fractures or joints are intersected. Details of groundwater bores sourced from the listed in the Department of Planning, Industry and Environment (Water) database (WaterNSW, 2020) as being for the purpose of supply/irrigation/recreational/industrial use, and located within the vicinity of the predicted extent of groundwater level drawdown are shown in Figure 16-7.

There are 17 registered groundwater bores within one kilometre of the project, including:

- Seven bores for household use
- Seven for recreation use
- Two for irrigated agriculture
- One for water supply.



Indicative only – subject to design development

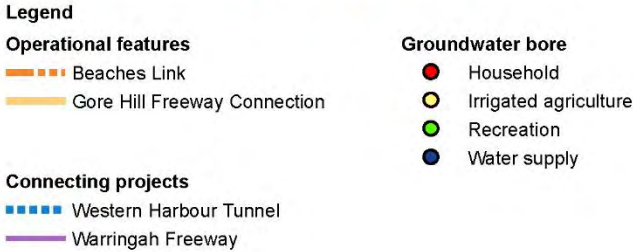


Figure 16-7 Existing groundwater bores within one kilometre of the proposed alignment

16.3.5 Contamination

Land contamination

Several sources were referenced, and investigations were carried out to determine the potential for land contamination within and adjacent to the project. The sources and investigations included:

- Historic and current aerial photographs
- NSW EPA Contaminated Sites Register and Record of Notices
- Yellow Pages business directory search
- Contaminated site investigations.

Historical and current aerial photographs

Historical aerial photographs from several years between 1930 and 2005 were reviewed with a focus on the key surface disturbance areas and temporary construction support sites. Additional details are provided in the Stage 1 Contamination Investigation in Appendix M (Technical working paper: Contamination). Based on this review a summary of the potential contamination issues for surface disturbance areas is provided in Table 16-6.

Table 16-6 Summary of potential contamination issues at surface disturbance areas

Surface disturbance area	Potential contamination issue
Temporary construction support sites	
Cammeray Golf Course (BL1)	<ul style="list-style-type: none"> • Inappropriate handling and disposal of building materials during demolition of buildings for construction of the Warringah Freeway • Filling with material of unknown quality during construction of the Warringah Freeway • Particulate matter deposition from vehicles using the Warringah Freeway • Chemical use and storage at golf course
Flat Rock Drive (BL2)	<ul style="list-style-type: none"> • Infilling with manmade waste material.
Punch Street (BL3)	<ul style="list-style-type: none"> • Commercial/industrial use of site and surrounding areas • Degradation of building materials used in bridge structure • Demolition - Inappropriate handling and disposal of building materials during demolition of bridge structure • Filling with material of unknown quality during creek realignment • Filling with material of unknown quality during construction of Gore Hill Freeway.
Dickson Avenue (BL4)	<ul style="list-style-type: none"> • Commercial/industrial use of site and surrounding areas.
Barton Road (BL5)	<ul style="list-style-type: none"> • Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of Gore Hill Freeway.
Gore Hill Freeway median (BL6)	<ul style="list-style-type: none"> • Filling with material of unknown quality during redevelopment of quarry • Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of Gore Hill Freeway.

Surface disturbance area	Potential contamination issue
Middle Harbour south cofferdam (BL7)	<ul style="list-style-type: none"> Contamination of Middle Harbour sediments (discussed below in the Middle Harbour contamination section).
Middle Harbour north cofferdam (BL8)	<ul style="list-style-type: none"> Contamination of Middle Harbour sediments (discussed below in the Middle Harbour contamination section).
Spit West Reserve (BL9)	<ul style="list-style-type: none"> Land reclamation.
Balgowlah Golf Course (BL10)	<ul style="list-style-type: none"> Filling with material of unknown quality during golf course construction works Demolition – Inappropriate handling and disposal of building materials during demolition of buildings for construction of Burnt Bridge Creek Deviation Chemical use and storage at golf course.
Kitchener Street, Balgowlah (BL11)	<ul style="list-style-type: none"> Filling with material of unknown quality during construction of Burnt Bridge Creek Deviation.
Wakehurst Parkway south (BL12)	<ul style="list-style-type: none"> Contamination resulting from degradation of asphalt road surface Degradation of hazardous building materials from structures currently present on site.
Wakehurst Parkway east (BL13)	<ul style="list-style-type: none"> Contamination resulting from degradation of asphalt road surface Degradation of paint from use of the adjacent site as water reservoirs.
Wakehurst Parkway north (BL14)	<ul style="list-style-type: none"> Stockpiling of material of unknown quality.
Other surface construction sites	
Gore Hill Freeway surface works	<ul style="list-style-type: none"> Commercial/industrial use of site and surrounding areas Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of Gore Hill Freeway.
Balgowlah connection surface works	<ul style="list-style-type: none"> Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of Burnt Bridge Creek Deviation Filling with material of unknown quality during construction of Burnt Bridge Creek Deviation.
Wakehurst Parkway surface works	<ul style="list-style-type: none"> Contamination resulting from degradation of asphalt road surface Potential historical illegal dumping of waste.
Motorway Control Centre	<ul style="list-style-type: none"> Commercial/Industrial use of site and surrounding areas.

Review of recent aerial imagery of the study area identified 18 sites, with activities or operations which could potentially represent potential contamination sources. These sites were located in Cammeray (three), North Sydney (one), Crows Nest (three), Naremburn (one), Artarmon (three), Middle Harbour (one), Balgowlah (two), Seaforth (three) and Frenchs Forest (one). Sites that may be contaminated included those used for commercial and industrial purposes and areas subject to the deposition of vehicle particulates.

NSW EPA Contaminated Sites Register and Records of Notices

An online search of the NSW EPA Contaminated Sites Record of Notices (NSW EPA, 2020) and the list of contaminated sites notified to the NSW EPA indicated that there are seven sites registered with the NSW EPA within 500 metres of the project that are either regulated (current notices) or have been notified. These sites were associated with service station activities and are listed in Table 16-7.

Table 16-7 Regulated/notified sites within 500 metres of the project

Suburb	Regulated/notified	Site and address	Distance from project
Neutral Bay	Notified (Section 60)	Caltex service station – 16-38 Military Road	About 150 metres south of the project
Neutral Bay	Notified (Section 60)	Shell Coles service station – 200-204 Ben Boyd Road	About 300 metres south east of the project
Cammeray	Notified (Section 60)	Coles Express service station – 477-483 Miller Street	About 300 metres north of the project
Artarmon	Notified (Section 60)	7-Eleven Service station – 477 Pacific Highway	About 200 metres north west of the project
Lane Cove North	Notified (Section 60)	BP Service station – 432 Pacific Highway	About 300 metres west of the project
Willoughby	Notified (Section 60)	Shell Coles service station – 616-626 Willoughby Road	About 500 metres north of the project
Balgowlah	Notified (Section 60)	BP service station – Corner of Sydney Road and Maretimo Street	Less than 100 metres south of the project

Contamination exposure risk from service stations located in the vicinity of surface works and temporary construction support sites is likely to be low, due to the relatively large distances from the project and the likely extent of contamination (contamination, if present is likely to be below the depth of surface works construction activities at around four to 10 metres below ground level).

Yellow Pages business directory search

The Yellow Pages business directory search identified 74 sites within or adjacent to the project area whose activities may cause contamination. These sites were located in Cammeray (two), Crows Nest (nine), Naremburn (one), Artarmon (43), Willoughby (four), Northbridge (one), Seaforth (one), Balgowlah (seven) and Frenchs Forest (six). The businesses were predominantly comprised of service stations, paint and chemical manufacturers, vehicle mechanics and dry cleaners.

Contamination investigations

Soil samples were analysed for common contaminant compounds including heavy metals, polycyclic aromatic hydrocarbons (PAH), total recoverable hydrocarbons (TRH), toluene, ethylbenzene and xylene (BTEX), organochlorine pesticides (OCP), organophosphorus pesticides

(OPP) with selected samples additionally analysed for phenols, volatile and semi volatile organic compounds, cyanide, polychlorinated biphenyls (PCB) and asbestos. The results of the sampling and analysis were compared against guidelines for the protection of ecological and human (investigation and screening levels) receptors under open space and commercial/industrial land usage.

The contamination investigations indicated that soil contamination was present in a number of samples. Exceedances of the human health guidelines were reported for PAH in near surface soils at Wakehurst Parkway. Guideline exceedances for nickel were reported in soils along Wakehurst Parkway, Frenchs Forest and Gore Hill Freeway, Artarmon.

Groundwater contamination

Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients and hydrocarbons. The contamination investigations indicated a number of groundwater samples from boreholes located in Artarmon, Willoughby, Northbridge, Balgowlah, and Wakehurst Parkway exceeded the Australian and New Zealand Environment and Conservation Council (ANZG) water quality guidelines for marine and freshwater ecosystems (95 per cent level of protection). The concentrations of contaminants above guideline levels may represent contamination, especially those contaminants and associated concentrations reported at Willoughby which may be associated with historical landfill.

Middle Harbour contamination

A review of the technical report *Sydney Harbour: A systematic review of the science* (Hedge et al., 2013) indicated that sediments in Sydney Harbour (Middle Harbour being a sub catchment) contain high concentrations of a suite of metals (most notably copper, zinc and lead). More recent studies have confirmed that sediments in large areas of Sydney Harbour are not only highly polluted by metals, but also by a wide range of non-metallic contaminants including OCP, PAH and polychlorinated dibenzo-para-dioxins (dioxins) and dibenzofurans (furans).

Most of the harbour's contamination results from a combination of historical inputs that remain in the sediments and some current sources of input such as stormwater. The very highest contamination concentrations are generally restricted to the bedded sediments and macroalgae of the upper reaches of embayments and decrease seaward in the harbour (Hedge et al., 2013).

Sediment samples were collected as part of the geotechnical investigations carried out for the project in Middle Harbour. Sediment samples were collected from a range of depths and analysed for a range of contaminant compounds including heavy metals, hydrocarbon compounds (TRH, BTEX, PAH), OCP, polychlorinated biphenyls, tributyltin (TBT), per- and poly-fluoroalkyl substances (PFAS) and dioxins. The results of the laboratory analysis were compared against the following guideline criteria:

- *High and Low Interim Sediment Quality Guidelines* (ISQG), that form a part of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG, 2018)
- *National Assessment Guidelines for Dredging* (NAGD) (Department of Environment, Water, Heritage and the Arts, 2009).

The results of the sediment sampling in Middle Harbour indicated a range of guideline exceedances including mercury, zinc, silver, lead, heavy metals, PAH, TRH, TBT and OCP. Contaminants were generally detected above guideline criteria in samples collected within the first metre of sediments. Contaminants detected above the respective guidelines in selected sediment samples are provided in Appendix M (Technical working paper: Contamination).

Elutriate testing provides an indication of the potentially soluble contaminants that are susceptible to migration and assesses the risk to the environment from these soluble contaminants. Two rounds of elutriate testing have been carried out for sediments samples from Middle Harbour. A total of seven samples were tested. The testing focussed on copper, lead, zinc, silver, mercury and dioxins. The majority of analytes were below laboratory detection and relevant ANZG (2018) water quality trigger values for marine water. However, exceedances were recorded for each analyte in at least one of the samples tested.

16.4 Assessment of potential construction impacts

16.4.1 Soils

Erosion and sedimentation

The proposed construction associated with the tunnel works, temporary construction support site establishment works and road upgrade works, would involve surface excavation and earthmoving (as described in Chapter 6 (Construction work)). The temporary exposure of soil to water runoff and wind could increase soil erosion potential, particularly where construction is carried out in soil landscapes characterised by a high and extreme erosion hazard (refer to Section 16.3.3). There is the potential for exposed soils and other unconsolidated materials, such as spoil, sand and other aggregates to be transported from the temporary construction support sites into surrounding waterways via stormwater runoff.

The highest potential for soil erosion would be associated with the disturbance of soils on existing slopes during construction, which is most likely to occur at temporary construction support sites. The majority of temporary construction support sites are not located in areas with steep terrain, reducing the potential for soil erosion. Higher soil erosion impact potential would be associated with surface work construction sites located adjacent to more environmentally sensitive areas (eg Garigal National Park and Manly Dam Reserve).

Uncompacted or unconsolidated materials (such as excavated and stockpiled soils) have the potential to leave construction areas during rain (through surface water run off) causing downstream sedimentation. Sedimentation in natural waterways can result in reduced water quality as well as smothering of vegetation and clogging of channels, impacting the natural flow paths of the waterway. Further details regarding erosion and sedimentation are provided in Chapter 17 (Hydrodynamics and water quality).

In general, management and control of erosion and sedimentation for major construction projects is well known, tried and proven. Standard management and mitigation measures are expected to be adequate in controlling any potential impacts.

Acid sulfate soils

The excavation of actual and potential acid sulfate soils and lowering of the groundwater table in the vicinity of acid sulfate soils during construction could cause the oxidation of sulfidic compounds within these soils which in turn could generate acid run off, leachate and mobilise other contaminants (namely heavy metals) into the environment. Acidic run off, leachate and contaminant mobilisation could potentially impact upon the following:

- Contaminant exposure risk to project personnel and the general public
- Contaminant exposure to environmental receivers
- Degradation of terrestrial and aquatic ecosystems
- Damage to existing structures.

Class 5 acid sulfate soil risks have been mapped in the Manly and Willoughby local environmental plans. Based on the classification scheme presented in the *Acid Sulfate Soils Assessment Guidelines* (Ahern, Stone and Blunden, 1998), areas classified as Class 5 are located within 500 metres on adjacent Class 1, 2, 3 or 4 land. It is noted that they are not typically found within Class 5 areas. Based on the information reviewed, the risk of acid sulfate soils being present within

the project area is low to negligible, with the exception of soils within Spit West Reserve and sediments within Middle Harbour and The Spit, which have been identified as potential acid sulfate soils. Measures to assess and manage potential and actual acid sulfate soils in these areas are contained in Section 16.7. Further geotechnical testing of underlying sub soil and rock stratum would be carried out to determine the composition of rock and soil types likely to be present within excavation areas.

If acid sulfate soils are encountered, they would be managed in accordance with the *Acid Sulfate Soil Manual* (ASSMAC, 1998). The manual includes procedures for the investigation, handling, treatment and management of such soils.

Soil salinity

Construction of the project has the potential to contribute to urban salinity through:

- Removal of deep-rooted vegetation or other activities which could raise the groundwater table above normal seasonal levels
- Soil compaction at areas of surface disturbance, such as at the temporary construction support sites, which can restrict groundwater flow and result in a concentrate of salt in one area.

As outlined in Section 16.3.3, naturally occurring soil salinity is not considered to be a major concern within the project footprint. Salinity is considered unlikely to represent a risk to surface water and/or groundwater during the construction of the project.

16.4.2 Ground movement

An assessment of ground settlement induced by tunnel excavation due to both stress redistribution in the surrounding ground (due to the removal of subsurface materials during tunnelling activities) and groundwater drawdown around drained tunnels has been carried out (Arup & WSP, 2020). The assessment approach and findings are summarised in Appendix N (Technical working paper: Groundwater).

Ground movement may occur as a result of:

- Tunnel induced movement caused by the relief of stress from the removal of intact rock during tunnelling
- Settlement induced by groundwater drawdown.

The risk to individual structures would be dependent on the geotechnical conditions, the depth of the tunnel, the number of storeys of the building, and the position, condition, and masonry of the structure itself.

Table 16-8 provides typical impacts which would be expected in relation to potential ground movement values and typical associated impacts for settlement.

Table 16-8 Building and structure settlement damage classification

Damage category	Maximum settlement of building (mm)	Degree of severity	Typical impact
0		Negligible	Hairline cracks less than 0.1 millimetres.
1	Less than 10	Very slight	Damage generally restricted to internal wall finishes. Cracks (0.1 to one millimetre) may be visible on external brickwork or masonry.
2	10 to 50	Slight	Cracks easily filled. Redecoration probably required. Recurrent cracks can be masked by suitable linings. Cracks may be visible externally and some repointing may be required to ensure weather tightness. Doors and windows may stick slightly. Typical crack widths between one to five millimetres.
3	50 to 75	Moderate	Cracks may require some opening and may be patched by a mason. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows may stick. Service pipes may fracture. Weather tightness often impaired. Typical crack widths between five to 15 millimetres.
4	Greater than 75	Severe	Extensive repair work involving break out and replacing sections of walls, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably; some loss of bearing in beams. Utilities disrupted. Typical crack widths between 15 to 25 millimetres.
5	Greater than 75 and maximum slope of ground (angular distortion) >1:50	Very severe	Impacts require a major repair job involving partial or complete rebuilding. Beams lose bearing; walls lean badly and require shoring. Windows broken with distortion. Danger of instability. Typical crack widths greater than 25 millimetres.

Note 1: Degree and typical impact adopted from Burland et al. (1977), and Boscardin and Cording (1989).

A summary of the maximum total predicted settlement along the tunnel alignment, based on unconstrained groundwater inflows into the tunnel, is provided in Table 16-9 and shown in Figure 16-8 and Figure 16-9.

Table 16-9 Maximum predicted surface settlement

Location	Maximum stress redistribution induced settlement (mm)	Maximum groundwater drawdown induced settlement (mm)	Maximum total settlement (mm)
Warringah Freeway portal	25 – 30	Less than five	30+
Cammeray ventilation tunnel	25 – 30	Less than five	25 – 30
Flat Rock Drive access decline	5 – 10	Less than five	10 – 15
Flat Rock Creek Reserve	Less than five	80	85
Gore Hill Freeway ventilation tunnel	20 – 25	Less than five	20 – 25
Lane Cove Tunnel exit/entry	20 – 25	Less than five	20 – 25
Middle Harbour crossing, west (Northbridge)	25 – 30	5 - 10	25 – 30
Mainline tunnels between Warringah Freeway and Middle Harbour	20 – 25	10 - 15	20 – 25
Middle Harbour crossing, east (Seaforth)	25 – 30	Less than five	25 – 30
Mainline and ramp tunnels between Middle Harbour Burnt Bridge Creek Deviation/Wakehurst Parkway	15 – 20	Less than five	15 – 20
Balgowlah ventilation tunnel/access decline	35	Less than five	35
Burnt Bridge Creek Deviation portal	35 – 40	Less than five	35 – 40
Wakehurst Parkway portal	35 – 40	Less than five	35 – 40

Preliminary ground movement predictions indicate that there may be potential settlement of up to 40 millimetres around the Burnt Bridge Creek Deviation and Wakehurst Parkway portals. This would be assessed as 'slight' severity under relevant guidelines.

Total settlement of 85 millimetres is predicted at Flat Rock Reserve, primarily due to the groundwater induced settlement. There are, however, no buildings present at this location. This prediction assumes that groundwater inflows into the tunnel beneath Flat Rock Reserve are unconstrained. Additional modelling and settlement predictions were completed at this location. The additional modelling included tunnel linings to preclude groundwater inflows beneath Flat Rock Reserve. When the reduced inflows and reduced groundwater drawdown were taken into account, the maximum predicted settlement reduced to 35 millimetres. This demonstrates that appropriate choice of linings can be used to minimise groundwater drawdown induced settlement at this location.

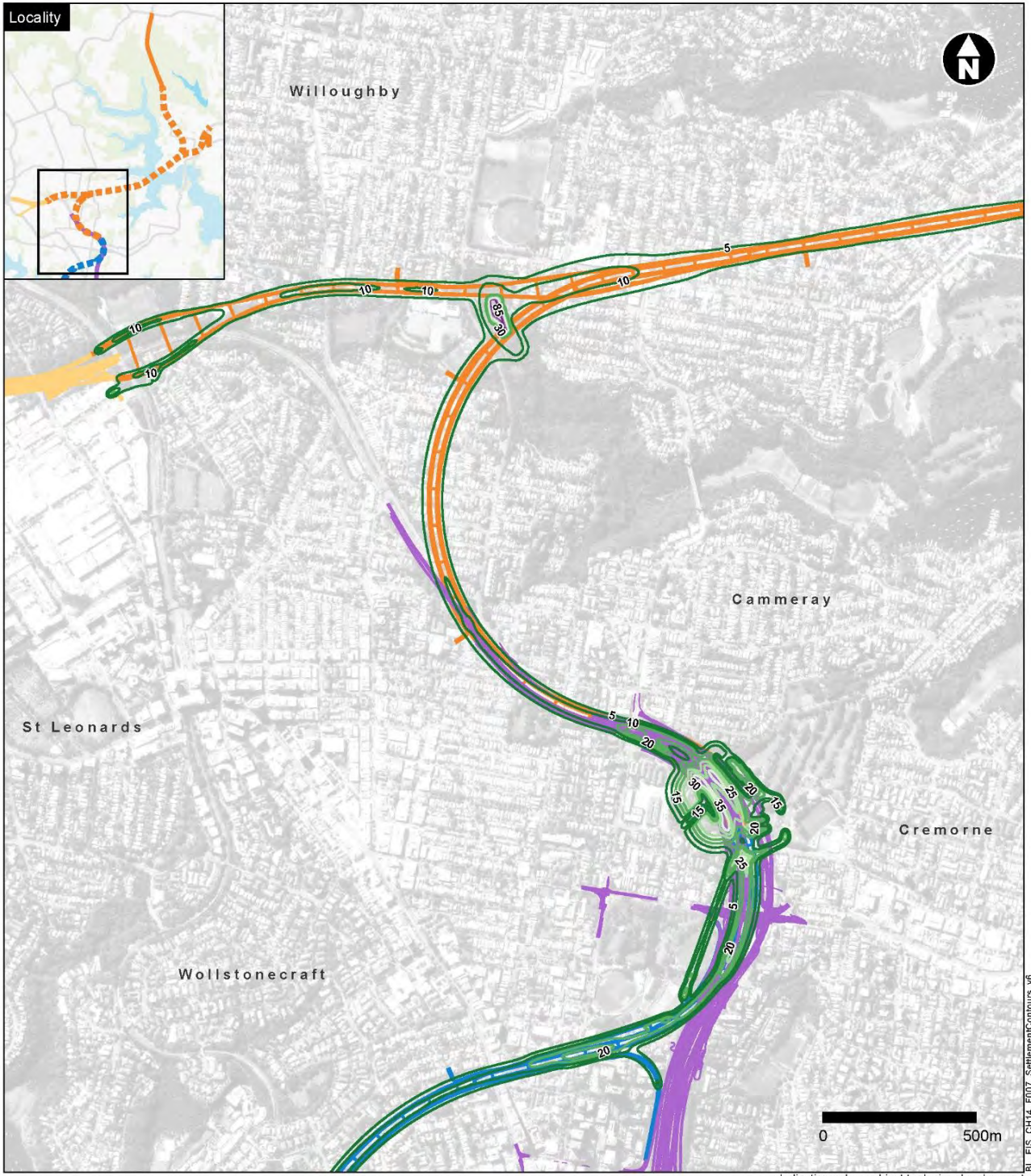
No buildings were predicted to be in the 'slight' to 'very severe' damage categories. Sixty-one buildings are categorised as potentially within the 'very slight' damage category. These buildings are mainly in the vicinity of locations where the tunnel would have shallow cover near portals and larger span caverns, including:

- The Warringah Freeway portal
- Northbridge, east of the Flat Rock Creek area

- Seaforth Bluff
- Seaforth at the junction of the mainline and ramp tunnels
- Wakehurst Parkway cavern and portal.

'Very slight' damage (fine cracks) would be easily treated during normal decoration. Damage would generally be restricted to internal wall finishes, with small cracks visible on external brickwork or masonry.

Building/structure condition surveys would be carried out as applicable prior to commencement of construction (refer to environmental management measure SG7 in Table 16-19).

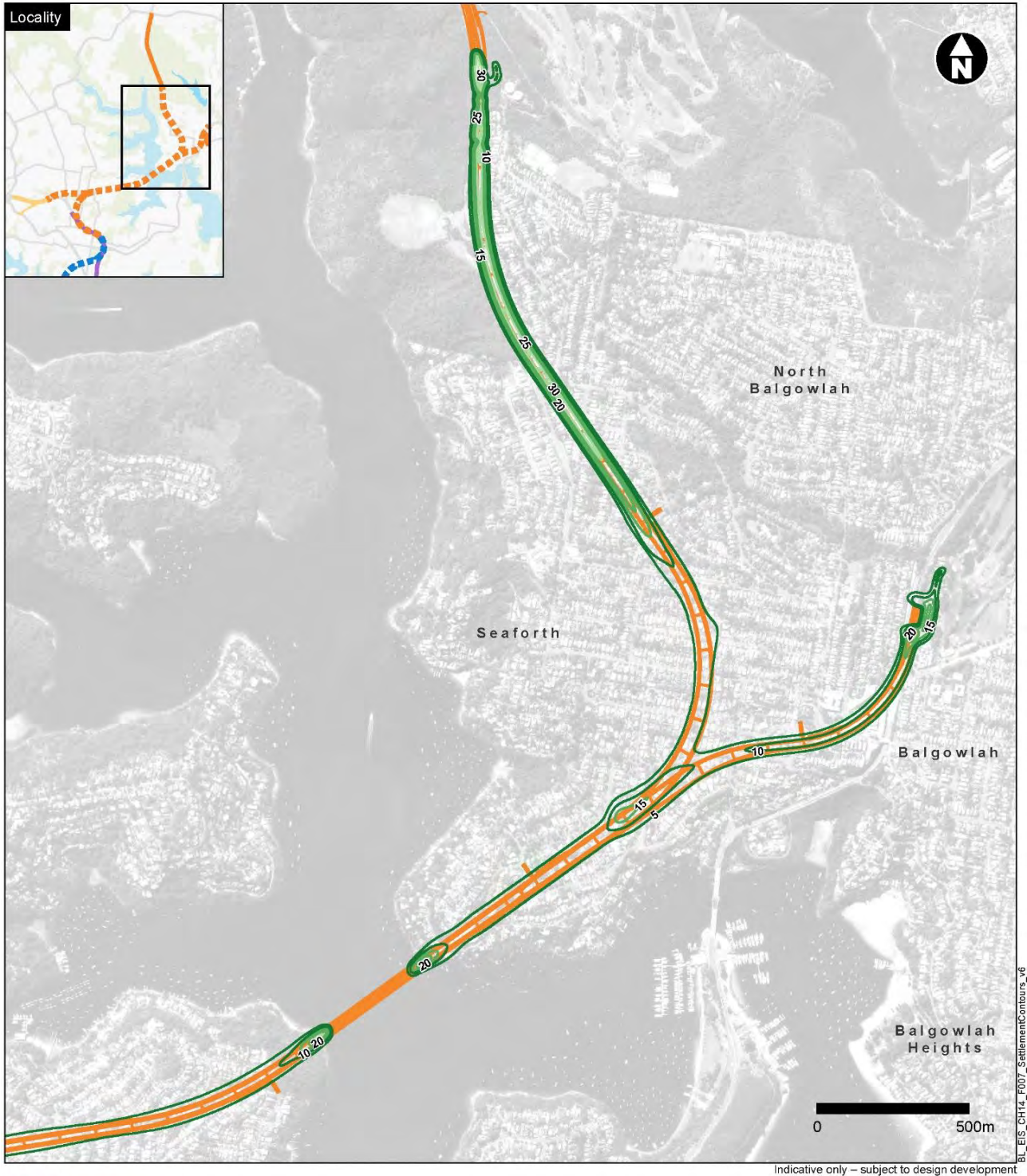


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- Legend**
- Operational features**
 - Beaches Link
 - Gore Hill Freeway Connection
 - Connecting projects**
 - Western Harbour Tunnel
 - Warringah Freeway Upgrade
 - Settlement contour**
 - 85 m
 - 5 m

Figure 16-8 Settlement contours – Cammeray, Willoughby



- Legend**
- Operational features**
- Beaches Link
 - Gore Hill Freeway Connection
- Connecting projects**
- Western Harbour Tunnel
 - Warringah Freeway Upgrade

- Settlement contour**
- 85 m
 - 5 m

Figure 16-9 Settlement contours – Middle Harbour, Seaforth, Balgowlah

16.4.3 Land contamination

Areas of environmental interest

A Stage 1 contamination investigation was carried out to identify potential areas of environmental interest which would assist in identifying construction limitations/constraints and management options for the project with respect to contamination.

Based on the assessment of known and potentially contaminated sites, most sites within and/or adjacent to the project area are considered to represent a low contamination risk and are not considered further. Thirteen locations were assessed as having a moderate to high risk rating for contamination and are considered to be potential areas of environmental interest.

A summary of these sites including their associated contaminants of concern is provided below. The location of areas of environmental interest identified along the project alignment are shown in Figure 16-10.

Warringah Freeway, North Sydney to Cammeray [B1 to B6]

Potentially contaminated soils may be presented within unsealed areas next to the Warringah Freeway between the Cammeray Golf Course at Cammeray and Willoughby Road at Naremburn. The contamination could be associated with the inappropriate handling and disposal of building materials or filling of some of the areas with material of unknown quality during the construction of the Warringah Freeway or even potentially from particulate matter deposition from large volume traffic flows using the Warringah Freeway since its opening. Contaminants could consist of a variety of heavy metals, hydrocarbons and particulate matter as well as asbestos. These areas pose a moderate contamination risk to construction given that contamination is potentially present within soils which are likely to be excavated and exposed during the carrying out of surface works and construction of the temporary construction support site at the Cammeray Golf Course (BL1).

Punch Street, Artarmon [B7]

The area along Punch Street may be contaminated with heavy metals, asbestos and pesticides as a result of the degradation of hazardous building materials contained within the old bridge structure and the potential inappropriate demolition and waste disposal practices used during the demolition of the bridge. In addition, possible infilling of the site with material of unknown quality (potentially contaminated with common contaminant compounds including but not limited to heavy metals, hydrocarbons, pesticides, polychlorinated biphenyls and asbestos) during construction of the Gore Hill Freeway may be present across the site. This area poses a moderate contamination risk to construction considering the potential presence of soil contamination and that soils are likely to be excavated and exposed during construction activities at the Punch Street construction support site (BL3).

Freeway Hotel site, Reserve Road, Artarmon [B8]

The site of the proposed Motorway control centre (Freeway Hotel site), Reserve Road in Artarmon, could be contaminated from current and historical commercial/industrial use of the site and adjacent areas. This area poses a moderate contamination risk to construction considering the potential presence of soil contamination and that soils are likely to be excavated and exposed during construction of the Motorway control centre.

Flat Rock Reserve, Northbridge [B9]

The location of the proposed Flat Rock Drive construction support site (BL2) has the potential for contamination risks given the history of landfill activities in the area. Information reviewed as part of the Stage 1 Contamination Investigation carried out for this project (Appendix M (Technical working paper: Contamination)) indicated that building type wastes are situated in the upper layers of the former landfill, with the possible presence of putrescible materials located at greater depths of the waste mass. Soils/wastes and groundwater beneath this site may be contaminated with a variety of contaminant compounds.

It is possible that the waste mass beneath this site and the adjacent Willoughby Leisure Centre and Bicentennial Reserve may present a source of landfill gas. With specific regard to the possible presence of landfill gas beneath the site and the adjacent Willoughby Leisure Centre and Bicentennial Reserve, there is the potential for landfill gas to migrate towards the proposed Flat Rock Drive (BL2) construction support site as a result of formation pressure due to ground disturbance from construction activities associated with the project. It is not known whether the road embankment restricts gas flow (if any) between the two areas. Sub-surface structures (where present) beneath the road embankment between the two areas may act as conduits for gas movement (if gas is present).

This area poses a moderate potential contamination risk associated with the possible presence of contamination beneath Flat Rock Drive construction support site (BL2) and known groundwater contamination in adjoining areas (Willoughby Leisure Centre and Bicentennial Reserve).

Willoughby Leisure Centre and Bicentennial Reserve, Willoughby [B10]

The historical landfill activities carried out within the areas surrounding the Willoughby Leisure Centre and Bicentennial Reserve are likely to contain soil, groundwater contamination sources within the buried waste mass. Soils may be contaminated with a variety of contaminant compounds, including asbestos. This area poses a high potential contamination risk associated with the known presence of contaminated soils/wastes and groundwater as a result of the waste mass in the vicinity of the tunnel alignment, which is likely to be exposed during construction of the tunnel. Construction activities could also create preferential pathways for groundwater contamination to other areas, particularly the adjacent Flat Rock Drive construction support site (BL2).

It is possible that the waste mass beneath Flat Rock Drive construction support site (BL2) and the adjacent Willoughby Leisure Centre and Bicentennial Reserve may present a source of landfill gas. Although not encountered during borehole investigations in the area, there remains the potential for pockets of landfill gas to be present within this area. Should landfill gas be present, there is the potential for it to migrate towards the proposed Flat Rock Drive construction support site (BL2) as a result of formation pressure gradients due to ground disturbance from construction activities associated with the project.

Spit West Reserve, Mosman [B11]

Spit West Reserve is located on partially reclaimed land. The source and the quality of the material used to reclaim this land is not known and may be impacted with common contaminant compounds including, but not limited to, heavy metals, hydrocarbons, pesticides, polychlorinated biphenyls, phenols, organotins and asbestos. Therefore, it is considered that this area poses a moderate contamination risk to construction given the potential for contamination to be present within soil which is likely to be excavated and exposed during construction of the Spit West Reserve construction support site (BL9).

Middle Harbour and the Spit [B12]

Contamination has been reported in sediments present within Middle Harbour and west of Spit West Reserve. Contamination is likely to be associated with inputs from the surrounding urbanised catchments and general maritime use within the harbour. The sediments pose a high contamination risk to construction given that contamination is known to be present within sediments which are likely to be excavated and exposed during the construction of the cofferdams in Middle Harbour, Middle Harbour south cofferdam (BL7) construction support site and Middle Harbour north cofferdam (BL8) construction support site as well as the construction of the Spit West Reserve (BL9) construction support site itself.

Balgowlah Golf Course, Balgowlah [B13]

Soil contamination is anticipated to be present within soils adjacent to and within the Balgowlah Golf Course. The potential contamination could be associated with the inappropriate demolition and waste disposal practices of structures historically present within this area as well as the unknown quality of fill used in the construction of the Burnt Bridge Creek Deviation and the golf course. Further contamination risks could be associated with the degradation of hazardous building materials which may have potentially been used in structures currently situated in the area. This area poses a moderate contamination risk during construction given that soils are expected to be excavated and exposed during construction of the Balgowlah Golf Course (BL10) construction support site, the Balgowlah connection surface works and the new open space and recreation facilities.

Dudley Street, Balgowlah [B14]

Potential soil contamination may be present within surface soils adjacent to the existing residential premises located along Dudley Street at Balgowlah. The potential contamination could be associated with the degradation of hazardous building materials which may have potentially been used in these structures. These areas pose a moderate contamination risk to construction given the potential for contamination and that soils are expected to be excavated and exposed during construction of the Balgowlah Golf Course construction support site (BL10), the Balgowlah connection surface works and the new open space and recreation facilities.

Residential properties, Judith Street & Kirkwood Street, Seaforth [B15]

Potential soil contamination may be present within surface soils adjacent to the existing residential premises located at the corners of Judith Street and Kirkwood Street with Wakehurst Parkway at Seaforth. The potential contamination could be associated with the degradation of hazardous building materials which may have been used in these structures. These areas pose a moderate contamination risk to construction given the potential for contamination and that soils are expected to be excavated and exposed during construction of the Wakehurst Parkway south construction support site (BL12).

Sydney Water Bantry Bay Reservoir site, Killarney Heights [B16]

There is the potential for possible contaminated soils at the Sydney Water Bantry Bay Reservoir site at Killarney Heights from the deposition of degraded materials from the surface of the reservoir. These areas pose a moderate contamination risk to construction given the potential for contamination and that soils are expected to be excavated and exposed during construction of the Wakehurst Parkway east support site (BL13).

Wakehurst Parkway, Seaforth to Frenchs Forest [B17]

Isolated contamination has been reported in surface soils adjacent to the Wakehurst Parkway (Seaforth to Frenchs Forest). The contamination is likely to be associated with the degradation of asphaltic road surfaces. The absence of formalised kerb and guttering along some sections of the Wakehurst Parkway may have caused asphalt to enter surface soils along these sections. These areas pose a high contamination risk to construction given the presence known soil contamination and that soils are expected to be excavated and exposed during the upgrade works to Wakehurst Parkway and adjacent construction of the support sites, Wakehurst Parkway south (BL12) and Wakehurst Parkway north (BL14).

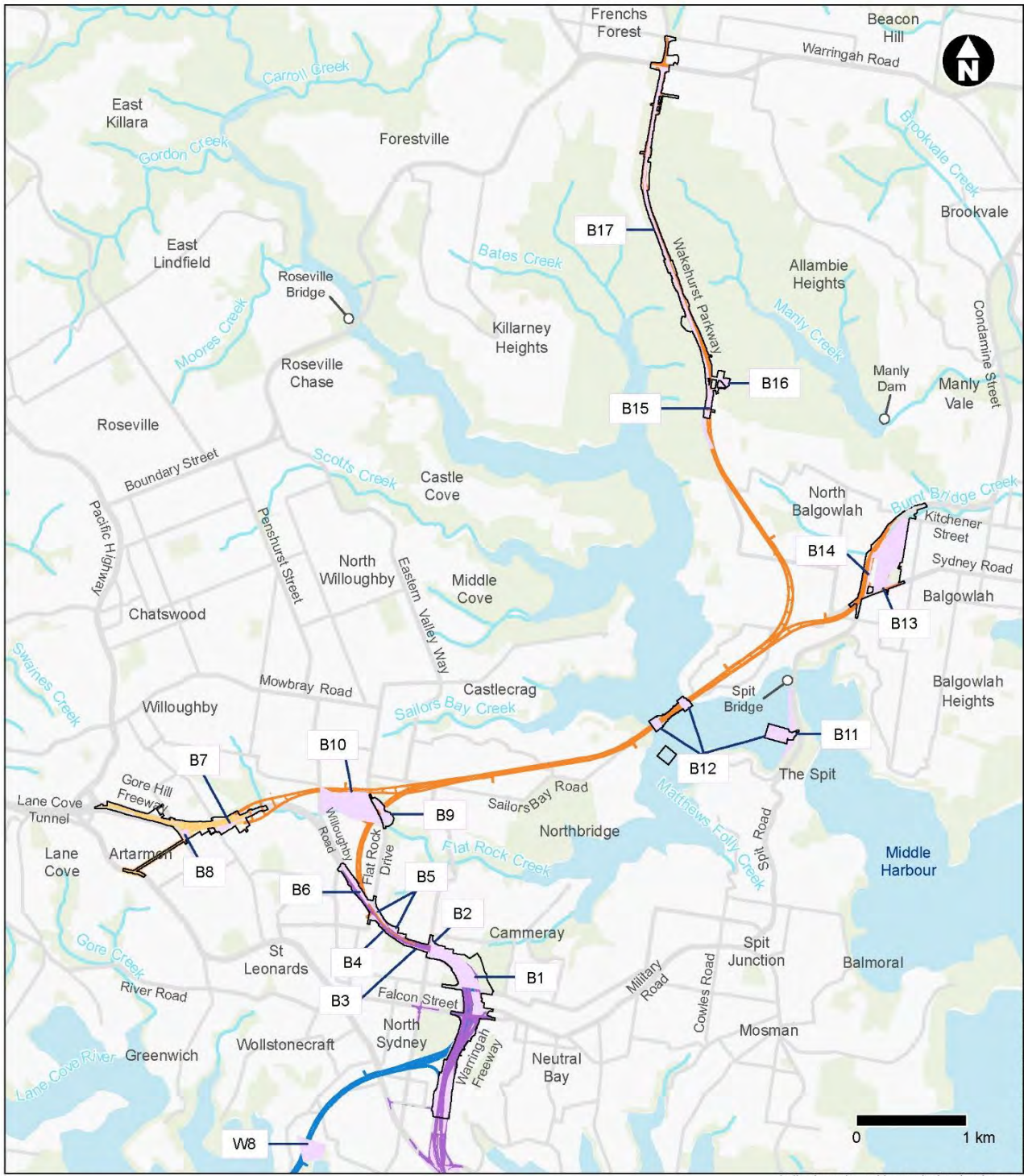
The non-urbanised areas immediately surrounding the Wakehurst Parkway may have been historically subject to the small-scale illegal dumping of waste. Illegally dumped waste presents a moderate contamination risk to construction given the potential for contamination and that soils/wastes are expected to be excavated and exposed during the upgrade works to the Wakehurst Parkway.

Waverton Park – Woolcott Road, Waverton [W8]

Contaminated fill materials have been reported within Waverton Park; however, no groundwater samples have been taken to date. It is possible that the contamination reported in respect to fill material could represent a contamination source to groundwater beneath the site. This area poses a high contamination risk to operation given that contamination is known within fill material which could impact upon groundwater. Groundwater could migrate during operation of the tunnel due to groundwater drawdown. No direct construction works associated with the project would occur in Waverton Park. Further information on the Waverton Park site is provided in the *Western Harbour Tunnel and Warringah Freeway Upgrade Technical Working Paper: Contamination* (Jacobs, 2020)

Potential contamination risks

As indicated above, seventeen sites would have a moderate to high risk rating and are considered to be potential areas of environmental interest. Table 16-10 identifies the potential contamination, impacts and associated risks. Management and mitigation measures to address the potential risks are discussed in Section 16.7.



- Indicative only - subject to design development
- | | |
|---|---|
| Operational features | Connecting projects |
| — Beaches Link | — Western Harbour Tunnel |
| — Gore Hill Freeway Connection | — Warringah Freeway Upgrade |
| Construction features | Contam sites |
| Construction footprint | Moderate to high risk contaminated site |

Figure 16-10 Areas of environmental interest and contaminated sites

Table 16-10 Potential contamination risks

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Warringah Freeway, North Sydney to Cammeray [B1 – B6]	Within construction footprint. Above proposed tunnel alignment and within Cammeray Golf Course construction support site (BL1).	<ul style="list-style-type: none"> • Temporary construction support site establishment works • Tunnelling and associated excavation and stockpiling. 	<p>Unsealed areas adjacent to Warringah Freeway may be contaminated with lead, hydrocarbons and asbestos as a result of the current and historical deposition of particulates from large volume traffic flows since its opening.</p> <p>Contaminants, including heavy metals, asbestos and pesticides, may be present within the fill material that was used in the construction of the Warringah Freeway.</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> • Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust • Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds • Excavation activities may mobilise and spread buried contaminants • Accidental leaks and spills during use of the temporary construction support site • Erosion and off site transport of sediment and contamination via overland flow and stormwater runoff, affecting the water quality of local waterways. 	<p>Moderate</p> <p>Possible contamination/ excavation activities within site footprint and within potential contamination distribution range (laterally and vertically – surface works only)</p> <p>Potential contamination distribution unlikely to impact upon tunnelling (based on depth of tunnel).</p>	<p>Moderate</p> <p>Groundwater quality data indicate potentially elevated heavy metals, ammonia and hydrocarbons at depth</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Punch Street, Artarmon [B7]	Within construction footprint and Punch Street construction support site (BL3).	<ul style="list-style-type: none"> Temporary construction support site establishment works. 	<p>The site of the proposed Punch Street construction support site (BL3) may be contaminated with heavy metals, asbestos and pesticides as a result of the degradation of hazardous building materials contained within the old bridge structure and the potential inappropriate demolition and waste disposal practices used during demolition of the bridge.</p> <p>In addition, possible infilling of the site with material of unknown quality (potentially contaminated with common contaminant compounds including but not limited to heavy metals, hydrocarbons, pesticides, polychlorinated biphenyls and asbestos) during construction of the Gore Hill Freeway may be present across the site.</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> Excavation activities may mobilise and spread buried contaminants Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds Accidental leaks and spills during use of the temporary construction support site. 	<p>Moderate</p> <p>Possible contamination/excavation activities within site footprint and within potential contamination distribution range (surface work only).</p>	<p>Moderate</p> <p>Moderate potential for land contamination migration to groundwater due to groundwater depths.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Freeway Hotel site, Reserve Road, Artarmon [B8]	Within footprint of Motorway control centre	<ul style="list-style-type: none"> Motorway control centre (surface) 	<p>Commercial/industrial use of site and surrounding areas (ie manufacturing, chemical use and storage, etc.) may have resulted in contaminated soils.</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> Excavation activities may mobilise and spread buried contaminants Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds Accidental leaks and spills during use of the temporary construction support site. 	<p>Moderate</p> <p>Possible contamination/ excavation activities within the site footprint and within potential contamination distribution range (surface work only).</p>	<p>Low</p> <p>Low potential for land contamination migration to groundwater due to groundwater depths.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Flat Rock Reserve, Northbridge [B9]	Within footprint of construction site.	<ul style="list-style-type: none"> Flat Rock Drive construction support site (BL2), access portal (approximately 7 metres below site surface level) 	<p>Potential for contamination risks given the history of landfill activities in the area. Information provided indicates that putrescible materials could be present at depth beneath Flat Rock Drive construction support site (BL2). Soils and groundwater beneath this site could be contaminated with a variety of contaminant compounds. It is possible that the waste mass beneath this site and the adjacent Willoughby Leisure Centre and Bicentennial Reserve to the west may present a source of landfill gas. These contamination risks could impact construction elements within the formation of the temporary construction support site and access decline.</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> Mobilisation and spread of buried contaminants as a result of excavations Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds Accidental leaks and spills during use of the temporary construction support site Erosion and off site transport of sediment and contamination via overland flow and stormwater runoff, affecting the water quality of local waterways. 	<p>Moderate</p> <p>Known contamination adjacent to site/possible contamination beneath site, within compound and access portal as well as within the potential contamination distribution range (laterally and vertically).</p> <p>Potential contamination distribution has potential to impact formation of the temporary construction support site and associated access decline.</p>	<p>Moderate</p> <p>Groundwater quality data indicate the presence of contamination. Depth to groundwater is estimated to be greater than 10 metres.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Willoughby Leisure Centre/ Bicentennial Reserve, Willoughby [B10]	Above tunnel and adjacent to footprint of temporary construction support site and tunnel portal	<ul style="list-style-type: none"> Tunnelling and associated excavation 	<p>The historical landfill activities carried out within and around the areas surrounding the Willoughby Leisure Centre and Bicentennial Reserve are likely to contain soil, groundwater and possible landfill gas contamination sources associated with the buried waste mass. Soils/wastes may be contaminated with a variety of contaminant compounds, including asbestos.</p> <p>Construction activities could also create preferential pathways for groundwater contamination and landfill gas (if present) to other areas, particularly the adjacent Flat Rock Drive construction support site (BL2).</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> Excavation activities may mobilise and spread buried contaminants Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds Accidental leaks and spills during use of the temporary construction support site. 	<p>High</p> <p>Known considerable contamination beneath and possibly adjacent to site footprint and within contamination distribution range (vertically). Potential contamination distribution unlikely to impact upon tunnelling (based on depth of tunnel).</p>	<p>High</p> <p>Known groundwater contamination.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Spit West Reserve, Mosman [B11]	Within Spit West Reserve construction support site (BL9).	<ul style="list-style-type: none"> Temporary construction support site establishment works. 	<p>The site of the proposed Spit West Reserve construction support site (BL5) may be contaminated with common contaminant compounds including, but not limited to heavy metals, hydrocarbons, pesticides, polychlorinated biphenyls, phenols, organotins and asbestos.</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> Excavation activities may mobilise and spread buried contaminants Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds Accidental leaks and spills during use of the temporary construction support site Erosion and off site transport of sediment and contamination via overland flow and stormwater runoff, affecting the water quality of local waterways. 	<p>Moderate</p> <p>Possible contamination/excavation activities for construction compound within site footprint and within potential contamination distribution range (surface work only).</p>	<p>Low</p> <p>Low potential for land contamination migration to groundwater due to coastal location.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Middle Harbour and the Spit [B12]	Within construction footprint. Above proposed tunnel alignment and within Middle Harbour south (BL7) and north (BL8) cofferdams and Spit West Reserve construction support site (BL9).	<ul style="list-style-type: none"> • Temporary construction support site establishment works • Tunnelling and associated excavation and stockpiling. 	<p>Contamination has been reported in sediments present within Middle Harbour and The Spit. Contamination is likely to be associated with inputs from the surrounding urbanised catchments and the general maritime use within the surrounding area. The sediments pose a high contamination risk to construction given that contamination is known to be present within sediments which are likely to be excavated and exposed during construction of the Spit West Reserve construction support site (BL9) and the Middle Harbour south and north cofferdams (BL7 and BL8).</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> • Excavation activities may mobilise and spread buried contaminants • Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust • Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds • Accidental leaks and spills during use of the temporary construction support site. 	<p>High</p> <p>Known contamination/excavation activities within the site footprint and within potential contamination distribution range (vertically).</p>	<p>Low</p> <p>Low potential for land contamination migration to groundwater due to coastal location.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Balgowlah Golf Course, Balgowlah [B13]	Within Balgowlah Golf Course construction support site (BL10) and wider Balgowlah Golf course area.	<ul style="list-style-type: none"> Temporary construction support site establishment works, Motorway facility and new open space and recreation facilities. 	<p>A number of houses and buildings were demolished during the construction of Burnt Bridge Creek Deviation. Inappropriate demolition and waste disposal practices may have resulted in demolition wastes and associated contamination (including heavy metals, asbestos and pesticides) remaining in areas adjacent to the road corridor (including within the wider Balgowlah Golf Course).</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> Excavation activities may mobilise and spread buried contaminants Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds Accidental leaks and spills during use of the temporary construction support site Erosion and off site transport of sediment and contamination via overland flow and stormwater runoff, affecting the water quality of local waterways. 	<p>Moderate</p> <p>Possible contamination/excavation activities for construction compound within site footprint and within potential contamination distribution range (surface work only).</p>	<p>Moderate</p> <p>Depth to groundwater is estimated to be less than two metres across a portion of the site and groundwater quality monitoring data indicates low pH and the presence of heavy metals at depth.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Residential properties, Dudley Street, Balgowlah [B14]	Above tunnel and adjacent to footprint of construction support site (BL10).	<ul style="list-style-type: none"> • Temporary construction support site establishment works • Tunnelling and associated excavation and stockpiling • Surface roadworks • Construction of new open space and recreational facilities. 	<p>Localised contamination may be present as a result of the degradation of hazardous building materials from structures present on site.</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> • Excavation activities may mobilise and spread buried contaminants • Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust • Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds • Accidental leaks and spills during use of the temporary construction support site. 	<p>Moderate</p> <p>Possible contamination/excavation activities for tunnel portal and construction compound within site footprint, within potential contamination distribution range (laterally and vertically).</p> <p>Potential contamination distribution unlikely to affect tunnelling below surface levels (based on depth of tunnel).</p>	<p>Low</p> <p>No known groundwater contamination.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Residential properties – Judith Street/ Kirkwood Street and Wakehurst Parkway at Seaforth. [B15]	Above tunnel and adjacent to footprint of construction support site (BL12).	<ul style="list-style-type: none"> • Temporary construction support site establishment works • Tunnelling and associated excavation and stockpiling • Surface roadworks. 	<p>Localised contamination may be present as a result of the degradation of hazardous building materials from structures present on site.</p> <p>If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> • Excavation activities may mobilise and spread buried contaminants • Inhalation and/or ingestion risk to site workers and nearby residents of hazardous building materials via dust • Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds • Accidental leaks and spills during use of the temporary construction support site. 	<p>Moderate</p> <p>Possible contamination/ excavation activities for tunnel portal and construction compound within site footprint, within potential contamination distribution range (laterally, not vertically).</p> <p>Potential contamination distribution unlikely to affect tunnelling below surface levels (based on depth of tunnel).</p>	<p>Low</p> <p>No known groundwater contamination.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Sydney Water Bantry Bay Reservoir site (and surrounding areas), Killarney Heights [B16]	Area within and adjacent to Wakehurst Parkway east construction support site (BL13) footprint and tunnel (laterally, not vertically)	<ul style="list-style-type: none"> • Temporary construction support site establishment works • Tunnelling and associated excavation and stockpiling • Roadworks. 	Potential soil contamination may be present within the surface soils at the location of the Wakehurst Parkway east construction support site (BL13) and the areas adjacent to it. The potential contamination could be associated with the degradation of painted surfaces on the reservoirs and windblown deposition of paints on adjoining areas. Contamination could also be potentially associated with the demolition of waste material observed across the surface of the site.	<p>Moderate</p> <p>Possible contamination/ excavation activities for construction compound and roadwork within site footprint and within potential contamination distribution range (laterally, not vertically)</p> <p>Potential contamination distribution unlikely to affect tunnelling (based on depth of tunnel).</p>	<p>Low</p> <p>No known groundwater contamination.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Wakehurst Parkway, Seaforth to Frenchs Forest [B17]	Within construction footprint and Wakehurst Parkway south construction support site (BL12). Above proposed tunnel alignment.	<ul style="list-style-type: none"> • Temporary construction support site establishment works • Tunnelling and associated excavation and stockpiling • Surface roadworks. 	<p>Localised contamination as a result of degrading asphalt road surfaces may be present along the length of Wakehurst Parkway from Seaforth to Frenchs Forest. Hydrocarbon contamination may be present in the surface soils along the road way.</p> <p>The non-urbanised areas immediately surrounding the Wakehurst Parkway may have been historically subject to the illegal dumping of waste. Illegally dumped waste may include heavy metals, hydrocarbons, pesticides and/or asbestos. If contamination is present and not appropriately controlled, there is the potential for:</p> <ul style="list-style-type: none"> • Excavation activities may mobilise and spread buried contaminants • Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds • Accidental leaks and spills during use of the temporary construction support site • Erosion and off site transport of sediment and contamination via overland flow and stormwater runoff, affecting the water quality of local waterways. 	<p>High</p> <p>Known contamination/excavation activities for construction compound and roadwork within site footprint and within potential contamination distribution range (laterally and vertically)</p> <p>Potential contamination distribution unlikely to affect tunnelling below surface levels (based on depth of tunnel).</p>	<p>Low</p> <p>No known groundwater contamination.</p>

Location	Location relative to construction footprint	Construction works	Potential contaminants and associated impacts	Risk of land contamination	Risk of existing groundwater contamination
Waverton Park – Woolcott Road, Waverton [W8]	About 1900 metres south west from construction footprint.	<ul style="list-style-type: none"> None 	<p>Known contamination (TRH) likely to be the result of historical infilling and reclamation adjacent to the shoreline. Potential for contamination migration due to groundwater drawdown. Contamination likely present at surface and depth (less than 20 metres) associated with various depths of infilling.</p> <p>Due to low depth of groundwater (less than four metres) there is the potential for contaminated groundwater to migrate to surrounding areas from groundwater drawdown due to the project.</p>	<p>High</p> <p>Known contamination (which could impact upon groundwater)</p>	<p>High</p> <p>Depth to likely contaminated groundwater is estimated to be less than four metres across this site</p>

Potentially contaminated sites identified in Table 16-10 would be subject to further investigation, remediation and/or management. All identified contamination risk areas would be managed during construction by the comprehensive environmental management measures detailed in Section 16.7 and in accordance with guidelines made or approved under section 105 of the *Contaminated Land Management Act 1997*.

Any contaminated material disturbed during construction would be separated from uncontaminated material on site to prevent cross contamination. Contaminated material would be encapsulated on site where possible, and in accordance with relevant regulatory requirements. Any material that is not suitable for encapsulation would be loaded into sealed and covered trucks for disposal at a suitably licensed facility. Further site investigations during the design development and construction planning phases would inform contamination management including determining where encapsulation is appropriate.

Structures and/or buildings located within the project footprint may also contain hazardous building materials. A hazardous building materials audit would be carried out prior to the demolition of any structure and/or building. Hazardous building materials (where present) would be managed to reduce the potential for contamination and ensure appropriate handling and waste disposal. Management and handling would be carried out in accordance with Australian Standard (AS 2601-2001) – The demolition of structures (Standards Australia, 2001).

Chapter 23 (Hazard and risk) provides further details regarding management of dangerous goods and hazardous substances.

16.4.4 Marine contamination

The sediments in Middle Harbour would potentially pose a high contamination risk due to the contamination associated with historical industrial use (over 150 years) of the harbour and the addition of polluted stormwater runoff originating from adjacent catchments. Contaminated sediments are likely to be disturbed during the dredging activities required for the installation of the immersed tube tunnel and associated piling works. Piling would also be required to establish temporary construction support site wharf structures at Spit West Reserve construction support site (BL9) and the temporary mooring facility for immersed tube tunnel units in Middle Harbour. Potential impacts as a result of disturbance of contaminated sediment may include contaminant exposure risk to project personnel and marine receptors if not appropriately managed.

Sediments requiring excavation and removal during construction, may be disposed of via:

- Offshore disposal – An application for offshore disposal of suitable dredged material has been submitted to the Commonwealth Department of Agriculture, Water and the Environment. The appropriateness of offshore disposal would be assessed in accordance with the *National Assessment Guidelines for Dredging* (NAGD) (Department of Environment, Water, Heritage and the Arts, 2009). Offshore disposal would only be appropriate for material that meets the requirements outlined in the NAGD
- Landfill disposal – Marine sediments unsuitable for offshore disposal and requiring disposal to landfill would be assessed in accordance with the *Waste Classification Guidelines* (NSW EPA, 2014a) and disposed of at an appropriately licensed waste facility.

Dredging has the potential to disturb and resuspend sea bed sediments, some of which may be contaminated. While suspended sediment would be subject to tidal water movement that can affect dispersion, the particles settle back to the bed of the harbour. The potential for dispersion can also be restricted through the use of control measures such as silt curtains.

The resuspension of sediments during dredging has the potential to result in the introduction of contaminants into the dissolved phase of the water column. Once in the dissolved phase, released contaminants can be subject to migration, by tidal currents for example, and can therefore result in different exposures and risks compared to the release of contaminants attached to suspended sediment particles. Based on the elutriate test results carried out for the project and the assessed

available natural dilution, however, water quality impacts at the dredging site due to contaminants in resuspended sediments entering the dissolved phase would not be expected.

The dredging methodology has been designed to minimise impacts on the marine environment and is detailed in Chapter 6 (Construction works). This includes the use of a closed bucket (environmental clamshell) and the use of silt curtains to minimise the spread of potentially contaminated material. Specific environmental management measures to avoid adverse impacts to water quality as a result of sediment plumes are described in Chapter 17 (Hydrodynamics and water quality).

16.4.5 Groundwater levels

Groundwater within parts of the study area has the potential to be impacted during the construction phase of the project. The potential impacts that have been identified are:

- Tunnel inflows and associated flooding
- Groundwater level decline (drawdown) including potential impacts for:
 - Saltwater intrusion
 - Contaminant migration from contaminated sites
 - Groundwater dependent ecosystems
 - Activation of acid sulfate soils
 - Decline in groundwater baseflow to surface water features (the groundwater that discharges to a creek or river) (discussed in Chapter 17 (Hydrodynamics and water quality)).

Tunnel inflows

Maximum groundwater inflow rates would generally occur when new sections of the tunnels are excavated and measures to mitigate inflows (such as tunnel linings) have not yet been installed. Greatest inflow rates are predicted to occur either side of the harbour crossing before the lining of the surrounding tunnel in 2025.

Groundwater inflows into the tunnel (ie tunnel inflows) were calculated for five time periods during the construction phase, as shown in Table 16-11. These predicted flows are unconstrained, in that no tunnel linings to reduce groundwater inflow have been assumed in the modelling. Peak inflows of 1.39 litres per second per kilometre (L/s/km) averaged over the whole tunnel were predicted to occur in 2025. The largest predicted inflows would be associated with the caverns at Flat Rock Drive and Northbridge, due to inflows from a palaeovalley at this location, and the transition structures connecting to the immersed tube tunnels in Middle Harbour. Total inflows over the construction period would be around 2817 megalitres (ML), with annual inflows during construction peaking at around 899 ML/year in 2025.

It is a design requirement of the project that groundwater inflows be limited to no more than one litre per second per kilometre on average and measures to achieve this requirement would be progressively installed during construction. Proposed measures to reduce, collect and dispose of tunnel inflows during construction are summarised in Section 16.7.

Table 16-11 Summary of modelled average tunnel inflows during construction (cumulative scenario)

Year	Cammeray/ Artarmon to Middle Harbour	Middle Harbour to Balgowlah/ Wakehurst Parkway	Entire project		Total annual inflows
	(L/s/km)	(L/s/km)	(L/s/km)	(ML/day)	(ML/year)
2023	0.70	0.12	0.41	0.75	275
2024	1.14	0.33	0.73	1.34	488
2025	1.54	1.23	1.39	2.46	899
2026	1.01	0.84	0.93	1.64	598
2027	0.90	0.83	0.87	1.53	557

The long term average annual extraction limit for the Sydney Central Basin is 45,915 ML/year and current groundwater access licences equate to 2592 ML/year, leaving around 43,323 ML/year of unassigned water. The predicted peak annual tunnel inflows would be less than seven per cent of the water unassigned under the long term average annual extraction limit for the Sydney Central Basin.

Groundwater level decline (drawdown)

Groundwater modelling has been used to predict groundwater levels at the end of the tunnel construction (end of 2027) and are presented in Figure 16-11.

The degree of drawdown would be dependent on a number of factors including the geology intersected, the hydrogeology and the tunnel configuration and depths.

At the end of tunnel construction, the maximum drawdown is predicted to be around 28 metres immediately overlying the tunnel centreline in the Northbridge area. Predicted drawdown propagates away from the tunnels, with the drawdown extending up to around 0.5 kilometres northwards in the Willoughby/Chatswood area, and extending southwards up to around 0.4 kilometres in the Crows Nest area. North of Middle Harbour, the drawdown would be slightly lower, with the maximum predicted drawdown of 16 metres between Seaforth and Balgowlah. It is noted that these groundwater drawdown predictions are conservatively based on unconstrained inflows into the tunnel. As measures would be installed to restrict groundwater inflow to no more than one litre per second per kilometre, actual drawdown levels and extents would likely be less than these predictions.

A review of current groundwater use has been conducted to identify registered groundwater users within the vicinity of the predicted extent of groundwater level drawdown (refer to Figure 16-11). Of the 17 groundwater bores all but three bores (GW107970, GW108224 and GW108991) are predicted to experience less than one metre of drawdown during construction and would therefore not be impacted by the project.

Modelling predicts that the maximum drawdown would be seven metres at GW107970, up to five metres at GW108224 and up to three metres at GW108991 for the cumulative (including the Sydney Metro City & Southwest and the Western Harbour Tunnel and Warringah Freeway Upgrade project) case. The drawdown at these bores (for the cumulative case) exceeds the minimal impact consideration of the NSW Aquifer Interference Policy (a drawdown impact of more than two metres at any water supply works). In accordance with the NSW Aquifer Interference Policy, further assessment is required and would be carried out to fully assess the predicted impact and identify any required make good provisions.

The first bore, GW107970, is 199 metres deep with a water level of 110 metres below ground level. Modelling predicts that the cumulative maximum drawdown at the bore would be up to seven metres in 2028, which equates to about eight per cent of available drawdown and is therefore not anticipated to cause significant impact to the groundwater supply.

The second bore, GW108224, is 132 metres deep and may be targeting a horizon of the Hawkesbury Sandstone from around 70 metres deep to the base of the bore. The interpreted pre-project groundwater table lies at about 42 metres below ground level in the vicinity of this bore. Therefore, a groundwater head of 90 metres is expected to be available within the bore. A groundwater level depressurisation of five meters equates to a change in of less than six per cent of the available head at the bore and is therefore anticipated to cause negligible impact to the groundwater supply.

The third bore, GW108991 is about 168 metres deep and may also be targeting a horizon of the Hawkesbury Sandstone. The interpreted pre-project groundwater table lies at about three metres below ground level in the vicinity of this bore. Therefore, a groundwater head of 165 metres is expected to be available within the bore. A groundwater level depressurisation of three metres at the bore equates to a change of less than two per cent of the available head and is therefore anticipated to cause negligible impact to the groundwater supply.

Measures to manage impacts at these bores are outlined in Section 16.7.

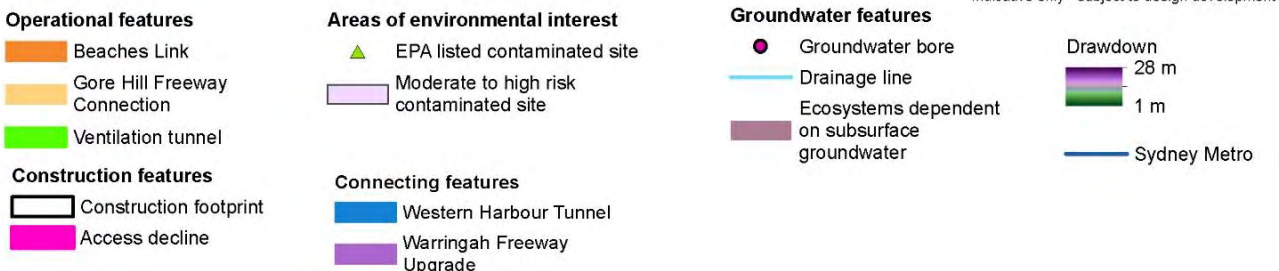
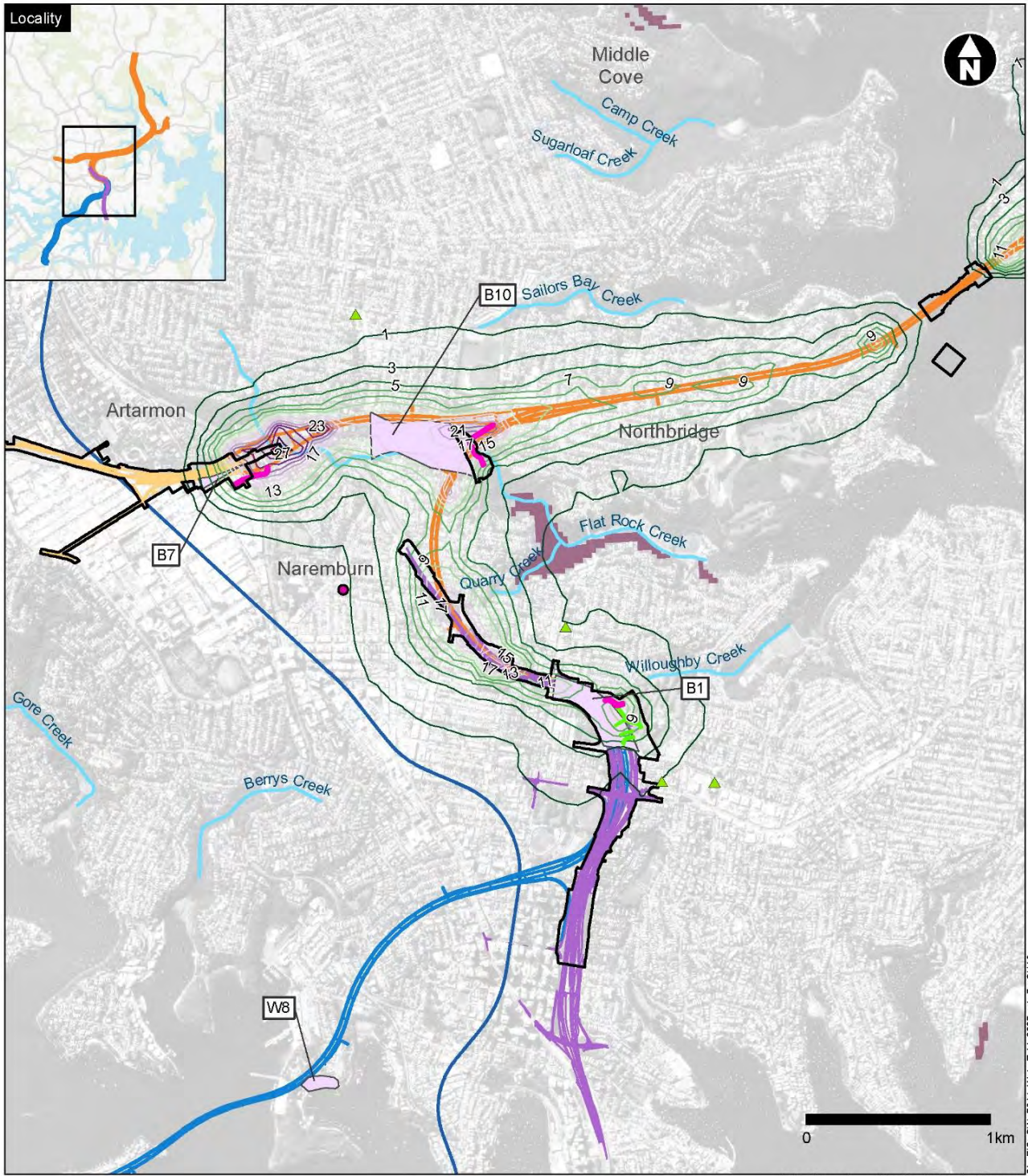


Figure 16-11 Predicted groundwater drawdown contours for the project at the end of tunnel construction (2028) – South of Middle Harbour

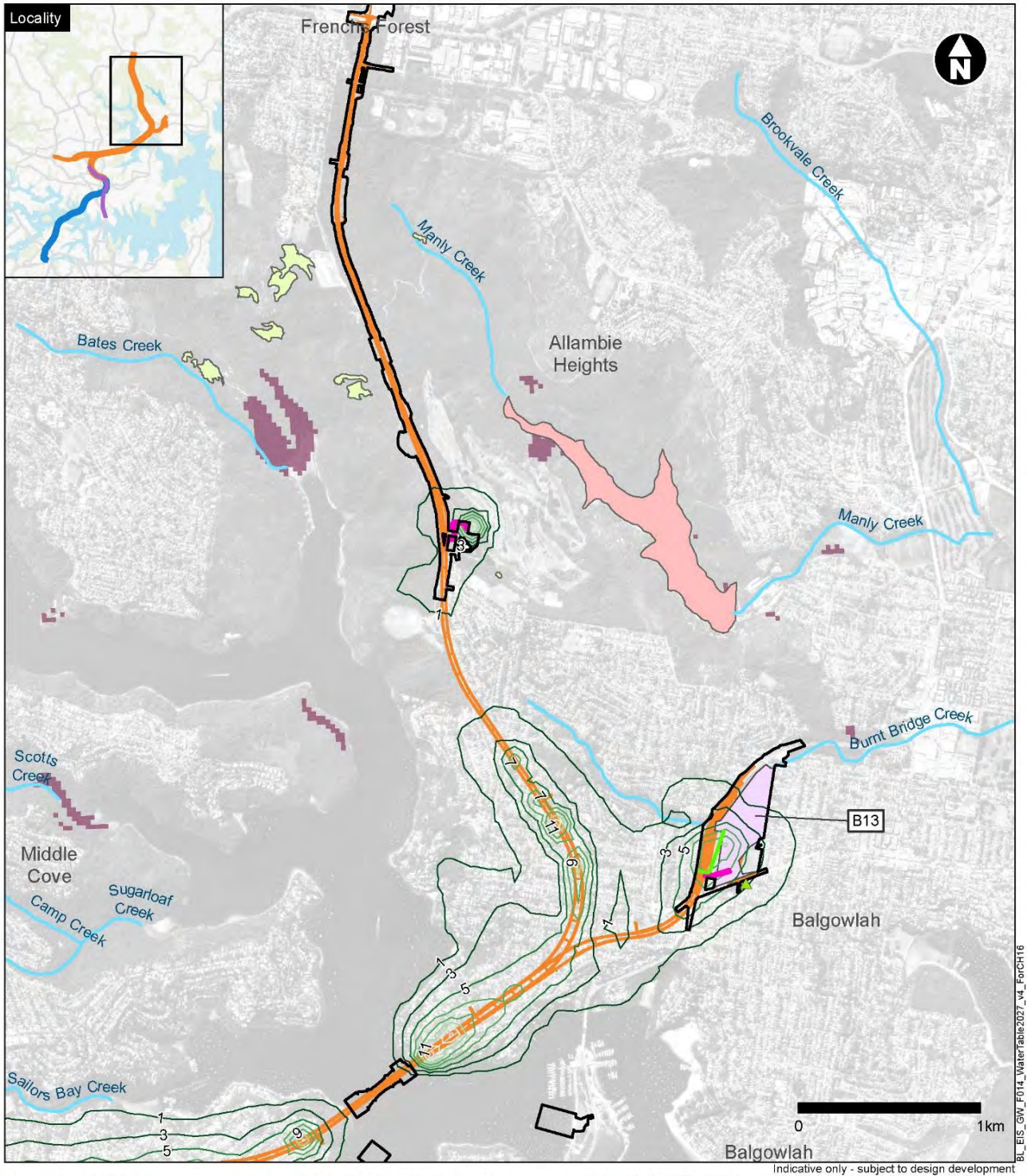


Figure 16-12 Predicted groundwater drawdown contours for the project at the end of tunnel construction (2028) – North of Middle Harbour

Saltwater intrusion

Aquifers adjacent to the harbour foreshore might experience saltwater intrusion as the hydraulic pressure between the aquifer and the harbour is reduced during drawdown, allowing saltwater to enter the aquifer. Depending on the extent of saltwater intrusion it could reduce the beneficial uses of the aquifer for existing users.

Additionally, saltwater intrusion into tunnels could occur during construction, which would increase saltwater loads requiring management and disposal.

Groundwater quality impacts due to saltwater intrusion, however, would be unlikely during construction of the project due to the low hydraulic conductivity of the Hawkesbury Sandstone formation and the naturally saline groundwater due to tidal mixing. This includes no impact to the groundwater bores (GW108224 and GW108991) located in Naremburn and Lane Cove respectively, which are separated from the shoreline by the tunnel, and the groundwater dependent ecosystem identified at Flat Rock Creek/Munro Park (Section 16.3.4).

Contaminant migration from contaminated sites

The groundwater model was used to assess the potential groundwater level drawdown at regulated/notified sites and areas of environmental interest, assessed to have a moderate or high risk of existing groundwater contamination within 500 metres of the project alignment. Drawdown at potentially contaminated sites is shown in Table 16-12 and is based on the water quality guidelines from the NSW Aquifer Interference Policy (NSW DPI, 2012a), which states that the beneficial use of a groundwater source 40 metres away from the activity must not be reduced. Drawdown predictions under the 'project only' (ie Beaches Link and Gore Hill Freeway Connection project in isolation) and 'cumulative' (Beaches Link and Gore Hill Freeway Connection project and other neighbouring proposed construction projects) scenarios are presented in Table 16-12 for areas of environmental interest for contamination within 500 metres of the project alignment with moderate or high risk.

Table 16-12 Predicted drawdown at areas of environmental interest for contamination at the end of tunnel construction (2028)

Area of environmental interest	Predicted drawdown – project only (metres)	Predicted drawdown – cumulative (metres)
Unsealed areas next to Warringah Freeway – Eastern side (Cammeray Golf Course) at Cammeray	Up to 13	Up to 17
Punch Street at Artarmon	Up to 19	Up to 19
Flat Rock Reserve at Northbridge	Up to 21	Up to 21
Willoughby Leisure Centre and Bicentennial Reserve at Willoughby	Up to 22	Up to 22
Balgowlah Golf Course at Balgowlah	Up to 11	Up to 11
Waverton Park – Woolcott Road, Waverton	Less than 1	Up to 12

If contaminants are mobilised from unsealed areas next to Warringah Freeway (eastern side by Cammeray Golf Course) at Cammeray; the Willoughby Leisure Centre and Bicentennial Reserve; Punch Street, Artarmon; or Balgowlah Golf Course at Balgowlah, they would travel towards the tunnel during construction. During construction, groundwater inflows would be collected and treated at the construction wastewater treatment plants.

Predicted drawdown is highest at the Willoughby Leisure Centre and Bicentennial Reserve, within both the 'project only' and 'cumulative' scenarios, and is up to approximately 22 metres as parts of this site are located immediately above the proposed tunnel centrelines. There is potential for contaminants associated with the former use of the land as a waste disposal area to migrate into areas of good quality groundwater and reduce the possible benefits of its use in such areas.

The levels of drawdown at Waverton Park during construction would be minor for the 'project only' scenario and would not be expected to cause significant migration of contaminants and contaminant migration into areas of good quality groundwater is unlikely to occur. Under the cumulative scenario, drawdown at Waverton Park would be largely due to the effect of the Western Harbour Tunnel and Warringah Freeway Upgrade project. The movement of groundwater would be towards the Western Harbour Tunnel and would be collected and treated at the water treatment plants established for that project.

The rate of contaminant migration would depend predominantly on the hydraulic conductivity at the area of environmental interest for contamination, contaminant viscosity and the hydraulic gradient at the site, but over the construction period a drawdown of this magnitude would cause migration of contaminants.

Given the relatively small predicted change in total water head within bores GW107970, GW108224 and GW108991, and the fact that these bores lie upgradient of direction of potential contaminant migration towards the tunnels from areas of environmental interest, the groundwater quality at these bores is not expected to be changed due to the project.

Contaminant migration caused by drawdown from the tunnel has the potential to degrade water quality more than 40 metres from the tunnel. The only groundwater dependent ecosystem in the vicinity of these areas of environmental interest is that which is present at the upper reaches of Flat Rock Creek and Quarry Creek in the vicinity of the Willoughby Leisure Centre and Bicentennial Reserve. This groundwater dependent ecosystem is not expected to be impacted by contaminant migration since the potentially contaminated fill area at this area of environmental interest is immediately overlying the tunnels and would therefore drain towards the tunnels and away from the groundwater dependent ecosystem, which would therefore satisfy the requirements of the NSW Aquifer Interference Policy (NSW DPI, 2012a).

Groundwater dependent ecosystems and sensitive environments

Four groundwater dependent ecosystems or sensitive environments occur within the area of predicted drawdown as shown in Table 16-13. Within the exception of the vegetation at Flat Rock and Quarry Creek, groundwater drawdown is predicted to be less than one metre at all these locations. Drawdown for the vegetation at Flat Rock and Quarry Creek is predicted to be less than five metres, however, has the potential to impact the groundwater dependent ecosystems at that location. The potential magnitude of these impacts is discussed further in Chapter 19 (Biodiversity) and Appendix S (Technical working paper: Biodiversity development assessment report). It is noted that these predicted drawdowns are based on unconstrained tunnel inflows and a model containing limited data which assumes full hydraulic connection in the hydrogeological layers between the identified groundwater dependent ecosystems and the underlying rock, which may not be the case. Additionally, due to the very low existing baseflows along Quarry Creek and the existing geomorphologies, the predicted baseflow reductions are unlikely to have any substantial ecological impacts.

Further studies will occur during development of the detailed design to confirm potential groundwater drawdown at Flat Rock Creek and associated potential impacts to the groundwater dependent ecosystem. Where unacceptable ecological impacts are predicted, feasible and reasonable mitigation measures to address the impacts will be identified, incorporated into the detailed design, and implemented during construction (refer to Section 16.7 and Chapter 19 (Biodiversity)).

Table 16-13 Predicted drawdown and impact at groundwater dependent ecosystems and sensitive environments at the end of tunnelling construction (2028)

Receptor	Location	Drawdown – project only (m)	Drawdown – cumulative (m)
Vegetation at Flat Rock and Quarry Creek	Northbridge	Up to 4	Up to 5
Vegetation at Bates Creek	Bates Reserve/Garigal National Park, Killarney Heights	Less than 1	Less than 1
Manly Dam Reserve	Manly Dam Reserve, Allambie Heights	Less than 1	Less than 1
Coastal Upland Swamp ¹	Bates Reserve/Garigal National Park, Killarney Heights	Less than 1	Less than 1

Note 1: Coastal Upland Swamp is not a groundwater dependent ecosystem but is considered a sensitive environment for the purposes of this assessment.

Activation of acid sulfate soils

Lowering of the groundwater table has the potential to expose acid sulfate soils top oxygen, which might result in oxidation and acid generation. Activation of acid sulfate soil has potential to alter groundwater quality by lowering pH and elevating heavy metal content. Acidic groundwater might impact the integrity of underground structures and the tunnel structure itself. The acidity and associated heavy metal content might also affect the quality of groundwater inflow to the tunnels which would be managed through the wastewater disposal process.

Outside of the harbour areas, potential areas of acid sulfate soil risk would be associated with low lying and estuarine sediments in the lower reaches of Flat Rock Creek and in Middle Harbour. Predicted drawdown extents during the construction period do not reach any areas of potential acid sulfate soil risk.

16.4.6 Groundwater quality

Potential construction impacts on groundwater quality due to saltwater intrusion, mobilisation of contaminants and potential acidification are discussed in Section 16.4.5.

Activities and materials used during tunnel construction which have the potential to impact groundwater quality in the surrounding aquifer are detailed below:

- Drilling/cutting fluids required for the road header
- Particulate material from tunnelling activities leading to an increase in suspended solids
- Cement pollution arising from shotcrete application, grouting or in-situ casting of concrete.

These potential contaminant sources are low risk and groundwater inflows are predicted to be generally towards and into the tunnel, limiting the potential for contamination of groundwater adjacent to the tunnel due to the tunnels. If contamination to groundwater was to occur during tunnel construction, the likelihood of the contaminated groundwater migrating away from the tunnel is considered very low.

The quality of this discharged water during construction is considered in Chapter 17 (Hydrodynamics and water quality). During construction, groundwater inflows would be treated to meet the following requirements:

- The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality ANZECC/ARMCANZ, 2000), and

- The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 95 per cent species protection levels, and
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) for which public comments are under consideration as of November 2020.

16.5 Assessment of potential operational impacts

16.5.1 Spills and leakages

Vehicle or plant and equipment leakages or a vehicle crash may cause spills of oils, lubricants, hydraulic fluids and chemicals during the operation of the project. Spills and leakages within the project footprint have the potential to pollute downstream waterways, as a result of being conveyed to waterways via the stormwater network. The severity of the potential impact would depend on the magnitude and/or location of the spill in relation to sensitive receivers, emergency response procedures and/or environmental management measures implemented on site and the nature of the receiving environment.

Further discussion on accidental spills is included in Chapter 23 (Hazard and risk). Spill control measures, as outlined in Section 16.7, would be implemented to reduce and manage the potential impacts to an acceptable level.

16.5.2 Groundwater levels

Groundwater levels within parts of the study area has the potential to be impacted during the operation phase of the project. The potential impacts that have been identified are:

- Tunnel inflows
- Groundwater level decline (drawdown) including potential for:
 - Saltwater intrusion
 - Contaminant migration from contaminated sites
 - Groundwater dependent ecosystems
 - Activation of acid sulfate soils
 - Decline in groundwater baseflow to surface water features (the groundwater that discharges to a creek or river) (discussed in Chapter 17 (Hydrodynamics and water quality)).

The modelling of operational impacts has assumed that the tunnels are not lined (except for a 125 metre section on either side of Middle Harbour) and therefore provides a relatively conservative estimate of groundwater inflows to the tunnels and associated groundwater level drawdown.

Tunnel inflows

Inflows during operation were calculated for two time periods the first year of operation in 2028, and after 100 years of operation (2128) (refer to Table 16-14). Tunnel inflows would diminish over time as the groundwater system reaches equilibrium.

Peak operational inflows of 0.86 litres per second per kilometre averaged over the whole tunnel are predicted to occur at the beginning of operation (2028). After 100 years of operation, inflows would decline to 0.69 litres per second per kilometre. This would be below the adopted criterion of one litre per second per kilometre. Predicted annual inflows would be around 551 megalitres per year in the first year of operation (2028), falling to 436 megalitres per year after 100 years. The predicted peak annual tunnel inflows would be less than two per cent of the water unassigned under the long term average annual extraction limit.

Table 16-14 Summary of modelled average tunnel inflow during operation

Year	Cammeray to Middle Harbour	Middle Harbour to Wakehurst Parkway	Entire project		Total annual inflows
	(L/s/km)	(L/s/km)	(L/s/km)	(ML/day)	(ML/year)
2028	0.88	0.83	0.86	1.51	551
2128	0.58	0.80	0.69	1.20	436

Groundwater Drawdown

Groundwater modelling has been used to predict groundwater levels after 100 years of operation (2128). Predicted groundwater drawdown at the commencement of operation is the same as that at the end of construction and therefore not reported here (refer to Table 16-11 for more information).

After 100 years of operation, the drawdown increases in comparison to the 2028 case (refer to Figure 16-13) in the Northbridge area, where predicted drawdown would be up to 36 metres, while in and around Seaforth and Balgowlah it would be up to 16 metres. Additional modelling was carried out for the tunnel beneath Flat Rock Reserve. The additional modelling assumed a lined section of tunnel with no inflows to reduce potential drawdown in the fill materials present along Flat Rock Creek. With the linings assumed, the predicted water table drawdown is predicted to be up to eight metres less than predicted without the lining (ie up to 28 metres).

With the exception of six bores identified below, other groundwater bores within the vicinity of the project footprint are predicted to experience less than one metre of drawdown during operation and would therefore not be impacted by the project.

Predicted drawdown at the following six bores is predicted to exceed the minimal impact consideration of the NSW Aquifer Interference Policy, as follows:

- GW023150 is recorded as less than two metres deep which may be an error in the record. Modelling predicts that drawdown at this bore would be up to three metres in 2128 (cumulative case). If this bore were to rely on shallow groundwater, water availability at this bore could be impacted
- GW026513 is about 64 metres deep with a water level of about 6 metres. Modelling predicts that the cumulative maximum drawdown at this bore would be up to two metres in 2128, which equates to about three per cent of available drawdown (water head) within the bore and is therefore anticipated to cause negligible impact to the groundwater supply.
- GW072478 is around 180 metres deep with a water level of about 48 metres below ground level. Modelling predicts that drawdown at this bore would be up to three metres in 2128 (cumulative case), which equates to about five per cent of available drawdown and is therefore anticipated to cause negligible impact to the groundwater supply
- GW107970 is 199 metres deep with a water level of 110 metres. Modelling predicts that the cumulative maximum drawdown at the bore would be up to 13 metres in 2128, which equates to about 15 per cent of available drawdown and is therefore not anticipated to cause significant impact to the groundwater supply.
- GW108224 is 132 metres deep with a water level of 35 metres below ground level. Modelling predicts that drawdown at the bore would be up to 11 metres in 2128 (cumulative case), which equates to about 11 per cent of available drawdown and is therefore anticipated to cause negligible impact to the groundwater supply
- GW108991 is 168 metres deep with a water level about 13 metres below ground level. Modelling predicts that drawdown at this bore would be up to four metres in 2128 (cumulative case), which equates to less than three per cent of available drawdown and is therefore anticipated to cause negligible impact to the groundwater supply.

It is, therefore, unlikely that the predicted drawdown at GW026513, GW072478, GW107970, GW108224 and GW108991 would detrimentally affect the operation of the bores. Further investigations are required to determine the potential for impact to GW023150 and to identify appropriate mitigation and rectification measures for implementation as required.

There are no groundwater dependent culturally sensitive sites within the predicted drawdown extents, therefore drawdown from the project would not affect these receptors and they have not been assessed further. Impacts to groundwater dependent ecosystems are discussed below.

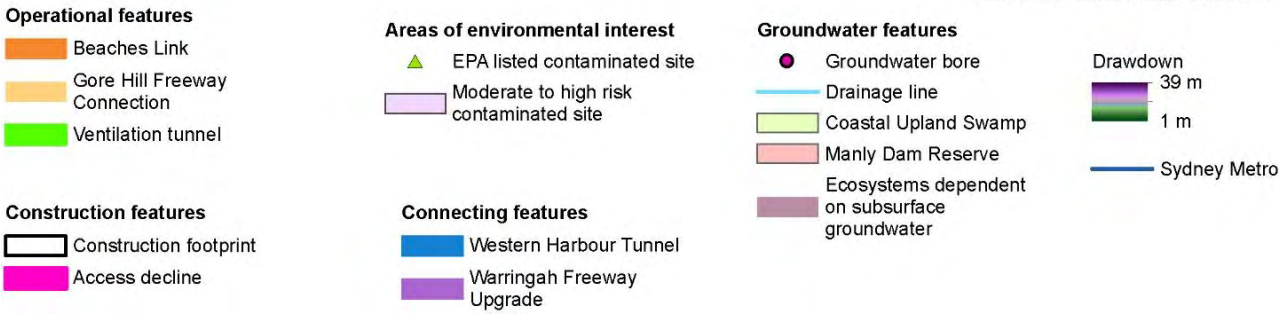
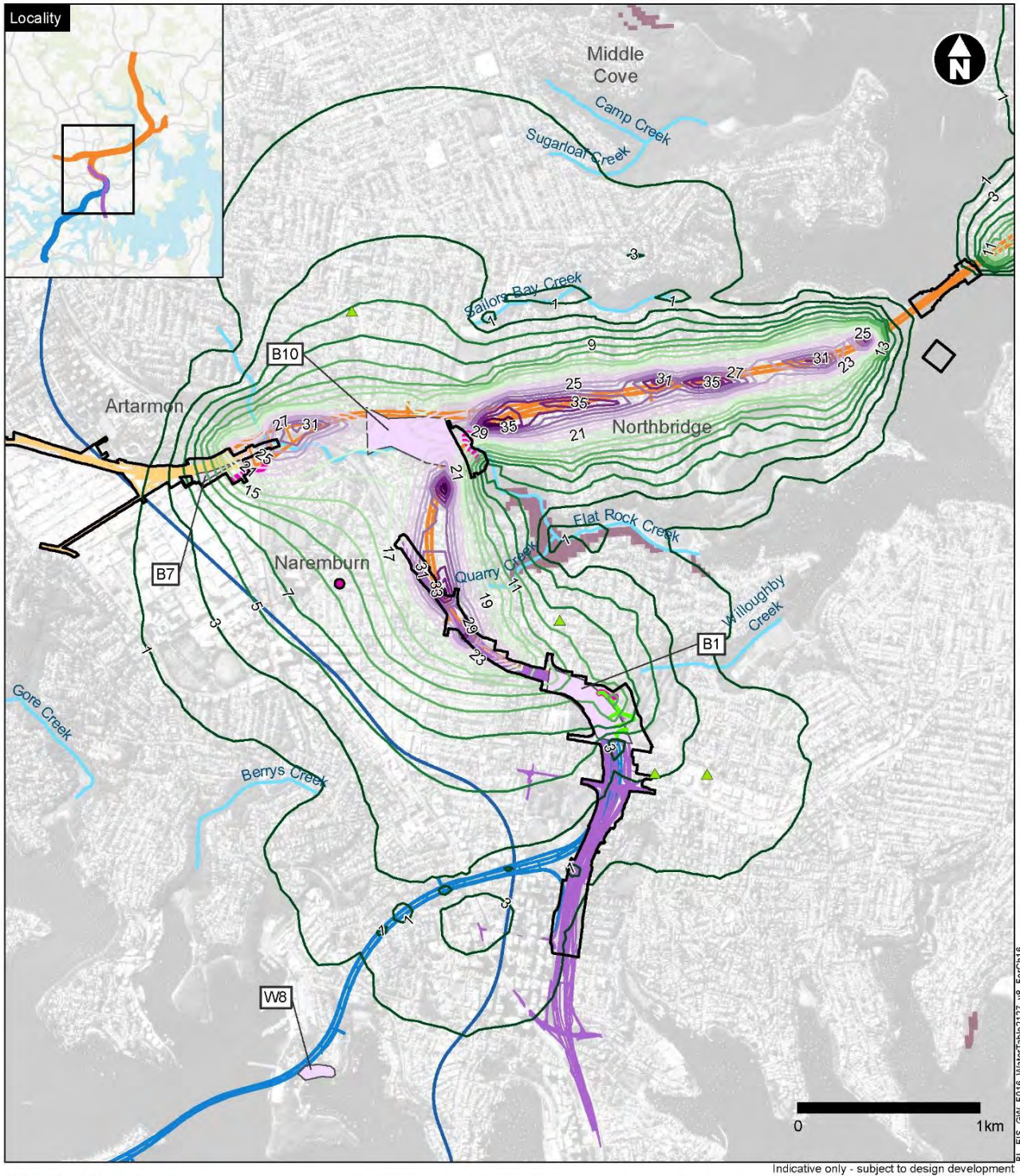


Figure 16-13 Groundwater drawdown contours for the project during operation in 2128 – South of Middle Harbour

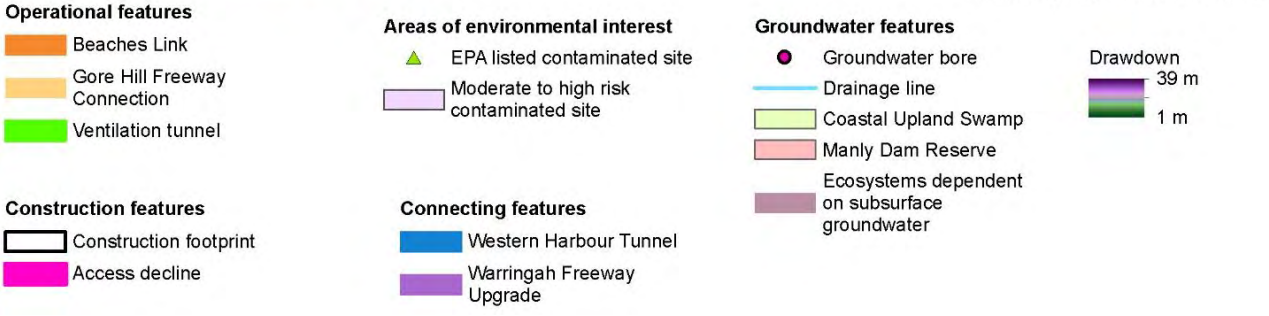
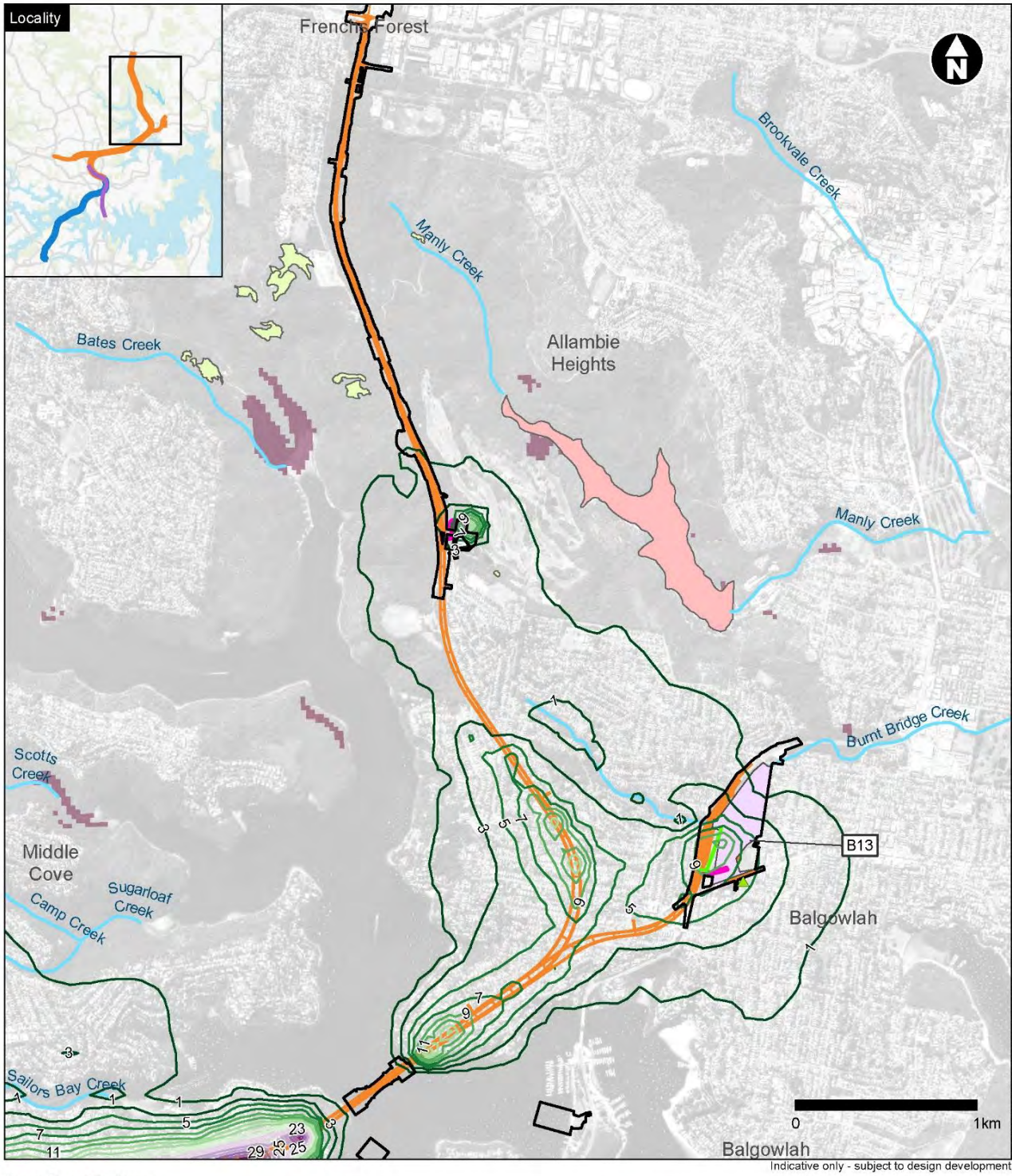


Figure 16-14 Groundwater drawdown contours for the project during operation in 2128 – North of Middle Harbour

Saltwater intrusion

Water table drawdown is predicted to stabilise early in the operational phase of the project due to the harbour acting as a recharge boundary. During the first few years of operation, drawdown would result in groundwater flow inland from the coast, and seawater would gradually intrude into the Hawkesbury Sandstone aquifer. At the same time, the fresh water/saltwater interface that is expected to underlie Hawkesbury Sandstone aquifer would rise due to the reduction in pressure caused by the drawdown.

Both the lateral and upward movement of the saline interface along the modelled cross-section is predicted to be negligible after 100 years of project operation. Therefore, impacts to groundwater users, groundwater dependent ecosystems and the beneficial use of the aquifer as a result of saltwater intrusion are not expected.

Contaminant migration from contaminated sites

Predicted drawdown at areas of environmental interest for contamination during operation in 2028 (first year of operation) and 2128 (100 years after operation commencement) are shown in Table 16-15.

Table 16-15 Predicted drawdown at areas of environmental interest for contamination during operation in 2028 and 2128

Area of environmental interest	Drawdown – project only 2028 (m)	Drawdown – project only 2128 (m)	Drawdown – cumulative 2028 (m)	Drawdown – cumulative 2128 (m)
Unsealed areas next to Warringah Freeway – Eastern side (Cammeray Golf Course) at Cammeray	Up to 13	Up to 13	Up to 17	Up to 19
Punch Street at Artarmon	Up to 19	Up to 21	Up to 19	Up to 21
Willoughby Leisure Centre and Bicentennial Reserve at Willoughby	Up to 22	Up to 27	Up to 22	Up to 27
Balgowlah Golf Course at Balgowlah	Up to 11	Up to 11	Up to 11	Up to 11
Waverton Park – Woolcott Road, Waverton	Less than 1	Less than 1	Up to 12	Up to 13

The rate of migration would depend predominantly on the hydraulic conductivity at the contaminant location, contaminant viscosity and the hydraulic gradient at the site.

Contaminant migration caused by drawdown from the tunnel has the potential to degrade water quality more than 40 metres from the tunnel. Given the relatively small predicted change in total water head within bores GW023150, GW026513, GW072478, GW107970, GW108224 and GW108991, and the fact that these bores lie upgradient of direction of potential contaminant migration towards the tunnels from areas of environmental interest, the groundwater quality at these bores is not expected to be modified due to the project.

The only groundwater dependent ecosystem in the area is at the upper reaches of Flat Rock Creek and Quarry Creek. This location is not expected to be impacted by contaminant migration since the potentially contaminated fill area is immediately overlying the project tunnels and would therefore drain towards the tunnels and away from the groundwater dependent ecosystem, which would satisfy the requirements of the NSW Aquifer Interference Policy (NSW DPI, 2012a).

If contaminants are mobilised towards the tunnel during operation, the quality of groundwater inflows would pose a potential human health risk and could impact the integrity of the construction materials. This risk would be managed through the ongoing monitoring of groundwater inflow quality and groundwater levels and quality. All groundwater inflows would be collected and treated at the Gore Hill Freeway wastewater treatment plant.

Groundwater dependent ecosystems and sensitive environments

As shown in Table 16-16, drawdown is predicted to be less than one metre at the Coastal Upland Swampland, the vegetation at Bates Creek and Manly Dam Reserve. Potential cumulative drawdown is predicted to be up to 12 metres for parts of the groundwater dependent ecosystem at Flat Rock Creek and Quarry Creek. Groundwater inflows to the tunnels would however be collected, treated and discharged into Flat Rock Creek which would partially offset the predicted baseflow reduction.

The predicted groundwater drawdown in the vicinity of Flat Rock Creek and Quarry Creek has the potential to impact the groundwater dependent ecosystem at that location. The potential magnitude of these impacts is discussed further in Chapter 19 (Biodiversity) and Appendix S (Technical working paper: Biodiversity development assessment report). It is noted that these predictions are based on unconstrained groundwater inflows into the tunnels and a model containing limited data which assumes full hydraulic connection in the hydrogeological layers between the identified groundwater dependent ecosystems and the underlying rock, which may not be the case. Additionally, due to the very low existing baseflows along Quarry Creek and the existing geomorphologies, the predicted baseflow reductions are unlikely to have any substantial ecological impacts.

The other groundwater dependent ecosystems in the project area are outside the predicted drawdown extents.

Further studies will occur during development of the detailed design to confirm potential groundwater drawdown at Flat Rock Creek and associated potential impacts to the groundwater dependent ecosystem. Where unacceptable ecological impacts are predicted, feasible and reasonable mitigation measures to address the impacts will be identified, incorporated into the detailed design, and implemented during construction (refer to Section 16.7 and Chapter 19 (Biodiversity)).

The closest listed Ramsar wetland of international importance is the Towra Point Nature Reserve, located 17 kilometres south of the project. Towra Point Nature Reserve and would not be impacted by the project.

Table 16-16 Predicted drawdown and impact at groundwater dependent ecosystems and sensitive environments during operation (2028 and 2128)

Receptor	Location	Drawdown – project only 2028 (m)	Drawdown – project only 2128 (m)	Drawdown – cumulative 2028 (m)	Drawdown – cumulative 2128 (m)
Vegetation at Flat Rock and Quarry Creek	Northbridge	Up to 4	Up to 11	Up to 4	Up to 12
Vegetation at Bates Creek	Bates Reserve/Garigal National Park, Killarney Heights	Less than 1	Less than 1	Less than 1	Less than 1

Receptor	Location	Drawdown – project only 2028 (m)	Drawdown – project only 2128 (m)	Drawdown – cumulative 2028 (m)	Drawdown – cumulative 2128 (m)
Manly Dam Reserve	Manly Dam Reserve, Allambie Heights	Less than 1	Less than 1	Less than 1	Less than 1
Coastal Upland Swamp	Bates Reserve/Garigal National Park, Killarney Heights	Less than 1	Less than 1	Less than 1	Less than 1

Activation of acid sulfate soils

Modelling indicates that water table drawdown could occur within sediments immediately adjacent to the waters of Middle Harbour, where the tunnel alignment crosses Middle Harbour. However, these sediments are expected to remain saturated (due to constant recharge from harbour waters) and are not expected to experience oxidation due to the project beyond historical levels.

Therefore, impacts to groundwater dependent ecosystems, sensitive sites and groundwater users from acid sulfate soils are considered unlikely.

16.5.3 Groundwater quality

Potential operational impacts on groundwater quality due to saltwater intrusion, mobilisation of contaminants and potential acidification are discussed in Section 16.5.2.

The quality of discharged water during operation is considered in Chapter 17 (Hydrodynamics and water quality).

During operation groundwater inflows would be transferred to a wastewater treatment plant prior to disposal to stormwater. For operation, the project would be designed to comply with the following discharge criteria:

- The relevant physical and chemical stressors set out in of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and
- The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 99 per cent species protection levels, and
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) for which public comments are under consideration as of November 2020.

16.6 Policy compliance

16.6.1 Consistency with minimum harm criteria

The *Water Management Act 2000* includes the concept of ensuring ‘no more than minimal harm’ for both the granting of water access licences and the granting of approvals. While the project does not require a licence/approval under the *Water Management Act 2000*, the minimal harm criteria in the NSW Aquifer Interference Policy (NSW DPI, 2012a) have been used for the purposes of assessment (refer to Table 16-17).

Table 16-17 Minimal harm criteria assessment

Minimal harm criteria	Assessment
Water table	
<p>Level 1</p> <p>Less than or equal to 10 per cent cumulative variation in the water table, allowing for typical climatic “post water sharing plan” variations, 40 metres from any:</p> <ul style="list-style-type: none"> • high priority groundwater dependent ecosystem; or • high priority culturally significant site listed in the schedule of the relevant water sharing plan. <p>A maximum of a two metre decline cumulatively at any water supply work.</p>	<p>Schedule 4 of the <i>Water Sharing Plan for the greater Metropolitan Region Groundwater Sources 2011</i> (NSW DPI, 2011a) identifies that within the Hawkesbury Sandstone and Ashfield Shale there are:</p> <ul style="list-style-type: none"> • No listed high priority groundwater dependent ecosystems (refer to Section 16.3.4) • No listed high priority culturally significant sites (refer to Section 16.4.5). <p>Groundwater modelling has predicted that drawdown could exceed two metres at bores GW107970, GW108224 and GW108991 during both construction and operation (refer to sections 16.4 and 16.5). Impact minimisation measures are discussed below.</p>
<p>Level 2</p> <p>If more than 10 per cent cumulative variation in the water table, allowing for typical climatic “post water sharing plan” variations, 40 metres from any:</p> <ul style="list-style-type: none"> • high priority groundwater dependent ecosystem; or • high priority culturally significant site listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister’s satisfaction that the variation will not prevent the long term viability of the dependent ecosystem or significant site. <p>If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.</p>	<p>Groundwater modelling has predicted that drawdown could exceed two metres at bores GW107970, GW108224, GW108991 during both construction and operation and GW023150, GW026513 and GW072478 during operation. The initial assessment, however, indicates that predicted drawdown due to the project would have a negligible impact on water availability at affected bores.</p> <p>Environmental management measures are detailed in Section 16.7.</p>
Water pressure	
<p>Level 1</p> <p>A cumulative pressure head decline of not more than a two metre decline, at any water supply work.</p>	<p>Investigation and environmental management measures to address impacts at the bores GW023150, GW026513, GW072478, GW107970, GW108224 and GW108991 are proposed in Section 16.7.</p>

Minimal harm criteria	Assessment
<p>Level 2</p> <p>If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not prevent the long term viability of the affected water supply works unless make good provisions apply.</p>	<p>The current viability of the bores is uncertain, but if it is proven, monitoring would be carried out. If impacts are realised, the make good provisions would be applied (if required) to either maintain the long term viability of the bores or to provide an alternative supply or compensation.</p>
<p>Water quality</p>	
<p>Level 1</p> <p>Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.</p>	<p>Impacts to groundwater quality from the project activities would be minor, and as the tunnel inflows create a hydraulic gradient towards the tunnel, and any contamination mobilised or caused by the works would flow back towards the tunnel rather than away from it. Contaminants associated with the project would therefore remain within 40 metres of the tunnel. Drawdown caused by the tunnel may cause contamination of groundwater more than 40 metres away from the tunnel due to:</p> <ul style="list-style-type: none"> • Inland migration of the saline interface • Migration of contaminated groundwater from existing contaminated sites into areas of fresher groundwater. • Potential activation of acid sulfate soils. <p>These processes mean that this requirement of the NSW Aquifer Interference Policy (NSW DPI, 2012a) would not be satisfied. Impact minimisation measures are discussed in Section 16.7.</p>
<p>Level 2</p> <p>If condition 1 is not met then appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long term viability of the dependent ecosystem, significant site or affected water supply works.</p>	<p>Intrusion of saline water from the coast into fresher groundwater and migration of already contaminated groundwater are not likely to impact the long term viability of groundwater dependent ecosystems or culturally significant sites as no sites exist within the area of drawdown surrounding the tunnel.</p>
<p>Additional considerations</p>	
<p>... any advice provided to a gateway panel, the Planning and Assessment Commission or the Minister for Planning on a State significant development or State significant infrastructure will also consider the potential for:</p> <ul style="list-style-type: none"> • Acidity issues to arise, for example exposure of acid sulfate soils 	<p>The level of predicted drawdown does not present a substantial risk of activation of acid sulfate soils if present. No work has been carried out so far to identify and test the acid generating potential of soil and rock in the project area. If additional areas of acid sulfate soils are identified, measures to mitigate impacts will be needed.</p>

Minimal harm criteria	Assessment
<ul style="list-style-type: none"> Water logging or water table rise to occur, which could potentially affect land use, groundwater dependent ecosystems and other aquifer interference activities. <p>Specific limits will be determined on a case-by-case basis, depending on the sensitivity of the surrounding land and groundwater dependent ecosystems to waterlogging and other aquifer interference activities to water intrusion.</p>	<p>There is no risk of water logging or water table rise since the tunnel would be drained during both construction and operation. The only tanked structures would be short distances either side of the harbour.</p> <p>Waterlogging or damming of groundwater flow is not expected to occur since the hydraulic gradient by the time the sections of the tunnel are tanked would cause flow towards the drained sections of the tunnel</p>

16.6.2 Consistency with Water Sharing Plan rules

All groundwater and surface water in the project area is managed through the Greater Metropolitan Region Water Sharing Plan. The Greater Metropolitan Region Water Sharing Plan provides rules to manage and allocate the groundwater resource, including specific rules on taking groundwater near high priority groundwater dependant ecosystems, groundwater dependent culturally significant sites, sensitive environmental areas, and near other licenced bores. The groundwater source relevant to the project is the 'Sydney Basin Central'. While the project does not require a licence and/or approval under the *Water Management Act 2000*, these rules have been used for the purposes of assessment (refer to Table 16-18).

Table 16-18 Compliance with water sharing plan rules

Water sharing plan rule	Assessment
Part 7 – Rules for granting access licences	<p>Transport for NSW is exempt from the requirement to hold a licence for the take of water during construction and operation of major projects as specified in Schedule 4, Part 1, clause 2 of the <i>Water Management (General) Regulation 2011</i>.</p> <p>The <i>Water Management Act 2000</i> requires that road authorities obtain a water supply work approval for groundwater ingress to tunnels. The inflow volume of up to 899 ML/year during construction, and up to 551 ML/year during operation need to be assigned under the long term average annual extraction limit.</p>
Part 8 – Rules for managing access licences	
Part 9 – 39: Distance restrictions to minimise interference between supply works	<p>The approval process would determine distance restrictions to minimise interference between water supply works.</p> <p>There are four bores (GW023150, GW072478, GW108224 and GW108991) that may be impacted by drawdown. Viability of water access at these bores is not expected to be impacted, with the potential exception of bore GW023150 if it is found to be viable and it relies on shallow groundwater.</p>
Distance restriction from the property boundary is 50 metres	<p>The project is within 50 metres of property boundaries and would result in drawdown at adjacent properties. This is considered acceptable as the tunnels are predominantly at depth below properties and there is a reticulated water supply to those properties. The project would therefore not impact water supply to adjacent properties.</p>

Water sharing plan rule	Assessment
Distance restriction from an approved water supply work is 100 metres	There are no approved water supply works within 100 metres of the project. Supply bores GW023150, GW026513, GW072478, GW107970, GW108224 and GW108991 are within the area of drawdown, but make good provisions would apply where required, as discussed above.
Distance restriction from a Department observation bore is 200 metres	The Department of Regional NSW does not have any observation bores within 200 metres of the project, or within the area of drawdown surrounding the project.
Distance restriction from an approved work nominated by another access licence is 400 metres	There are no approved works nominated by another access licence within 400 metres of the project.
Distance restriction from an approved water supply work nominated by a local water utility or major utility access licence is 1000 metres	There are no water supply works nominated by water utilities within 1000 metres of the project, or within the area of drawdown surrounding the project.
Part 9 – 40 Rules for water supply works located near contaminated sources	<p>In addition to the moderate to high risk areas of environmental interest for contamination identified within Appendix M (Technical Working Paper: Contamination) the NSW Environment Protection Authority notified contaminated sites have been identified as relevant to the project under the description of contaminated sites in Schedule 3 of the Water Sharing Plan.</p> <p>A water supply works approval must not be granted within:</p> <ul style="list-style-type: none"> • 250 metres of contaminant plumes associated with these sites • 250 to 500 metres of these sites as long as no drawdown would occur within 250 metres of the contaminant plume • At a specified distance more than 500 metres of a contaminant plume if needed to protect the water source and users. <p>The presence of contaminant plumes at these sites has not been assessed.</p> <p>Approval can be granted for water supply works within the specified distance of contaminated sites as long as the water source, dependent ecosystems, and public health and safety are not threatened.</p>
Part 9 – 41 Rules for water supply works located near sensitive environmental areas	<p>The project is outside the required distance for the following sensitive environmental areas:</p> <ul style="list-style-type: none"> • 200 metres of a high priority groundwater dependent ecosystem • 500 metres of a karst groundwater dependent ecosystem • 40 metres from a lagoon or escarpment (Section 4.3). <p>The project is within 40 metres of a first/second order stream (Flat Rock Creek/Quarry Creek), but as it is more than 30 metres deep and within the underlying parent material it satisfies the requirements of the Water Sharing Plan.</p>

Water sharing plan rule	Assessment
Part 9 – 42 Rules for water supply works located near groundwater dependent culturally significant sites	There are no groundwater dependent culturally significant sites in the area of drawdown surrounding the project.
Part 9 – 44 Rules for water supply works located within distance restrictions	As the potential supply bores (GW023150, GW026513, GW072478, GW107970, GW108224 and GW108991) and the areas of environmental interest for contamination may be within restricted distances, the proponent must not take more water than specified in the water access licence. Although Transport for NSW is exempt from having to hold a water access licence, Ministerial approval may still specify an allowable extraction volume (or inflow rates) for the project to protect the bore user and avoid contaminant migration.
Part 10 – Access dealing rules	Refer to Part 7 response.

16.7 Environmental management measures

Environmental management measures relating to geology, soils and groundwater impacts are outlined in Table 16-19.

Table 16-19 Environmental management measures - geology, soils and groundwater

Ref	Phase	Impact	Environmental management measure	Location
SG1	All phases	Groundwater drawdown and quality	The existing groundwater monitoring program for both groundwater levels and quality will be continued through construction. Outcomes of updated groundwater modelling (environmental management measure SG2) will identify any requirements for further groundwater monitoring during the operational phase.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
SG2	All phases	Groundwater drawdown	<p>As more information becomes available on groundwater levels through ongoing groundwater monitoring, groundwater modelling will be updated to refine the predictions. Inflow predictions will be updated prior to finalising detailed design and will include designed tunnel linings, and the detailed design will be updated based on the updated operational inflow and impact predictions.</p> <p>If refined predictions of groundwater levels and drawdown indicate that impacts would be greater than the impacts presented in the environmental impact statement, feasible and reasonable mitigation measures will be incorporated into the detailed design and implemented.</p> <p>Groundwater modelling will be conducted considering <i>Australian Groundwater Modelling Guidelines</i> (Barnett et al., 2012), including sensitivity analysis and consideration of future climate change, as required.</p>	BL/GHF
SG3	All phases	Impact to registered groundwater bores	<p>The viability of the following domestic bores will be confirmed prior to construction.</p> <ul style="list-style-type: none"> • GW023150 • GW026513 • GW072478 • GW107970 • GW108224 • GW108991 <p>If drawdown at the bore exceeds two metres (in accordance with the NSW Aquifer Interference Policy (NSW DPI, 2012a)) and impacts to the ongoing use of the bores are unacceptable, measures will be taken to 'make good' the impact by restoring the water supply to pre-development levels. The measures taken will be dependent upon the impacts to the bore and will be determined in consultation with the affected licence holder but could include deepening the bore, providing a new bore or providing an alternative water supply.</p>	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
SG4	Design	Ground movement impacts	Detailed predictive settlement models will be developed for areas of concern to guide tunnel design and construction methodology, including the selection of options to minimise settlement where required.	BL/GHF
SG5	Pre-construction	Ground movement impacts	An Independent Property Impact Assessment Panel, comprising geotechnical and engineering experts, will be established prior to the commencement of works to independently verify building condition survey reports, resolve any property damage disputes and establish ongoing settlement monitoring requirements.	BL/GHF
SG6	Pre-construction	Water table drawdown impact on baseflow and groundwater dependent ecosystems	A focussed study will be carried out to confirm potential groundwater drawdown and associated baseflow reductions at Burnt Bridge Creek, Flat Rock Creek and Quarry Creek due to tunnelling, and confirm potential impacts on freshwater ecology in the affected watercourses and nearby groundwater dependent ecosystems. The study will consider how existing site features affect the interaction between surface water and groundwater along the affected reaches of these watercourses, and the hydraulic connectivity in the underlying geology. Where unacceptable ecological impacts are predicted, feasible and reasonable mitigation measures to address the impacts will be identified, incorporated into the detailed design, and implemented during construction. The mitigation measures considered will include tunnel linings.	BL

Ref	Phase	Impact	Environmental management measure	Location
SG7	Pre-construction, construction	Ground movement impacts	<p>Pre-construction building structure condition surveys will be offered and prepared (where the offer is accepted by the owner) for properties (and heritage assets) within the zone of influence of tunnel settlement where the degree of severity has been assessed as 'slight' or above and within the minimum working distances for cosmetic and structural damage due to vibration. The surveys will be carried out by a suitably qualified person prior to the commencement of the tunnelling and vibration intensive activities in the vicinity with the potential to affect the building/structure.</p> <p>Within three (3) months of the completion of construction activities that have the potential to cause settlement or vibration-related damage to the subject surface/subsurface structure, all property owners of buildings for which a pre-construction building condition survey was carried out will be offered a second building condition survey. Where an offer is accepted, a post-construction building condition survey will be carried out by a suitably qualified person. The results of the survey will be documented in a post-construction building condition survey report for each building surveyed.</p> <p>Copies of building condition survey reports will be provided to the owners of the buildings surveyed within one (1) month of the survey being completed.</p> <p>Any building and/or property damage from settlement caused by the project will be repaired at no cost to the owner. Any repairs to listed heritage items required as a result of the settlement damage, will be carried out under the guidance of a suitably qualified and experienced heritage professional.</p>	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
SG8	Pre-construction and construction	Impacts on site workers and/or local community through disturbance and mobilisation of contaminated material	<p>Potentially contaminated areas directly affected by the project will be further investigated and managed in accordance with the requirements of guidance endorsed under section 105 of the <i>Contaminated Land Management Act 2008</i>.</p> <p>This includes, but is not limited to, further investigations in potential areas of environmental interest in the project footprint, including:</p> <ul style="list-style-type: none"> • Warringah Freeway (from North Sydney to Cammeray) • Punch Street, Artarmon • Willoughby Leisure Centre and Bicentennial Reserve, Willoughby • Flat Rock Reserve, Northbridge • Spit West Reserve, Mosman • Balgowlah Golf Course, Balgowlah • Wakehurst Parkway (from Seaforth to Frenchs Forest). <p>Subject to the outcomes of the investigations, a Remediation Action Plan will be implemented in the event that site remediation is warranted.</p> <p>The Remediation Action Plan will be prepared in accordance with <i>Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land</i> (Department of Urban Affairs and Planning and Environment Protection Authority, 1998). If Remediation Action Plan(s) are required for works at Flat Rock Drive (BL2), Balgowlah Golf Course (BL10) construction support sites and surface works and construction support site locations along the Wakehurst Parkway (BL12, BL13 and BL14) these will be developed with consideration of environmental management measure WM6.</p> <p>An independent NSW EPA Accredited Site Auditor will be engaged where contamination is complex to review applicable contamination reports and evaluate the suitability of sites for a specified use as part of the project.</p>	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
SG9	Construction	Erosion and sedimentation	<p>Erosion and sediment control measures will be implemented at all work sites and surface road upgrades in accordance with the principles and requirements in <i>Managing Urban Stormwater – Soils and Construction, Volume 1</i> (Landcom 2004), <i>Managing Urban Stormwater: Volume 2D Main Road Construction</i> (NSW Department of Environment and Climate Change, 2008) and relevant guidelines, procedures and specifications of Transport for NSW.</p> <p>A soil conservation specialist will be engaged for the duration of construction of the project to provide advice regarding erosion and sediment control including review of Erosion and Sediment Control Plans.</p>	BL/GHF
SG10	Construction	Impacts on site workers and/or local community through disturbance and mobilisation of contaminated material	Asbestos handling, management and disposal will be carried out in accordance with relevant legislation, codes of practice and Australian standards.	BL/GHF
SG11	Construction	Impacts on site workers and/or local community through disturbance and mobilisation of contaminated material	A hazardous materials assessment will be carried out prior to and during the demolition of structures. Demolition works will be carried out in accordance with the relevant Australian Standards and relevant NSW WorkCover Codes of Practice, including the Work Health and Safety Regulation 2011 (NSW) to minimise potential exposure of construction personnel and the public to hazardous materials.	BL/GHF
SG12	Construction	Impacts on site workers and/or local community through disturbance and mobilisation of contaminated material	A Construction Waste Management Plan will be prepared and implemented during construction. The plan will include but not be limited to procedures for handling and storing potentially contaminated substances.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
SG13	Construction	Impacts on site workers and/or local community through disturbance and mobilisation of contaminated material	The discovery of previously unidentified contaminated material will be managed in accordance with an unexpected contamination discovery procedure, as outlined in the <i>Guideline for the Management of Contamination</i> (Roads and Maritime Services, 2013).	BL/GHF
SG14	Construction	Impacts from disturbance of acid sulfate soils	Prior to ground disturbance in high risk acid sulfate areas at Spit West Reserve and Middle Harbour, testing will be carried out to determine the presence of acid sulfate soils. If acid sulfate soils are encountered, they will be managed in accordance with the <i>Acid Sulfate Soil Manual</i> (Acid Sulfate Soil Management Advisory Committee, 1998).	BL
SG15	Construction	Ground gas impacts	Ground gas investigations will be carried out in Flat Rock Reserve to further assess the potential presence of landfill generated gas which could impact on the construction and/or operation of the project. Ground gas investigations will be carried out in accordance (where applicable) with the <i>Guideline for the Assessment and Management of Sites Impacted by Hazardous Ground Gases</i> (NSW EPA, 2012).	BL
SG16	Construction	Groundwater drawdown during operation	Measures will be implemented during tunnel construction to ensure that groundwater inflows during the operation phase do not exceed 1L/s/km on average over the entire tunnel length.	BL
SG17	Construction	Marine contamination impacts	The appropriateness of offshore disposal will be assessed in accordance with the Australian Government Department of Agriculture, Water and the Environment's <i>National Assessment Guidelines for Dredging</i> (Department of Environment, Water, Heritage and the Arts, 2009). Offshore disposal will only occur for material that meets the criteria provided in the guidelines.	BL

Ref	Phase	Impact	Environmental management measure	Location
SG18	Construction and operation	Groundwater drawdown	<p>The groundwater monitoring program will consider additional locations for monitoring that are subject to medium and high risk of groundwater contamination during construction and operation.</p> <p>Where relevant, modelling/mass balance analysis will be carried out to assess potential impacts on beneficial aquifer use and the likely quality of groundwater inflows.</p>	BL/GHF
SG19	Construction and operation	Groundwater quality impacts	<p>If the groundwater quality monitoring and associated analysis identifies potential impacts to beneficial aquifer use from the migration of contaminated groundwater, or the quality of groundwater tunnel inflows, feasible and reasonable management measures will be identified and implemented.</p>	BL/GHF
SG20	Construction and operation	Contamination due to leakage or spills	<p>Emergency procedures, including material bunding and appropriately sized spill containment kits, will be developed to avoid and manage accidental spillages of fuels, chemicals, and fluids to minimise the risk of human health impacts and contamination of groundwater.</p>	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 17

Hydrodynamics and water quality

17 Hydrodynamics and water quality

This chapter provides an assessment of the construction and operational impacts associated with hydrodynamics and (surface) water quality and identifies measures which address these impacts.

A detailed surface water quality and hydrology assessment has been carried out for the project and is included in Appendix O (Technical working paper: Surface water quality and hydrology). Hydrodynamic and dredge plume modelling has also been carried out and is detailed in Appendix P (Technical working paper: Hydrodynamic and dredge plume modelling). A marine water quality assessment is provided in Appendix Q (Technical working paper: Marine water quality). The impacts associated with flooding are detailed in Chapter 18 (Flooding), while assessments of contamination and groundwater impacts are included in Chapter 16 (Soils, geology and groundwater).

The Secretary's environmental assessment requirements as they related to hydrodynamics and water quality, and where in the environmental impact statement these have been addressed, are detailed in Table 17-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to hydrodynamics and water quality are included in Section 17.6.

Table 17-1 Secretary's environmental assessment requirements – hydrodynamics and water quality

Secretary's requirement	Where addressed in EIS
Water – Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes and groundwater dependent ecosystems) likely to be impacted by the project, including rivers, streams, wetlands and estuaries as described in Appendix 2 of the <i>Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects</i> (OEH, 2014).	The existing hydrological regime for surface water resources is described in Section 17.3 . Details of water resources likely to be impacted by the project is presented in Section 17.3.1 . Biodiversity considerations are outlined in Chapter 19 (Biodiversity) and the hydrological regime for groundwater is considered in Chapter 16 (Soils, geology and groundwater).
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations (including mapping of these locations), volume, frequency and duration for both the construction and operational phases of the project.	A surface water balance for construction and operation is provided in Section 17.4.5 and Section 17.5.6 respectively. Further details, including wastewater treatment plants and associated discharge locations, are provided in Section 17.4.3 . Refer to Chapter 5 (Project description) for locations of permanent water quality basins proposed for the project.

Secretary's requirement	Where addressed in EIS
	Refer to Chapter 16 (Geology, soils and groundwater) for groundwater inflow predictions.
<p>3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:</p> <p>a. natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity, water-dependent fauna and flora and access to habitat for spawning and refuge;</p>	<p>Surface water hydrological impacts and impacts on natural processes are included in Section 17.4 and Section 17.5.</p> <p>Groundwater hydrological impacts are included in Chapter 16 (Geology, soils and groundwater).</p> <p>Impacts on flooding are included in Chapter 18 (Flooding). Surface water and groundwater hydrological impacts on the health of the fluvial, riparian, estuarine or marine system, aquatic connectivity, fauna and flora, and access to habitat for spawning and refuge are included in Chapter 19 (Biodiversity).</p>
<p>b. impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;</p>	<p>Groundwater hydrological impacts are included in Chapter 16 (Geology, soils and groundwater).</p> <p>Implications for groundwater dependent ecosystems and species are included in Chapter 19 (Biodiversity).</p>
<p>c. changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources including the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course;</p>	<p>An assessment of the changes to environmental water availability and flows (including the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course) is included in Section 17.4.5 and Section 17.5.6.</p>
<p>d. direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;</p>	<p>Potential impacts on surface water with regard to erosion, siltation, and bank stability are assessed in Section 17.4 and Section 17.5.</p> <p>Impacts from scour and erosion on geomorphology are discussed in Section 17.4.4 and Section 17.5.4.</p> <p>Impacts on riparian vegetation are included in Chapter 19 (Biodiversity).</p>
<p>e. minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater</p>	<p>The effects of proposed stormwater and wastewater management on surface water quality are assessed in Section 17.4.3 and Section 17.5.3.</p> <p>Information on wastewater discharge, including volumes and rates of discharge, are included in Section 17.4.3 and Section 17.5.3.</p>

Secretary's requirement	Where addressed in EIS
systems where discharges are proposed through such systems;	
f. measures to mitigate the impacts of the proposal and manage the disposal of produced and incidental water; and	Environmental management measures relating to surface water are detailed in Section 17.6 . Water drainage and management infrastructure is detailed in Chapter 5 (Project description) and Chapter 6 (Construction work).
4. The assessment must provide details of the final landform of the sites to be excavated or modified (eg portals), including final void management and rehabilitation measures.	Details of the final landforms and rehabilitation for the project are provided in Chapter 22 (Urban design and visual amenity). Landscape treatments for the project are detailed in Chapter 5 (Project description).
5. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	A description of surface water monitoring carried out to inform this environmental impact statement, and requirements for operational monitoring are provided in Section 17.2.3 and Section 17.6 respectively. Proposed surface water monitoring locations are presented in Section 17.2.2 .
6. The assessment must include details of proposed surface and groundwater monitoring.	A description of surface water monitoring carried out to inform this environmental impact statement, and requirements for operational monitoring are provided in Section 17.2.3 and Section 17.6 respectively. Proposed groundwater monitoring is identified in Chapter 16 (Geology, soils and groundwater).
7. The Proponent must identify design approaches to minimise or prevent drainage of alluvium in the paleochannels.	Palaeochannels near the project are described in Chapter 16 (Geology, soils and groundwater). Details of tunnel design are provided in Chapter 5 (Project description) and Chapter 6 (Construction work).
Water – Quality	
1. The Proponent must: a. describe the background conditions for any surface or groundwater resource likely to be affected by the development	A description of the background surface water and groundwater conditions is included in Section 17.3 and Chapter 16 (Geology, soils and groundwater) respectively.
b. state the ambient NSW Water Quality Objectives (NSW WQO) (as endorsed by the NSW Government [see www.environment.nsw.gov.au/ieo/index.htm]) and environmental values for the receiving waters (including groundwater where appropriate) relevant to the project and that represent the community's uses and values for those receiving waters, including the	A list of the ambient NSW water quality objectives for receiving waters within the project area is included in Section 17.1.2 . Environmental values for the receiving waters are discussed in Section 17.3.9 . The ANZG (2018) and ANZECC/ARMCANZ (2000) default trigger values are provided in Appendix O (Technical working paper: Surface water quality and hydrology).

Secretary's requirement	Where addressed in EIS
<p>indicators and associated trigger values or criteria for the identified environmental values in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government;</p>	
<p>c. identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;</p>	<p>Potential pollutants of concern are identified in Section 17.4, Section 17.5 and Appendix O (Technical working paper: Surface water quality and hydrology).</p> <p>An assessment of the potential for construction to introduce pollutants into receiving waterways is provided in Section 17.3.5.</p> <p>Discharge quantities and locations are provided in Section 17.4.3 and Section 17.5.3.</p>
<p>d. identify the rainfall event that the water quality protection measures will be designed to cope with;</p>	<p>Section 17.1.3 identifies design standards, targets and considerations to be adopted during construction and operation, including criteria to which water quality protection measures would be designed for.</p>
<p>e. assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;</p>	<p>The significance of identified impacts on ambient water quality outcomes is assessed in Section 17.4 and Section 17.5.</p>
<p>f. demonstrate how construction and operation of the project (including mitigating effects of proposed stormwater and wastewater management) would, to the extent that the project can influence, ensure that:</p> <ul style="list-style-type: none"> - where the NSW WQOs for receiving waters are currently being met they would continue to be protected; and - where the NSW WQOs are not currently being met, activities would work toward their achievement over time; 	<p>Discussion of whether the NSW water quality objectives are currently met is included in Section 17.3.5. An assessment on how construction and operation of the project would impact on the NSW water quality objectives is included in Section 17.1.2.</p> <p>Management measures relevant to surface water quality impacts are provided in Section 17.6.</p> <p>The ability of the project to meet the NSW water quality objectives is discussed in Section 17.4.3 and Section 17.5.3.</p>
<p>g. justify, if required, why the WQOs cannot be maintained or achieved over time;</p>	<p>Treatment of wastewater to meet ANZG (2018) and ANZECC/ARMCANZ (2000) would maintain or improve existing water quality. The ability of the project to meet the NSW WQOs is discussed in Section 17.4.3 and Section 17.5.3.</p>
<p>h. demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;</p>	<p>Practical management measures to be adopted for the project are provided in Section 17.6.</p> <p>The project has been designed to avoid or minimise environmental impacts. Relevant</p>

Secretary's requirement	Where addressed in EIS
	<p>environmental controls are detailed in Chapter 5 (Project description) and Chapter 6 (Construction work).</p> <p>Management measures to ensure the protection of human health are outlined in Chapter 13 (Human health).</p>
<p>i. identify sensitive receiving environments (which may include estuarine and marine waters downstream including Quarry Creek and its catchment) and develop a strategy to avoid or minimise impacts on these environments; and</p>	<p>Sensitive receiving environments are identified and described in Section 17.3.8. Management measures to avoid (or minimise) impacts are provided in Section 17.6.</p> <p>The project has been designed to avoid or minimise environmental impacts, relevant environmental controls are detailed in Chapter 5 (Project description) and Chapter 6 (Construction work).</p>
<p>j. identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.</p>	<p>Surface water monitoring locations are discussed in Section 17.2.3. Proposed surface water monitoring is included in Section 17.6.</p> <p>Appendix O (Technical working paper: Surface water quality and hydrology) provides further detail on the proposed surface water quality monitoring for the project. It is anticipated that the same monitoring sites detailed in Section 17.2.3 and indicators detailed in Section 3.2, Annexure A and Annexure B of the Appendix O (Technical working paper: Surface water quality and hydrology) would be monitored in the future.</p> <p>Details relating to the proposed groundwater monitoring are provided in Chapter 16 (Geology, soils and groundwater).</p>
<p>k. identify how the development meets the objectives of the <i>Coastal Management Act 2016</i> and management objectives of relevant Coastal Management Areas defined under the <i>Coastal Management Act 2016</i>.</p>	<p>Consistency with the objectives of the <i>Coastal Management Act 2016</i> is outlined in Section 17.1.1 and discussed further in Appendix O (Technical working paper: Surface water quality and hydrology).</p>
<p>l. demonstrate consistency with any relevant certified Coastal Management Program (or Coastal Zone Management Plan).</p>	<p>Consistency with the vision and objectives presented in the Greater Sydney Harbour Estuary Coastal Management Program Scoping Study which are consistent with the <i>Coastal Management Act 2016</i> is outlined in Section 17.1.1 and discussed further in Appendix O (Technical working paper: Surface water quality and hydrology).</p>
<p>2. The assessment should consider the results of any current water quality studies, as available, in the project catchment.</p>	<p>Water quality studies considered for this assessment are listed in Section 17.2.2.</p>

17.1 Legislative and policy framework

17.1.1 Relevant legislation

Chapter 2 (Assessment process) describes the environmental impact assessment and approval process for the project, including relevant NSW and Commonwealth legislation applicable to the project. Legislative requirements specific to water quality and hydrodynamics are provided in Table 17-2.

Table 17-2 Legislation relevant to the project

Legislation	Relevance to project
<i>Protection of the Environment Operations Act 1997</i>	Environment protection licences are issued for a broad range of activities listed in Schedule 1 of the <i>Protection of the Environment Operations Act 1997</i> and aim to address air, noise, waste, land contamination and water pollution issues created by those activities. An environment protection licence for road construction and road tunnel emissions under Chapter 3 of the Act would be required for construction of the project.
<i>Fisheries Management Act 1994</i>	In accordance with section 199 of the <i>Fisheries Management Act 1994</i> , notification to the Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) is required if dredging or reclamation works are required in water land classed as Key Fish Habitat.
<i>Water Management Act 2000, Water Management Amendment Act 2014, and Water Management (General) Regulation 2011</i>	The project is located within an area covered by the <i>Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources</i> (NSW DPI, 2011b). This plan applies to surface water sources and includes rules for protecting the environment, water extraction, managing licence holders' water accounts, and water trading within the plan area. Under Schedule 4, Part 1, clause 2 of the Water Management (General) Regulation 2011, roads authorities are exempt from the requirement to hold a water access licence to take water for road construction and road maintenance.

Legislation	Relevance to project
<p><i>Coastal Management Act 2016</i> and the related State Environmental Planning Policy (Coastal Management) 2018</p>	<p>The objects of the <i>Coastal Management Act 2016</i> are to manage the coastal environment in a manner consistent with the principles of ecologically sustainable development for the social, cultural and economic well-being of the people of the State.</p> <p>State Environmental Planning Policy (Coastal Management) 2018 promotes an integrated and coordinated approach to land use planning in the coastal zone, consistent with the objects of the <i>Coastal Management Act 2016</i>. It provides development controls for four coastal management areas – coastal wetlands and littoral rainforests areas, coastal vulnerability areas, coastal environment areas and coastal use areas. Management objectives are listed in the <i>Coastal Management Act 2016</i> for each of the four coastal management areas.</p> <p>The construction footprint is located on land mapped as “proximity area for coastal wetlands” and “proximity area for littoral rainforest”, “coastal environment area” and “coastal use area”. As described in Chapter 2 (Assessment process), environmental planning instruments do not apply to State significant infrastructure; however, consideration has been given to the management objectives of the coastal management areas through which the project passes. The applicable management objectives are established in the <i>Greater Sydney Harbour Estuary Coastal Management Program Scoping Study</i> (BMT WBM, 2018), which was prepared in 2018 to facilitate the development of the Coastal Management Program coastal management program for Greater Sydney Harbour. This program will soon supersede the <i>Clontarf/Bantry Bay Estuary Management Plan</i> (Manly Council, 2008) and provide more coverage over the study area. The objectives presented in the scoping study are consistent with the <i>Coastal Management Act 2016</i> and are proposed for inclusion in the development of the Greater Sydney Harbour Coastal Management Program. The vision and objectives of the program and relevance to marine water quality are presented in Section 17.1.2 and Appendix O (Technical working paper: Surface water quality and hydrology) and Appendix Q (Technical working paper: Marine water quality).</p>
<p>Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005</p>	<p>The Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 covers all the waterways of the harbour, the foreshores and entire catchment. It provides an improved and clearer planning framework and better environmental outcomes for Sydney Harbour and its tributaries.</p>

17.1.2 Relevant policies and guidelines

The water quality assessment has been prepared in accordance with a number of policies and guidelines as described below.

Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ, 2000) provide guidelines for water quality, taking into account their environmental values. The guidelines were updated in 2018 to incorporate new science and knowledge developed over the past 18 years (ANZG, 2018).

The study area would typically fall under the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines for 'South-east Australia slightly disturbed lowland rivers and estuaries'. Wastewater treatment plants during construction and operation would be designed such that discharges comply with these guidelines.

NSW Water Quality and River Flow Objectives

Water quality objectives have been developed for the Sydney Harbour and Parramatta River and Northern Beaches Lagoons catchments (DECCW, 2006a; DECCW, 2006b). The water quality objectives are 'primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable, water supply'. Waterways relevant to this assessment (Willoughby Creek, Quarry Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and Trefoil Creek) have been classified as 'waterways affected by urban development'. Based on this classification, the water quality objectives and nominated environmental values relevant to the project include:

- Protection of aquatic ecosystems – ecological condition of waterways and the riparian zone (lower and upper estuary)
- Protection of visual amenity – aesthetic qualities of waters (lower and upper estuary)
- Protection of primary contact recreation – water quality for activities, such as swimming (lower and upper estuary)
- Protection of secondary contact recreation – water quality suitable for activities, such as boating and wading (lower and upper estuary)
- Aquatic foods (cooked), which refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities.

Environmental values, as identified by the Department of Planning, Industry and Environment (Environment, Energy and Science), for the Sydney Harbour and Parramatta River and Northern Beaches Lagoon catchments are discussed further in Section 17.3.9.

Guidelines for Managing Risks in Recreational Water

The *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008b) aim to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters. The guidelines have been applied in the background research for the project to understand the current recreational water quality and threat to public health of waterways relevant to the project.

Sydney Harbour Water Quality Improvement Plan

The *Sydney Harbour Water Quality Improvement Plan* (Greater Sydney Local Land Services, 2015) provides a coordinated management framework to improve the future health of Sydney Harbour and its catchments. This plan applies to the majority of the construction footprint, which ultimately drains to Sydney Harbour. While the plan itself does not include pollutant reduction targets for individual developments, catchment load and estuary condition targets have been

developed for some sub-catchments and local government areas using feasible scenario options for both the management of stormwater and improvements in sewer outflow performance.

Greater Sydney Harbour Estuary Coastal Management Program Scoping Study

As described above, the *Greater Sydney Harbour Estuary Coastal Management Program Scoping Study* (BMT WBM, 2018) was prepared in 2018 to facilitate the development of the coastal management program for Greater Sydney Harbour. A vision and objectives were presented in the scoping study that are consistent with the *Coastal Management Act 2016* for inclusion in the Greater Sydney Harbour Coastal Management Program. The objectives of the program relevant to marine water quality and references to applicable parts of this environmental impact statement are outlined in Table 17-3. Other coastal management objectives are deemed not applicable to the project.

Table 17-3 Relevant Greater Sydney Harbour coastal management objectives

Relevant coastal management objectives	Consideration
To protect and enhance natural processes and environmental values of the Greater Sydney Harbour coastal zone.	Section 17.3 with respect to the protection of environmental values of the estuary.
To support the social and cultural values of the Greater Sydney Harbour and maintain public access, amenity, use and safety.	Section 17.3 with respect to the maintenance of the estuary as a public amenity and for public use and safety.
To acknowledge Aboriginal peoples' spiritual, social, customary and economic connection with and use of the Greater Sydney Harbour coastal zone.	Chapter 15 (Aboriginal heritage) discusses the potential impacts of the project on Aboriginal heritage including potential submerged Aboriginal sites.
To recognise the Greater Sydney Harbour coastal environment is a vital economic zone, the maritime gateway to Australia's largest city.	Chapter 21 (Socio-economics) outlines the potential economic impacts of the project.
To facilitate ecologically sustainable development in the Greater Sydney Harbour coastal zone and promote strategic, coordinated and sustainable land use planning decision-making.	Chapter 25 (Sustainability) outlines how the project would meet the principles of ecologically sustainable development.
To mitigate current and future risks from coastal hazards, taking into account the effects of climate change, including impacts from extreme storm events.	Chapter 26 (Climate change and greenhouse gas) outlines how the project would mitigate current and future climate risks.

17.1.3 Design standards, targets and considerations

Construction

Construction erosion and sediment controls would be designed in accordance with:

- *Managing Urban Stormwater: Soils and Construction*, Volume 1, 4th Edition (Landcom, 2004) (known as the Blue Book Volume 1)
- *Managing Urban Stormwater: Soils and Construction*, Volume 2D Main Road Construction (DECC, 2008) (known as the Blue Book Volume 2)
- Guideline for Construction Water Quality Monitoring (RTA, 2003a)
- Road Design Guideline, Section 8 Erosion and Sediment (RTA, 2003b)
- Erosion and Sediment Management Procedure (RTA, 2009)

- Code of Practice for Water Management – Road Development and Management (RTA, 1999)
- QA Specification G38 – Soil and Water Management, Edition 2/Revision 4 (Transport for NSW, 2020f).

The ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines would be used for designing temporary construction wastewater treatment plants and setting their discharge criteria.

Operation

Impervious surfaces and stormwater discharges

New or modified drainage would be provided along the Gore Hill Freeway, and along modified or new surface roads at Balgowlah, North Balgowlah, Killarney Heights, Seaforth and Frenchs Forest. Also, new water quality basins would be provided at Balgowlah Golf Course and along Wakehurst Parkway.

The project would provide water quality treatment that meets the design targets listed in Table 17-4 where feasible and reasonable. These targets are as based on typical requirements for pollutant reduction described in the *Draft Managing Urban Stormwater – Council Handbook* (NSW EPA, 1997). Where the design targets cannot be met due to site constraints, the project would provide water quality treatment to meet or improve existing conditions to ensure that there is no impact on surface water quality as a result of the project.

The design targets listed in Table 17-4 require annual average pollutant reduction as opposed to pollutant reduction levels for a specific rainfall event. Long term impacts are best described by the use of long term rainfall data which has been expressed as average annual pollutant loads.

The type and design of specific stormwater treatment measures would be refined during further design development including confirmation of performance with modelling, if required.

Table 17-4 Operational water quality design targets

Issue	Design target
Total nitrogen	45 per cent annual average pollutant load reduction
Total phosphorus	65 per cent annual average pollutant load reduction
Total suspended solids	85 per cent annual average pollutant load reduction
Grease	No visible grease
Water quality	Neutral or beneficial impacts where percentage design targets cannot be practicably met
Spills	Spill containment of up to 40 cubic metres where possible for environmentally sensitive areas
Existing infrastructure	Minimise impacts to existing water quality infrastructure and performance as a result of the design

It is noted that these targets largely align to the stormwater quality targets established in Sydney Water's *Stormwater quality targets (Version 2)* (Sydney Water, 2020), with the exception of phosphorus, for which the project exceeds the Sydney Water stormwater quality target of a 60 per cent average annual pollutant load reduction. If stormwater discharge from the project is required to connect to Sydney Water's stormwater assets, the project would install and operate water treatment devices during operation to achieve the Sydney Water pollutant load reduction targets where feasible and reasonable.

Wastewater treatment plant discharges

The Gore Hill Freeway wastewater treatment plant would be designed to achieve the following discharge criteria:

- The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000)
- The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) of which public comments are under consideration as of November 2020.

17.2 Assessment methodology

17.2.1 Overview

The methodology for the assessment included:

- A review of the existing environment including water quality data and reporting from previous monitoring activities
- Water quality monitoring and visual condition assessment at selected locations in the study area
- Site classification as sensitive receiving environments, identification of environmental values and assessment of existing geomorphic characteristics
- Hydrodynamic modelling to assess the potential hydrodynamic impacts on Middle Harbour during project construction and operation
- Dredge plume modelling to assess potential water quality impacts as a result of dredging activities during construction of the immersed tube tunnels
- Assessment of potential impacts during construction and operation to water quality with reference to the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines and with regard to the relevant environmental values
- MUSIC (Model for Urban Stormwater Improvement Conceptualisation) modelling to assess the operational impacts against the water quality design targets and standards
- Assessment of changes to the North Sydney Council and Balgowlah Golf Course stormwater harvesting schemes
- Identification of appropriate management measures to mitigate potential hydrology and water quality impacts.

17.2.2 Desktop review

The desktop review involved a review of existing information that was available for the surface water environment upstream and downstream of the construction footprint and marine water quality information for Middle Harbour and Sydney Harbour. The review was carried out to develop an understanding of the existing environment and the potential impacts of the project. The review of information included data collected by Willoughby City Council, North Sydney Council and Northern Beaches Council, as well as the following sources:

- *Sydney Harbour Catchment Coastal Zone Management Plan Scoping Study*. Literature and Data Review – Management and Use of Sydney Harbour (Sydney Coastal Council Group, 2015)

- *Sydney Harbour: A systematic review of the science*, Sydney Institute of Marine Science (Hedge et al., 2013)
- *Flat Rock Creek Catchment Flood Study and Overland Flow Mapping Volume 1. Draft Report for Public Exhibition* (Lyll and Associates, 2017)
- *Water Quality Monitoring Program for Willoughby City Council. Spring 2015-Autumn 2016* (Sydney Water, 2016)
- The National Atlas of Groundwater Dependent Ecosystems to identify the location and groundwater dependence of surface water systems and vegetation (Bureau of Meteorology, 2018)
- *Water Sharing Plan for the Greater Metropolitan Region groundwater sources 2011* (NSW DPI, 2011a)
- Water quality data collected between 2014 and 2016 as part of Transport for NSW's Northern Beaches Hospital road upgrade project (SMEC, 2017)
- *The chemistry of suspended particulate material in a highly contaminated embayment of Port Jackson (Australia) under quiescent, high-wind and heavy-rainfall conditions*. Environmental Geology (Birch & O'Hea, 2007)
- *Parramatta River Estuary Data Compilation and Review Study* (Cardno Lawson Treloar, 2008)
- *Trace metal and total suspended solids concentrations in freshwater: the importance of small-scale temporal variation*. Journal of Environmental Monitoring (Hatje et al., 2001)
- *Dissolved trace metal distributions in Port Jackson estuary (Sydney Harbour), Australia*. Marine Pollution Bulletin (Hatje et al., 2003)
- *Water Quality of the Upper Parramatta River. Analysis of data collected between 1990 and 1996* (Laxton, 1997)
- *Mid Parramatta (North) River Stormwater Management Plan* (Robinson GRC Consulting, 1999)
- *Water Quality Sampling of Parramatta River - Methods & Sampling Protocol*. Sydney Institute of Marine Science (Harrison, 2012)
- *Contaminant dynamics in offchannel embayments of Port Jackson, New South Wales*. AGSO Journal of Australian Geology and Geophysics (Taylor & Birch, 1999)
- The Barangaroo project's monthly water quality reports 2012 to 2017 (Lend Lease, 2017).

17.2.3 Monitoring

Hydrodynamic monitoring of Middle Harbour

Hydrodynamic monitoring was carried out between August and November 2017 to measure variability in hydrodynamic conditions within Middle Harbour due to tidal and non-tidal influences. Specifically:

- An acoustic doppler current profiler type instrument was used at two locations to take continuous measurements of water level, current speed, current direction, and acoustic backscatter. The monitoring sites also measured water quality parameters (primarily turbidity)
- Vessel-based monitoring using a mounted acoustic doppler current profiler was carried out along two transects across Middle Harbour near the proposed location of the immersed tube tunnel crossing during spring tidal conditions to determine the spatial variability in currents and discharge throughout a tidal cycle
- Opportunistic surface sediment samples were collected from the bed of the harbour and analysed for particle size distribution.

Water quality monitoring of Middle Harbour

Water quality monitoring was carried out as part of the marine water quality assessment in two discrete sampling periods:

- Sampling period 1 – an eight week period from 5 December 2017 to 31 January 2018
- Sampling period 2 – a five week period from 17 April 2020 to 1 June 2020.

Sampling period 1 focused on collecting information about the effects of turbidity on underwater light that would assist interpretation of the potential effects of dredging. Data were collected at a high temporal resolution using the following methods:

- Two water quality monitoring moored loggers deployed from 5 December 2017 to 31 January 2018 to monitor turbidity, photosynthetically available radiation, chlorophyll-a, salinity, pressure and temperature in shallow waters near areas of known benthic primary producers, namely seagrass and rocky reef habitats
- Water sampling and water column vertical profiling carried out at eight sites over two days (18 and 31 January 2018) to monitor water quality parameters (turbidity, photosynthetically available radiation, conductivity, temperature, depth, fluorometric chlorophyll-a, pH and dissolved oxygen) through the water column from the bed of the harbour to the surface. Water samples were also collected at a depth of 1.5 metres below the water surface at each site for laboratory testing of total suspended solids (turbidity) and chlorophyll-a concentrations
- The collation of meteorological and oceanographic data to provide information on the weather and ocean conditions that are key drivers of the estuary water quality response.

Sampling period 2 was designed to better understand dissolved oxygen concentration variability within the deep water to assist with understanding the potential impacts of the Middle Harbour crossing, and included the following methods:

- Two water quality moored loggers deployed from 27 April 2020 to 1 June 2020
- Water column profiling carried out on six days in 2020 (17 April, 4, 14, 23 and 27 May and 1 June)
- The collation of meteorological and oceanographic data to provide information on the weather and ocean conditions that are key drivers of tidal flushing and the water quality response.

The locations of monitoring sites for sampling period 1 were informed by preliminary predictions of the dredge plume footprint in Middle Harbour (Royal HaskoningDHV, 2020). Sites for sampling period 2 were spread further apart to better understand upstream and downstream potential variability in tidal flushing.

Table 17-5 details the Middle Harbour water quality monitoring locations for the project, including the two sites monitored as part of the hydrodynamic assessment. These monitoring locations are shown in Figure 17-1.

Table 17-5 Middle Harbour hydrodynamic and water quality monitoring sites

Site Name	Location	Monitoring activity
Sampling period 1		
BL1	Pickering Point, Seaforth	Fixed water quality monitoring mooring and profiling site
BL2	Clive Park, Northbridge	Fixed water quality monitoring mooring and profiling site
BLP1	Yeoland Point, Castle Cove	Water quality profiling site

Site Name	Location	Monitoring activity
BLP2	Peach Tree Bay, Seaforth	Water quality profiling site
BLP3	Seaforth Bluff, Seaforth	Water quality profiling site
BLP4	Hallstrom Point, Northbridge	Water quality profiling site
BLP5	Beauty Point, Mosman	Water quality profiling site
BLP6	The Spit, Mosman	Water quality profiling site
MH1	Seaforth Bluff, Seaforth	Hydrodynamic monitoring location
MH2	Southwest of Spit Bridge	Hydrodynamic monitoring location
Sampling period 2		
BM1/B1	Clontarf Point, Clontarf	Fixed water quality monitoring mooring and profiling site
BM2/B5	Seaforth Bluff, Seaforth	Fixed water quality monitoring mooring and profiling site
B2	The Spit, Mosman	Water quality profiling site
B3	Shell Cove, Clontarf	Water quality profiling site
B4	Seaforth Bluff, Seaforth	Water quality profiling site
B6	Quakers Hat, Mosman	Water quality profiling site
B7	Fig Tree Point, Northbridge	Water quality profiling site
B8	Sailors Bay, Northbridge	Water quality profiling site
B9	Seaforth Bluff, Seaforth	Water quality profiling site
B10	Peach Tree Bay, Seaforth	Water quality profiling site
B11	Pickering Point, Seaforth	Water quality profiling site
B12	Yeoland Point, Castle Cove	Water quality profiling site
B13	Bantry Bluff, Seaforth	Water quality profiling site

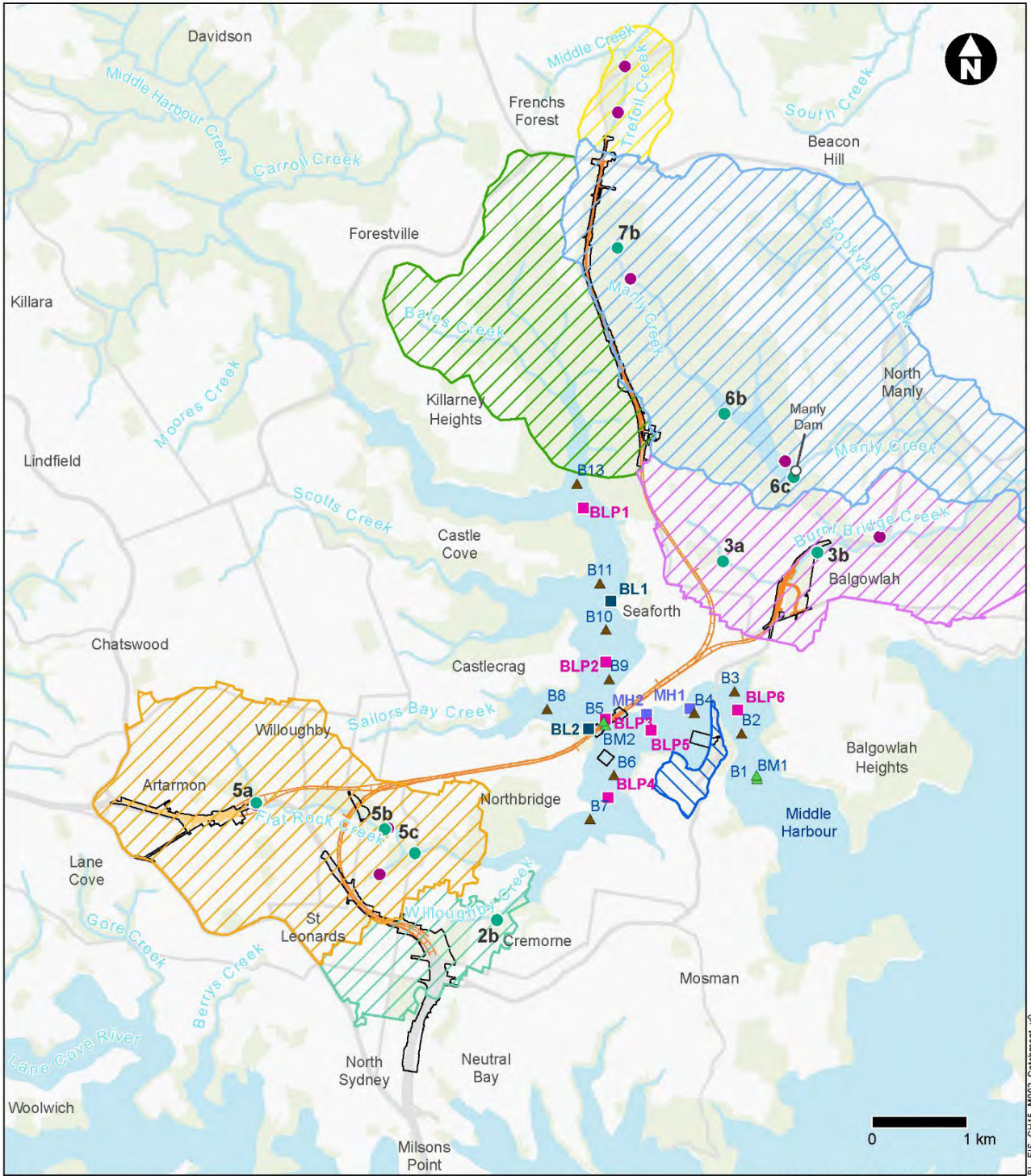
Surface water quality monitoring

Site visits were carried out between October 2017 and February 2018 to monitor surface water quality and visually assess the conditions of waterways relevant to the project.

Nine monitoring locations were selected immediately upstream and downstream of the project alignment, except for sites where access was prevented. It is noted only one wet weather event was captured, with the results representing mainly dry weather events. Dry weather is classified as less than 15 millimetres of rainfall recorded at the Bureau of Meteorology rainfall gauge (Gauge #066011) in the 24 hours prior to sampling, with wet weather classified as 15 millimetres or more of rainfall recorded. Monitoring locations are provided in and Table 17-6 and shown in Figure 17-1.

Table 17-6 Water quality monitoring sites in waterways

Site	Waterway	Location
2b	Willoughby Creek downstream	Primrose Park, Cremorne
3a	Burnt Bridge Creek upstream	Footbridge near Worrobil Street, North Balgowlah
3b	Burnt Bridge Creek downstream	Kitchener Street, Balgowlah
5a	Flat Rock Creek upstream	Grandview Street, Naremburn
5b	Flat Rock Creek downstream (upstream of Quarry Creek inflow)	Flat Rock Reserve, Northbridge
5c	Flat Rock Creek downstream (downstream of Quarry Creek inflow)	Tunks Park, Long Gully bridge, Northbridge
6b	Manly Dam mid (downstream)	Mid dam – Section 4 picnic area, Allambie Heights
6c	Manly Dam downstream	Dam wall, Allambie Heights
7b	Manly Creek downstream	Allambie Heights



Indicative only - subject to design development

Legend		Marine water quality monitoring sites	
Operational features	Catchments and waterways	Fixed and profiling site (2017)	Surface water quality monitoring sites
Beaches Link	Bantry Bay	Hydrodynamic site (2017)	Project monitoring site
Gore Hill Freeway Connection	Burnt Bridge Creek	Profiling site (2017)	Existing monitoring site
Construction features	Flat Rock Creek	Fixed and profiling site (2020)	
Construction footprint	Manly Creek	Profiling site (2020)	
	Pearl Bay		
	Trefoil Creek		
	Willoughby Creek		
	Waterways		

Figure 17-1 Catchments, waterways and hydrodynamic and water quality monitoring locations

17.2.4 Model development

Hydrodynamic model development

A three-dimensional hydrodynamic model of Middle Harbour was developed using MIKE 3 software which simulated currents, water levels and flow characteristics to:

- Provide a realistic representation of the existing marine environment within Middle Harbour near the project, as it relates to hydrodynamic characteristics
- Understand the potential impacts of the construction and operation of an immersed tube tunnel on the hydrodynamic characteristics within Middle Harbour.

Plume model development

Construction of the project would involve dredging of the bed of Middle Harbour to create the trench within which the immersed tube tunnel units would be placed (refer to Chapter 6 (Construction work) for more information relating to dredging).

Numerical modelling was used to determine the likely movement of sediments released into the water column (known as a plume) from dredging. Plume modelling simulates the dispersal of suspended sediment by ambient currents in Middle Harbour, as well as the subsequent deposition of these sediments. The modelling was carried out using the hydrodynamic model of Port Jackson.

The plume modelling was applied to fine sediments only, as these would be the most mobile within the water column. The modelling was based on the sequence of dredging activities (both the dredge plant and sediment types) and the location of sediment types within the dredging footprint, for four sizes of fine sediment (clay, fine silt, medium silt and coarse silt). Plume modelling incorporated the use of the two proposed 12 metre deep draft silt curtains, however, did not consider the proposed floating silt curtain enclosures (sometimes referred to as a 'moon pool') that would be attached to the dredge or the additional shallow draft silt curtains that would be installed along the shorelines at the crossing location to provide protection to nearby ecologically sensitive areas (eg seagrass and rocky reef habitat).

Sydney Harbour Ecological Response Model

The Sydney Harbour Ecological Response Model simulates numerous physical, nutrient, algal and biological processes in response to tidal forcing, river inflows, wind, waves and atmospheric heat fluxes.

The model was not run specifically for this project, however adopted simulation results that were available for a 12 month simulation period from April 2012 to March 2013 have been used to inform the assessment on marine water quality.

Surface water quality modelling

A Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was carried out to assess the operational impact of the project and performance of the proposed water quality management strategy against the water quality design targets and standards. The MUSIC modelling results are presented in Appendix O (Technical working paper: Surface water quality and hydrology) for the main locations where stormwater would be discharged (Gore Hill Freeway Connection, surface connections at the Burnt Bridge Creek Deviation, Balgowlah as well as the surface connection and integration works along the Wakehurst Parkway and the realigned and upgraded Wakehurst Parkway).

17.3 Existing environment

17.3.1 Catchments and waterways

The project is within the broader Sydney Harbour and Parramatta River catchment and the Northern Beaches Lagoons catchment.

The Sydney Harbour and Parramatta River catchment is comprised of three harbours: North Harbour, Middle Harbour and Sydney Harbour (the main branch of the estuary). The Middle Harbour region of Sydney Harbour is the north western branch of the estuary, and is one of the three main tributaries; the other two being Parramatta River (Western Harbour) and Lane Cove River.

The Sydney Harbour and Parramatta River catchment is a highly urbanised catchment (86 per cent) which results in rapid runoff during high rainfall events. The catchment is heavily influenced by human factors which have altered the frequency, volume and seasonality of stream flows.

The Northern Beaches Lagoons catchment consists of Narrabeen Lagoon and catchment, Dee Why Lagoon and catchment, Curl Curl and Manly lagoons and their catchments and Manly Dam (within the Manly Lagoon catchment). Relevant sub-catchments to the project include Narrabeen Lagoon, Manly Lagoon and Manly Dam. Narrabeen Lagoon is the largest of the coastal lagoons within the Northern Beaches local government area and an important environmental and recreational area (SMEC, 2011). Manly Lagoon is a small shallow coastal lagoon in the Northern Beaches local government area and is considered of poor water quality due to local pollution sources including urban stormwater runoff, sewage overflows, former landfill leachate and illegal discharge and dumping of industrial and trade waste (Cardno, 2010).

The project and surroundings are dominated by residential areas (ranging from low to high density), with some industrial and commercial developments in Artarmon, St Leonards and Willoughby. At the northern end of the project, the Garigal National Park and Manly Dam War Memorial Park are located to the west and east of Wakehurst Parkway respectively. The main bodies of water surrounding the project area are Middle Harbour and Manly Dam. The main waterways in proximity to the project include Willoughby Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and Trefoil Creek. Burnt Bridge Creek is a first order stream that discharges to Manly Lagoon via Manly Creek. Trefoil Creek is also a first order stream that feeds into Middle Creek which discharges to Narrabeen Lagoon. Manly Creek feeds into Manly Dam. Willoughby Creek and Flat Rock Creek are first order streams that discharge directly into Middle Harbour.



The waterways and associated catchments within the study area are shown in Figure 17-1. Table 17-7 outlines the catchments that form part of the Sydney Harbour and Parramatta River and Northern Beaches Lagoons catchments as relevant to the project and provides a description of the key waterways relevant to the project.



Some areas of the project would be located on catchments dominated by drainage lines, rather than watercourses and would include:

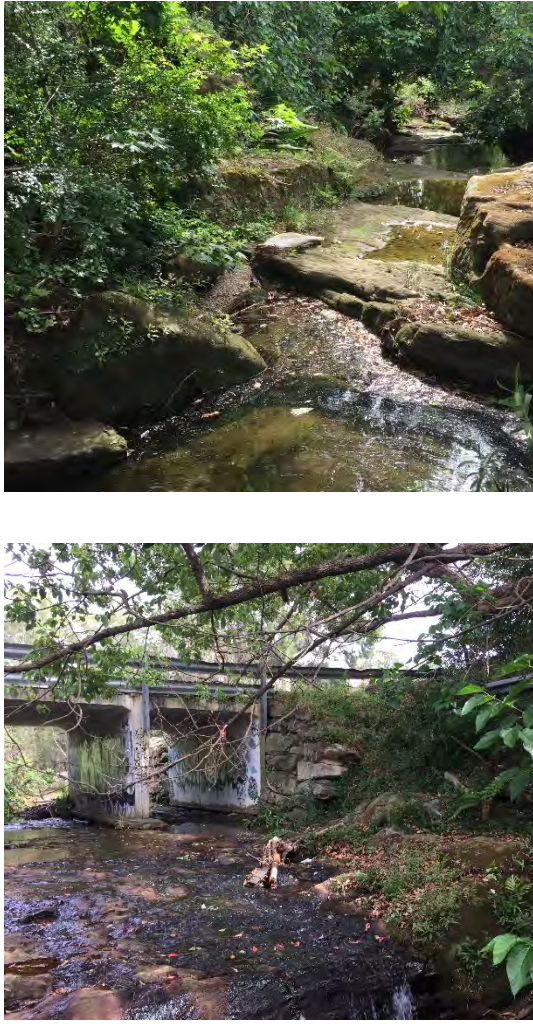
- Spit West Reserve construction support site (BL9) has drainage lines which drain towards Middle Harbour
- Wakehurst Parkway south (BL12) and Wakehurst Parkway east (BL13) construction support sites drain towards Burnt Bridge Creek and Manly Dam, respectively
- The eastern edge of the connections to and from the Wakehurst Parkway has drainage lines which drain towards Burnt Bridge Creek and Manly Dam
- The western edge of the connections to and from the Wakehurst Parkway has drainage lines which traverse Garigal National Park and drain into Bantry Bay.


Table 17-7 Description of key waterways and catchments relevant to the project



Waterway/catchment	Description	Relevant project features
<p>Middle Harbour (Sydney Harbour and Parramatta River catchment)</p>	<ul style="list-style-type: none"> • The Middle Harbour region of Sydney Harbour is the north western branch of the estuary, and is one of the three main tributaries; the other two being Parramatta River and Lane Cove River • It drains a large catchment of about 7700 hectares of a wide variety of land-uses • The main channel of Middle Harbour features a relatively shallow, constricted, sharp bend between The Spit and Seaforth, which controls the volume of tidal waters that propagate upstream beyond The Spit • The channel is surrounded by a number of bays (including Quakers Hat Bay to the south, Sailors Bay to the west and Fig Tree Cove to the north) which act as reservoirs for the tidal waters • The immersed tube tunnel crossing of Middle Harbour would be located in a low energy hydrodynamic environment with relatively low current speeds and little to no expected transport of sediment from the bed of the harbour • The surface currents in the vicinity of the Spit West Reserve construction support site (BL9) are relatively slow, with the exception of the shoreline area associated with a return eddy that forms in Pearl Bay during the flood tide. During both the flood and the ebb current speeds reduce slightly with depth • The immersed tube tunnel crossing of Middle Harbour would be located in a low energy or mild wave environment. Waves are mainly derived from local winds and vessels (generally recreation craft) • Fresh and saline waters are typically well mixed due to low fresh water discharges and turbulent tidal mixing. 	<ul style="list-style-type: none"> • Gore Hill Freeway Connection western edge drains into Bantry Bay • Crossing of Middle Harbour • Middle Harbour south cofferdam (BL7) • Middle Harbour north cofferdam (BL8) • Spit West Reserve construction support site (BL9) • Upgrade and integration works along the Wakehurst Parkway western edge drains into Bantry Bay.

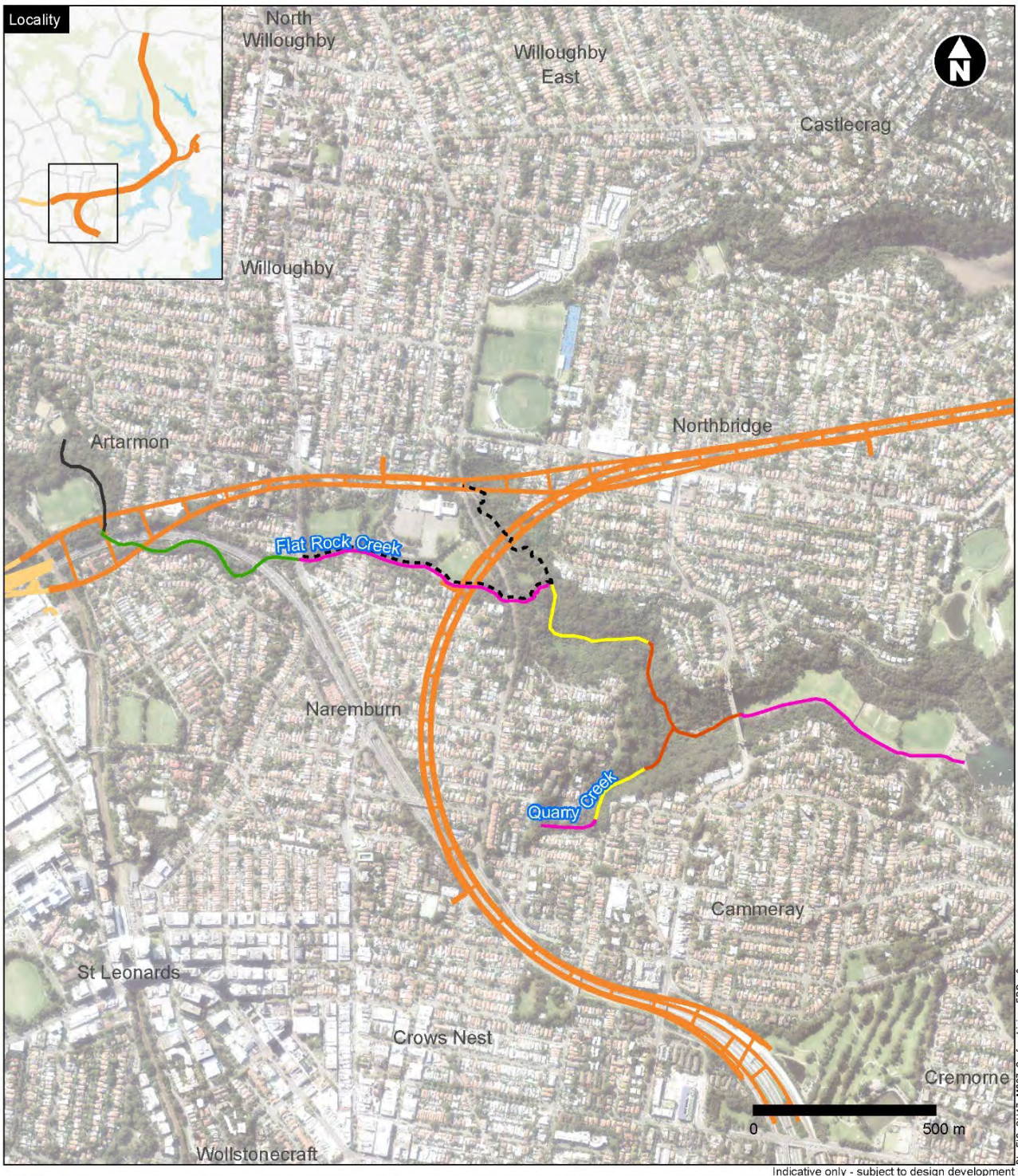
Waterway/catchment	Description	Relevant project features
<p>Willoughby Creek (Willoughby Creek catchment)</p> 	<ul style="list-style-type: none"> • Willoughby Creek is a small modified concrete and rock channel which drains a catchment of around 150 hectares that includes the suburbs of Neutral Bay and Cammeray directly into Willoughby Bay at Cremorne • The development of impervious surfaces within the catchment has increased the volume and rate of runoff, which has in turn necessitated flood mitigation measures • Willoughby Bay and Long Bay are popular boating and swimming areas for local residents. 	<ul style="list-style-type: none"> • Southern portion of Beaches Link. • Cammeray Golf Course construction support site (BL1).
<p>Quarry Creek (part of Flat Rock Creek catchment)</p> 	<ul style="list-style-type: none"> • Quarry Creek is a small natural estuarine tributary of Flat Rock Creek which drains Cammeray • The creek has steep embankments on both sides now densely vegetated by weeds and has limited accessibility. 	<ul style="list-style-type: none"> • Southern portion of Beaches Link.

Waterway/catchment	Description	Relevant project features
<p>Flat Rock Creek (Flat Rock Creek catchment)</p>  	<ul style="list-style-type: none"> • Flat Rock Creek is predominantly a concrete lined (open drain and closed box culvert) stormwater channel which drains a catchment of around 390 hectares that include Artarmon, Willoughby and Naremburn. • The upper reaches of Flat Rock Creek in Artarmon consist of a covered concrete lined drain and vegetated floodway associated with the Artarmon Reserve detention basin. The creek is a concrete lined channel as it crosses the Gore Hill Freeway for the first time and continues in an open lined channel as it meanders east and crosses back under the Gore Hill Freeway. • As the creek continues east, it enters a concrete box culvert near Willoughby Road and flows underground until it reaches a point in Flat Rock Reserve around 150 metres east of Flat Rock Drive where the box culvert outlets into a human made (naturalised) excavated bedrock channel followed by a natural bedrock stream until it enters Tunks Park, where it again flows through an underground box culvert. The various surface water linings of Flat Rock Creek are shown in Figure 17-2 • The natural drainage characteristics of Flat Rock Creek have been altered by residential, commercial and industrial development • At its downstream reach the creek drains a relatively steep catchment characterised by rocky riffle and runs. The downstream reaches are surrounded by native Coachwood forests with popular walking tracks and give access to large sporting fields at Tunks Park, Cammeray • The end point of the creek is a tidally influenced naturalised estuary at the base of Flat Rock Gully discharging into Long Bay. 	<ul style="list-style-type: none"> • Beaches Link and Gore Hill Freeway Connection • Flat Rock Drive construction support site (BL2) • Punch Street construction support site (BL3) • Dickson Avenue construction support site (BL4) • Barton Road construction support site (BL5) • Gore Hill Freeway median construction support site (BL6).

Waterway/catchment	Description	Relevant project features
<p>Burnt Bridge Creek (Burnt Bridge Creek catchment)</p> 	<ul style="list-style-type: none"> • Burnt Bridge Creek is an urban intermittent waterway which flows through Seaforth, North Balgowlah, Balgowlah and Manly Vale into Manly Lagoon. It is a freshwater first order stream receiving multiple inflows of stormwater. The various surface water linings of Burnt Bridge Creek are shown in Figure 17-3 • It drains a catchment of about 380 hectares of a wide variety of land-uses including residential areas, the Balgowlah Industrial Estate, golf courses and roads • The creek is naturalised upstream with rock, sand and mud substrate with narrow vegetated buffer zones. Downstream it is a combination of concrete and rock fill construction, which is present at the Kitchener Road crossing in Balgowlah • The creek has been heavily modified due to urban pressure (ie sewage and sewer outfalls) resulting in poor water quality, extensive weed infestation, erosion of creek banks, build-up of sediment and reduced biodiversity • The Balgowlah Golf Course Stormwater Harvesting Dam was installed in 2013 and has allowed the golf course to extract water from the dam rather than Burnt Bridge Creek allowing creek water to remain as environmental flows which has improved the ecological conditions in the creek (Manly Council, 2014) • Surface runoff discharging into Burnt Bridge Creek between Sydney Road and north of Kitchener Street currently does not receive any water quality treatment • The section of creek through the Balgowlah Golf Course has been modified and realigned in the past and is known to experience hazardous flooding. 	<ul style="list-style-type: none"> • Northern portion of Beaches Link (Balgowlah) • Balgowlah Golf Course construction support site (BL10) • Kitchener Street construction support site (BL11).

Waterway/catchment	Description	Relevant project features
<p>Manly Dam (Manly Creek catchment)</p> 	<ul style="list-style-type: none"> <li>• Manly Dam drains a catchment of 510 hectares of predominantly open space (bushland), and some commercial, industrial and residential areas <li>• The catchment is characterised by sandstone slopes, rock platforms and gullies, as well as some shale areas. Over half of the catchment has gradients steeper than 10 degrees and soils have very high to severe erosion potential <li>• The steep terrain and urban interface pose challenges to water quality, including occurrence of blue-green algal blooms due to external nutrient loading <li>• One of the largest freshwater lakes in Sydney which provides a valued facility for swimming, fishing, water-skiing, canoe/kayaking and boating <li>• The dam is no longer used as a source of drinking water by Sydney Water <li>• Immediately downstream of the dam, the creek is polluted and heavily infested with weeds. 	<ul style="list-style-type: none"> <li>• Northern portion of Beaches Link (upgrade and integration works along the Wakehurst Parkway) <li>• Wakehurst Parkway south construction support site (BL12) <li>• Wakehurst Parkway east construction support site (BL13).

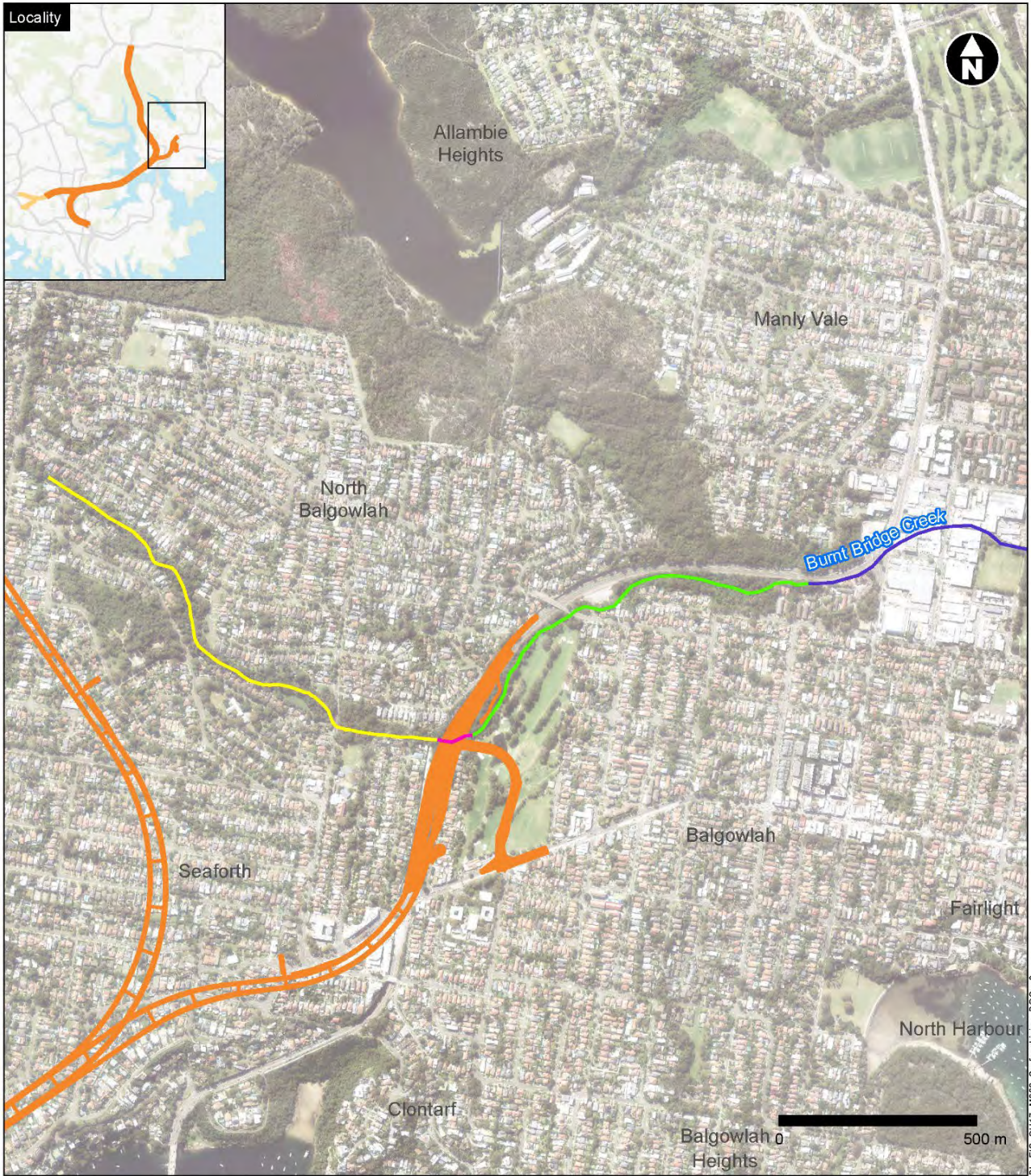
Waterway/catchment	Description	Relevant project features
<p>Manly Creek (Manly Creek catchment)</p> 	<ul style="list-style-type: none"> • Manly Creek drains a catchment in the urban areas of French Forest and flows into Manly Dam via War Memorial Park • The creek channel is formed of bedrock shelves, boulder and cobble runs and riffles, and pools that hold some sediment. Its banks are generally low and stable • During storm events, the creek is likely to experience high velocity flows. Riparian vegetation creates greater bank stability; however, natural scouring is likely to occur during high rainfall events. 	<ul style="list-style-type: none"> • Northern portion of Beaches Link (upgrade and integration works along the Wakehurst Parkway).
<p>Trefoil Creek (Trefoil Creek catchment)</p> 	<ul style="list-style-type: none"> • Narrow natural waterway, engorged through a gully located near the corner of Frenchs Forest Road and Wakehurst Parkway • Drains through the suburbs of Frenchs Forest and Oxford Falls and underneath Wakehurst Parkway into Middle Creek (which flows to Narrabeen Lagoon) • The area consists of low density housing and substantial bushland, which is susceptible to flooding and road closures • The creek line is characterised by dense native and exotic vegetation, sediment substrate and rocky outcrops. 	<ul style="list-style-type: none"> • Northern portion of Beaches Link (Frenchs Forest) • Wakehurst Parkway north construction support site (BL14).



Indicative only - subject to design development

- Legend**
- Beaches Link
 - Gore Hill Freeway Connection
 - Surface water lining
 - Above and below ground concrete lined storm water channel
 - Alluvium
 - Constructed surface creek
 - Naturalised bedrock
 - Underground box culvert
 - Covered concrete lined drain and vegetated floodway associated with Artarmon Reserve detention basin

Figure 17-2 Surface water lining of Flat Rock Creek



Indicative only - subject to design development

Legend







- | | |
|--|--|
|  Beaches Link |  Above ground concrete lined storm water channel |
|  Gore Hill Freeway Connection |  Modified creek/bedrock and above ground concrete lined storm water channel |
| |  Naturalised bedrock |
| |  Underground box culvert |

Figure 17-3 Surface water lining of Burnt Bridge Creek

17.3.2 Hydrodynamic features

Bathymetry

The bed of Middle Harbour is made up of many deep holes, basins, shoals and reefs. At the proposed location of the immersed tube tunnel crossing of Middle Harbour, there is a deep 'U' shaped channel reaching a depth of 32 metres. Other key bathymetry features near the crossing of Middle Harbour include:

- The main channel of Middle Harbour, between The Spit and Seaforth is relatively shallow in comparison to the main reaches of Middle Harbour directly downstream. The Spit along with Spit Bridge and its associated piers act as a constriction to tidal flows
- There is a near 180 degree bend in the main channel as it passes between The Spit and Seaforth. This acts to control the volume of tidal waters that propagate upstream beyond The Spit
- Bays near the proposed immersed tube tunnels act as large reservoirs for tidal waters including Quakers Hat Bay, Sailors Bay and Fig Tree Cove.

Tides and currents

Port Jackson is a semi-diurnal estuary meaning that it has two high tides and two low tides per day. It has a small tidal range (less than two metres) and the ebb (outgoing), and flood (incoming) tidal discharges are the dominant cause of water movement.

Current patterns in Middle Harbour are influenced by the complex shape of the harbour, the relatively deep U-shaped channel, and the constriction at The Spit. Tidal current speeds at the proposed Middle Harbour crossing location are substantially lower than those at Spit Bridge due to increased depth. The Spit experiences faster peak flood currents than ebb currents. Spatial measurements and monitoring show little change in current speed with changes in depth.

A summary of the current speeds observed as part of the hydrodynamic monitoring is shown in Table 17-8.

Table 17-8 Current speeds near the Middle Harbour crossing

Monitoring location	Parameter	Maximum	95 th percentile	Average
Southwest of Spit Bridge (MH9)	Flood current speed (m/s)	0.72	0.42	0.17
	Ebb current speed (m/s)	0.37	0.21	0.09
Seaforth Bluff, Seaforth (MH8)	Flood current speed (m/s)	0.15	0.07	0.03
	Ebb current speed (m/s)	0.21	0.08	0.04

Wind

The wind statistics from the Bureau of Meteorology's weather station at Fort Denison (1990 to 2017) were considered to be the most representative of overwater wind conditions at the proposed immersed tube tunnel crossing of Middle Harbour and indicate that:

- Easterly winds are the prominent wind direction in the spring/summer months, with westerly winds dominating during autumn/winter months
- Wind speeds during the year range from 4.2 to 4.7 metres per second (50th percentile) to 6.7 to 8.3 metres per second (90th percentile)
- Wind speeds are slightly higher during spring/summer compared to autumn/winter.

Waves

Ocean swells that enter Middle Harbour are deflected by the complex bathymetry and shoreline formation such that most of Middle Harbour is affected only by locally derived wind and vessel generated waves. Most vessels in Middle Harbour are relatively small recreational craft, resulting in limited vessel wakes. The wave climate near the proposed immersed tube tunnel crossing of Middle Harbour is a low energy wave climate with wave heights typically less than 0.3 metres and wave periods of less than four seconds.

The bathymetry near the proposed immersed tube tunnel crossing of Middle Harbour is relatively deep, meaning that the potential effect of waves (either wind waves or vessel wakes) on hydrodynamic or sediment plumes at the bed of the harbour is minimal.

Rainfall and freshwater runoff into Middle Harbour

Rainfall in Sydney varies substantially both year-to-year and month-to-month. Much of the variability in precipitation is due to large-scale climate variations, with El Niño Southern Oscillation being the most important. Weather data recorded at Observatory Hill; Sydney indicates that average annual rainfall is 1215 millimetres. Average monthly rainfall between the years 1859 and 2017 ranged from a minimum of 67.9 millimetres in September to a maximum of 133.2 millimetres in June.

Middle Harbour has a catchment area of around 7700 hectares. While there are no major rivers flowing into Middle Harbour there are many small creeks including Middle Harbour Creek, Rocky Creek, Carroll Creek, Gordon Creek, Moores Creek, Bates Creek, Scotts Creek, Willoughby Creek and Flat Rock Creek.

Suspended sediments

Turbidity is typically used as an indicator of suspended sediment concentrations. A review of historical data for turbidity of the waters in Port Jackson identifies a noticeable gradient from high turbidity in the shallower upper reaches of the Parramatta River and longer bays, to low turbidity in the lower reaches of the harbour where tidally driven ocean exchange influences water quality.

As there is limited existing turbidity data for Middle Harbour, a summary of measured turbidity for the waters around Balls Head (about six kilometres south west of the Middle Harbour crossing) is provided in Table 17-9 to provide a reference for expected turbidity levels in Middle Harbour during dry and wet weather events.

Table 17-9 Ambient measured turbidity near Balls Head

Weather	Ambient turbidity (Nephelometric Turbidity Units (NTU))
Dry weather	less than 1 to 4 NTU
Wet weather	4 to 20 NTU – short-lived events, less than two days with higher values on ebb tide

Project specific turbidity data recorded during monitoring for the project near the Middle Harbour crossing identified similar low ambient turbidity levels (less than 5 NTU) (Table 17-10).

Table 17-10 Instantaneous turbidity statistics (in NTU) at Middle Harbour site BL2

Statistical parameter	Ambient total suspended solids (NTU)
95 th percentile	1.0
90 th percentile	0.9
50 th percentile (median)	0.5
10 th percentile	0.3
5 th percentile	0.3

An example of the high turbidity which occurs within Middle Harbour following heavy rainfall is shown in Figure 17-4 (near Clive Park, near the Middle Harbour crossing in Northbridge) for an event in February 2020.

17.3.3 Marine water quality

A review of historical marine water quality data and project specific monitoring of Middle Harbour indicates that:

- The complex interactions between rainfall/runoff, mixing within the broader Sydney Harbour and Parramatta River regional catchment and exchange with ocean waters, leads to seasonal variations in temperature and salinity that in turn influence the mixing of the Middle Harbour deep waters
- Total suspended solids concentrations are generally low (below one milligram per litre) during extended dry periods with peaks up to 30 milligrams per litre after heavy rainfall events (refer to Figure 17-4). During the wetter months, total suspended solids concentrations are elevated at around three to five milligrams per litre
- Low dissolved oxygen levels can occur at the bed of the harbour, however vertical mixing maintains high dissolved oxygen content of the overall water column
- Good light penetration occurs through the water column. The euphotic depth, where light decreases to one per cent of its surface value, is typically greater than 15 metres depth.

17.3.4 Existing road surface water quality infrastructure

Existing infrastructure related to road surface water quality control relevant to the project includes:

- Drainage from the existing Warringah Freeway road surface and nearby road networks in North Sydney and Willoughby local government areas discharges to local stormwater drainage systems, and ultimately to Sydney Harbour or Middle Harbour. The Warringah Freeway does not have any specific spill risk management devices
- Drainage from the Gore Hill Freeway discharges to existing water quality basins located at Punch Street and Artarmon Oval. Basin discharges then travel in local drainage systems into Flat Rock Creek which ultimately discharges into Middle Harbour
- Water quality treatment is not provided at Burnt Bridge Creek Deviation between Sydney Road and north of Kitchener Street however the weir located within the golf course provides some water quality treatment by default, capturing some coarse sediment. Stormwater runoff is collected through a pit and pipe network that discharges into Burnt Bridge Creek via several cross drainage pipes without treatment
- Water quality treatment is not provided along Wakehurst Parkway aside from the operational water quality infrastructure that was recently constructed as part of the Northern Beaches Hospital road upgrade project. Road runoff is collected through natural drainage lines before reaching the receiving waterways. Flows travelling to the west reach Middle Harbour while flows travelling to the east reach Manly Dam.

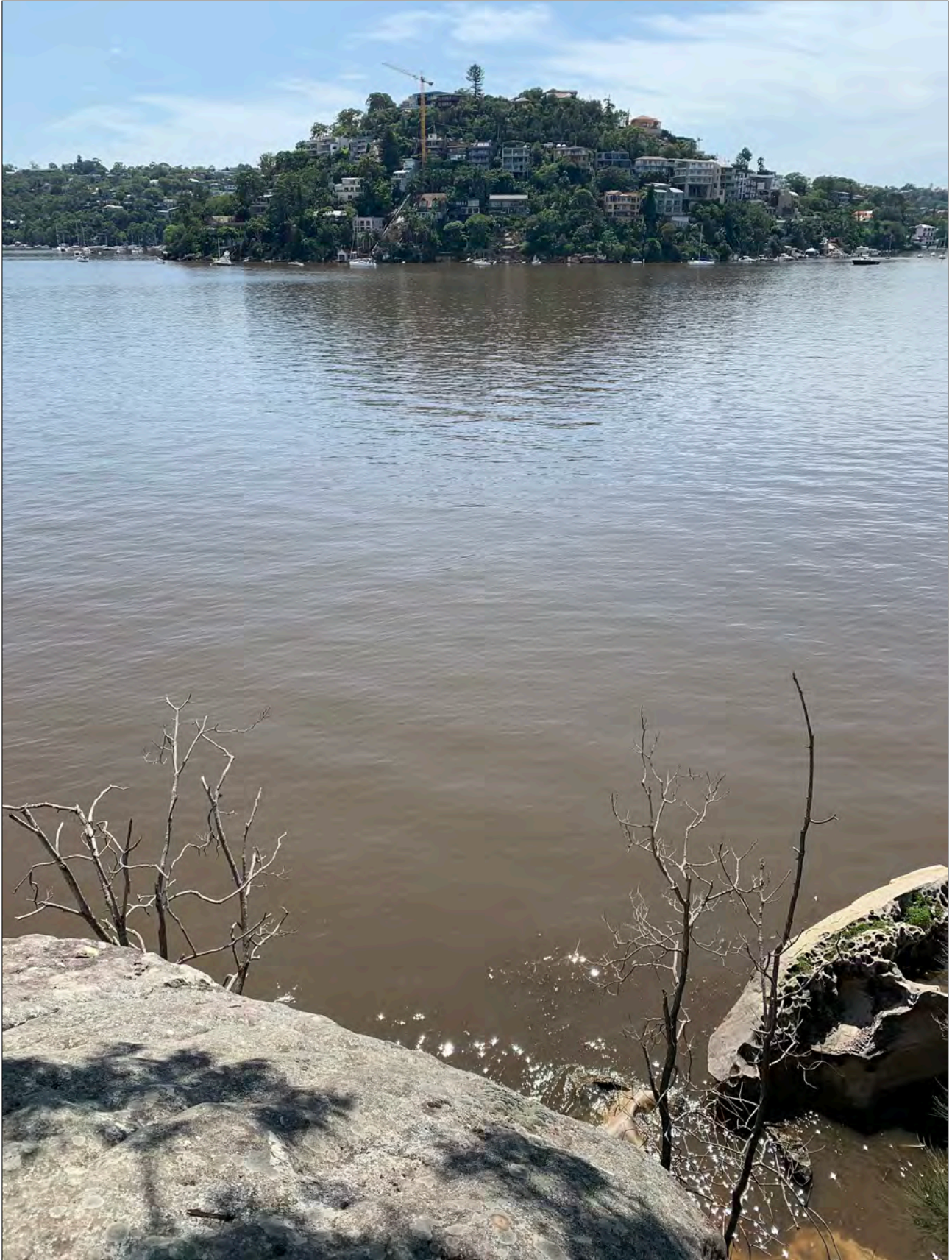


Figure 17-4 Evidence of increased turbidity at Clive Park (looking north) after heavy rain in February 2020

17.3.5 Surface water quality

The water quality of waterways relevant to the project is influenced by several factors including:

- Current and former polluting land uses within the catchments
- Stormwater and sewage overflows and leachate from contaminated and/or reclaimed land
- Urbanisation of the catchments and subsequent reduction in permeable area, increasing run-off and pollutant loads entering waterways

A review of the existing water quality data and site-specific water quality monitoring indicates that the waterways in the study area are in very poor condition and are representative of a heavily urbanised system. The water quality at each assessed waterway is summarised in Table 17-11.

Table 17-11 Existing water quality conditions in the project area

Waterway	Commentary on ANZG (2018) and ANZECC/ARMCANZ (2000) indicators	Monitoring sites/source data
Willoughby Creek	<ul style="list-style-type: none"> • High levels of heavy metals • High nutrient concentrations • Low dissolved oxygen levels. 	<ul style="list-style-type: none"> • Site 2b
Quarry Creek	<ul style="list-style-type: none"> • High levels of heavy metals • High nutrient concentrations • High pH (ie alkaline conditions) • High dissolved oxygen levels • Very high faecal coliform counts indicating microbial contamination. 	<ul style="list-style-type: none"> • North Sydney Council
Flat Rock Creek	<ul style="list-style-type: none"> • High concentrations of heavy metals • Very high nutrient concentrations, indicating eutrophic conditions • Microbiological contamination • High pH (ie alkaline conditions) in some areas • Varied dissolved oxygen levels. 	<ul style="list-style-type: none"> • Sites 5a, 5b, 5c • Willoughby City Council
Burnt Bridge Creek	<ul style="list-style-type: none"> • High levels of heavy metals • High nutrient concentrations • Low dissolved oxygen levels • Low chlorophyll-a levels. 	<ul style="list-style-type: none"> • Sites 3a, 3b • Northern Beaches Council
Manly Dam	<ul style="list-style-type: none"> • Dissolved oxygen levels just below the recommended limit • High concentrations of total nitrogen and oxidised nitrogen • Total phosphorus levels were compliant 	<ul style="list-style-type: none"> • Sites 6b, 6c • Northern Beaches Council

Waterway	Commentary on ANZG (2018) and ANZECC/ARMCANZ (2000) indicators	Monitoring sites/source data
	<ul style="list-style-type: none"> • Low concentrations of heavy metals. 	
Manly Creek	<ul style="list-style-type: none"> • Low dissolved oxygen levels • High levels of heavy metals • Varied nutrient levels • Low chlorophyll-a levels. 	<ul style="list-style-type: none"> • Site 7b • Northern Beaches Council
Trefoil Creek	<ul style="list-style-type: none"> • High concentrations of heavy metals • High nutrient concentrations (total nitrogen). 	<ul style="list-style-type: none"> • Northern Beaches Hospital road upgrade project • Northern Beaches Council

17.3.6 North Sydney Council stormwater harvesting scheme

North Sydney Council has established an extensive stormwater harvesting scheme, which includes a storage dam at Cammeray Golf Course of about 45 metres by 35 metres in size. The dam receives stormwater harvested from the surrounding catchments that is then used to irrigate a number of community parks and the golf course itself. Harvested water is also piped through the existing stormwater system back to St Leonards Park, which is used to irrigate the public parklands and North Sydney Oval. The dam also serves as a sediment settlement pond which improves the quality of water re-entering the catchment and harbour. The dam has become habitat for wildlife such as ducks and saves about 30 million litres of clean water each year. The dam would be directly impacted by the proposed Western Harbour Tunnel and Warringah Freeway Upgrade project prior to the Beaches Link project using the Cammeray Golf Course construction support site (BL1).

17.3.7 Balgowlah Golf Course stormwater harvesting dam

The construction of the Balgowlah Golf Course stormwater harvesting project was completed in 2013. The stormwater harvesting project involved construction of a four megalitre pond/dam with a maximum nominal water depth of 2.5 metres and installation of a gross pollutant trap in Balgowlah Oval upstream of Balgowlah Golf Course. Dam storage of four megalitres allows for around 60 million litres per year of captured stormwater to be used for irrigation. The dam and the underground gross pollution trap treat 100 per cent of the stormwater flowing through the golf course. A key outcome of the Balgowlah Golf Course stormwater harvesting project is the golf course no longer extracts water from Burnt Bridge Creek for irrigation. As such, creek water remains as environmental flows, which re-creates the natural creek conditions.

17.3.8 Sensitive receiving environments

A sensitive receiving environment is an environment that has high conservation or community value, or that supports ecosystem or human uses of water and is particularly sensitive to pollution or degradation of water quality.

The classification of the waterways within the study area regarding their status as sensitive receiving environments is shown in Table 17-12.

Table 17-12 Sensitive receiving environments

Waterway	Sensitive receiving environment	Reason for classification
Middle Harbour	Yes	<ul style="list-style-type: none"> • Considered a Type 1 Key Fish Habitat (due to known presence of several species of seagrass) • Potential habitat for vulnerable species such as the Black Rockcod which is listed under the <i>Fisheries Management Act 1994</i> and <i>Environment Protection and Biodiversity Conservation Act 1999</i> • Includes endangered populations of the seagrass <i>Posidonia Australis</i> which is listed under the <i>Fisheries Management Act 1994</i> • Is a primary contact recreation area.
Willoughby Creek	No	<ul style="list-style-type: none"> • Considered a Type 3 minimally sensitive Key Fish Habitat • Is a highly urbanised stormwater channel containing limited natural features.
Quarry Creek	Yes	<ul style="list-style-type: none"> • Downstream Flat Rock Creek characterised as Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge.
Flat Rock Creek	Yes	<ul style="list-style-type: none"> • Downstream Flat Rock Creek characterised as Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge • Is a secondary contact recreation area.
Burnt Bridge Creek	No	<ul style="list-style-type: none"> • Considered a Type 2 moderately sensitive Key Fish Habitat (NSW DPI, 2013) due to limited aquatic habitat and urbanisation of the channel.
Manly Dam	Yes	<ul style="list-style-type: none"> • Considered a Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge • Located within 100 metres of the Coastal Sandstone Gully Forest groundwater dependent ecosystem • Located near patches of endangered ecological community Coastal Upland Swamp in the Sydney Basin Bioregion, as listed under the <i>Biodiversity Conservation Act 2016</i> • Is a primary contact recreation area.
Manly Creek	Yes	<ul style="list-style-type: none"> • Considered a Type 1 highly sensitive Key Fish Habitat (NSW DPI, 2013) due to potential fish refuge • Located within 100 metres of the Coastal Sandstone Gully Forest groundwater dependent ecosystem • Located near patches of endangered ecological community Coastal Upland Swamp in the Sydney Basin Bioregion, as listed under the <i>Biodiversity Conservation Act 2016</i> • Is a secondary Contact Recreation area.
Trefoil Creek	Yes	<ul style="list-style-type: none"> • Potential habitat for the Red-Crowned Toadlet which is listed as Vulnerable under the <i>Biodiversity Conservation Act 2016</i> • Is a secondary contact recreation area.

17.3.9 Environmental values

The Department of Planning, Industry and Environment (Environment, Energy and Science) identifies a number of environmental values for the Sydney Harbour and Parramatta River catchment (which includes Middle Harbour) and Northern Beaches Lagoons catchment including relevant indicators and guideline levels. Environmental values relevant to the regional catchment are:

- Aquatic ecosystems – which signal physical and chemical water quality stressors that cause degradation of aquatic ecosystems. For the purpose of this assessment, indicators include nutrient levels, dissolved oxygen, pH, metals, salinity and turbidity
- Visual amenity – the aesthetic appearance of a waterbody. For the purpose of this assessment, indicators include transparency, odour and colour
- Primary and secondary contact recreation – where primary contact recreation implies direct contact with the water via bodily immersion or submersion with a high potential for ingestion (eg swimming, diving and water skiing), and secondary contact recreation implies some direct contact with the water would be made but ingestion is unlikely (eg boating, fishing and wading). Bacteriological indicators are used to assess the suitability of water for recreation
- Aquatic foods (cooked) – which refers to protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities. This objective applies to all waters where aquatic foods are taken for non-commercial and commercial harvesting. For this assessment this includes turbidity, metals and organochlorines.

These environmental values have been assigned to each waterway within the study area as shown in Table 17-13. Aquatic ecosystems and visual amenity apply to all waterways within the study area.

Table 17-13 Assigned environmental values

Waterway	Environmental value				
	Aquatic ecosystems	Visual amenity	Primary contact recreation	Secondary contact recreation	Aquatic foods (cooked)
Middle Harbour	✓	✓	✓	✓	
Willoughby Creek	✓	✓		✓	
Burnt Bridge Creek	✓	✓			
Flat Rock Creek	✓	✓		✓	
Manly Dam	✓	✓	✓	✓	✓
Manly Creek	✓	✓		✓	✓
Trefoil Creek	✓	✓		✓	✓

17.4 Assessment of potential construction impacts

17.4.1 Hydrodynamic features of Middle Harbour

Construction of the immersed tube tunnel has the potential to affect tidal and current flows within Middle Harbour due to:

- The establishment of Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)
- The establishment of deep draft silt curtains at either side of the proposed immersed tube tunnel crossing location where most of the dredging works would occur
- The establishment of the Spit West Reserve construction support site (BL9).

Each cofferdam would be constructed using steel tubular piles, which would act as a temporary but complete barrier to the flow of water.

The modelling of hydrodynamic impacts has identified that during the ebb (outgoing) tide, the Middle Harbour north cofferdam (BL8) would cause a reduction in current speeds around Seaforth Bluff at all water depths. There would be an increase in current speeds in the middle of the channel and at the bed of the harbour (ie beneath the silt curtain). Current speeds would also increase at the upper layers of the water column between the bank near Clive Park and the Middle Harbour south cofferdam (BL7).

During the flood tide (recharging of the estuary), there would be a decrease in current speed at both cofferdams as well as within and surrounding the silt curtains. There would also be a decrease in current speed along Seaforth Bluff upstream of the Middle Harbour north cofferdam (BL8). An increase in current speed along the bank upstream of the Middle Harbour south cofferdam (BL7) would occur.

A general reduction in current speeds adjacent to the shoreline is predicted near the Spit West Reserve construction support site (BL9), in particular during the flood tide. The reduced current speeds result from the temporary structures impeding the eddy that forms in this area. The eddy would be redirected, particularly in the surface layers, towards the west resulting in a small area of current speed increase to the west of the immersed tube tunnel unit casting facility.

Due to the existing low energy hydrodynamic environment, the changes in current speeds observed during ebb and flood tides are not expected to have a substantial impact on the surrounding environment.

During both ebb and flood tide, the current reductions would be more pronounced in the surface layer due to the effect of the silt curtains on the upper water column. As these changes are more pronounced in the surface layer it is not expected that any major erosion or accretion of the bed of the harbour would occur in this area. The localised increases in current speeds near the bed of the harbour are not expected to result in a substantial change to the sediment dynamics in this area.

17.4.2 Marine water quality

Construction of the immersed tube tunnels would require dredging of the bed of Middle Harbour, which would result in sediments being released into the water column. Other construction activities within and adjacent to the harbour would also have the potential to impact marine water quality including:

- Dredging, excavating and piling activities associated with the establishment of the Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and immersed tube tunnel support piles, as well as adjacent land based activities at the Spit West Reserve construction support site (BL9) have the potential to reduce water quality and disturb contaminated sediments

- Construction vessel movements have the potential to generate localised plumes of suspended sediments associated with vessel wash in shallower waters, generally less than five to ten metres water depth
- Maintenance or refuelling of construction plant and equipment resulting in spills or leaks of fuels and chemicals that could be discharged directly or indirectly to the marine environment
- Transport of dredged and excavated material that is unsuitable for offshore disposal to a suitable shore-based load out facility prior to disposal at a licensed land-based facility. This would be at a shore-based location outside Middle Harbour
- Land based activities involving the exposure or handling of soils may result in possible soil erosion and off-site transport of sediment via air or runoff to receiving marine waterways.

Potential marine water quality impacts from these activities would include:

- Increases in turbidity resulting in a visible plume and reducing light penetration into the water column
- Increases in turbidity resulting in lowered dissolved oxygen levels and increased nutrients
- Transfer of sediment deposits onto the bed of the harbour
- Mobilisation of contaminants associated with the transportation and dispersion of disturbed sediments
- Direct impacts from discharges, runoff, spills and leaks.

These are discussed in more detail below.

Increases in turbidity

Water quality impacts as a result of the dispersion of sediments released during dredging was assessed using dredge plume modelling, which identified the following:

- The extent of the dredge plume (two milligrams per litre suspended sediment concentration) would be relatively small. It would spread further at the bed of the harbour than at the surface
- Deep draft silt curtains would effectively contain the surface layer suspended sediments and to a lesser degree the deeper suspended sediments. Additional shallow draft silt curtains are proposed and would further reduce potential impacts and protect near shore ecologically sensitive areas
- Suspended sediment concentrations would be generally low (less than five milligram per litre) for areas outside of the silt curtains. Concentrations would be highest in the bottom layer
- Suspended sediment in the lower layers would be transported via relatively slow upstream and to a greater extent downstream currents within a tidal stream adjacent to the Seaforth shoreline
- Suspended sediment concentrations in the waters next to Seaforth would peak (up to eight milligrams per litre) during the first four weeks of dredging due to the removal of soft surface sediments. For the majority (95 per cent) of the dredge time the concentrations are predicted to be less than 2.5 milligrams per litre
- Brief periods of increased suspended sediment concentrations (up to 3.5 milligrams per litre) are predicted at the surface layer immediately outside the silt curtain surrounding the Middle Harbour south cofferdam (BL7) near Clive Park. For the majority (99 per cent) of the dredge time, surface layer concentrations are predicted to be less than 1.7 milligrams per litre.

Figure 17-5 shows the results of the dredge plume modelling for the 95th percentile (ie the value that is predicted to be exceeded for only five per cent of the time, or 8.4 hours in a week) for the 37 week dredging program for the bottom, middle and surface layers of Middle Harbour.

The results indicate that the dredging program would not have a substantial impact on marine water quality. The dredging and construction activities for the project are likely to cause short term

increases in suspended sediment concentrations but due to the rapid dispersion of suspended sediments in Middle Harbour, impacts on water quality would be temporary and minimal in nature. Monitoring during the dredging activities would provide data to assess the compliance of the activities with this assessment.

Although there is limited existing data for turbidity during high rainfall events in Middle Harbour, the expected dredge plumes are likely to result in less impact than turbidity that occurs due to ongoing high rainfall events. One such high rainfall event occurred in February 2020 (refer to Figure 17-4) resulting in an increase in turbidity in Middle Harbour.

Along with the use of several shallow and deep draft silt curtains around cofferdams and dredging activities, shallow draft silt curtains would be installed along the shorelines where appropriate to mitigate potential impacts to nearby ecologically sensitive areas (eg seagrass and rocky reef habitat).

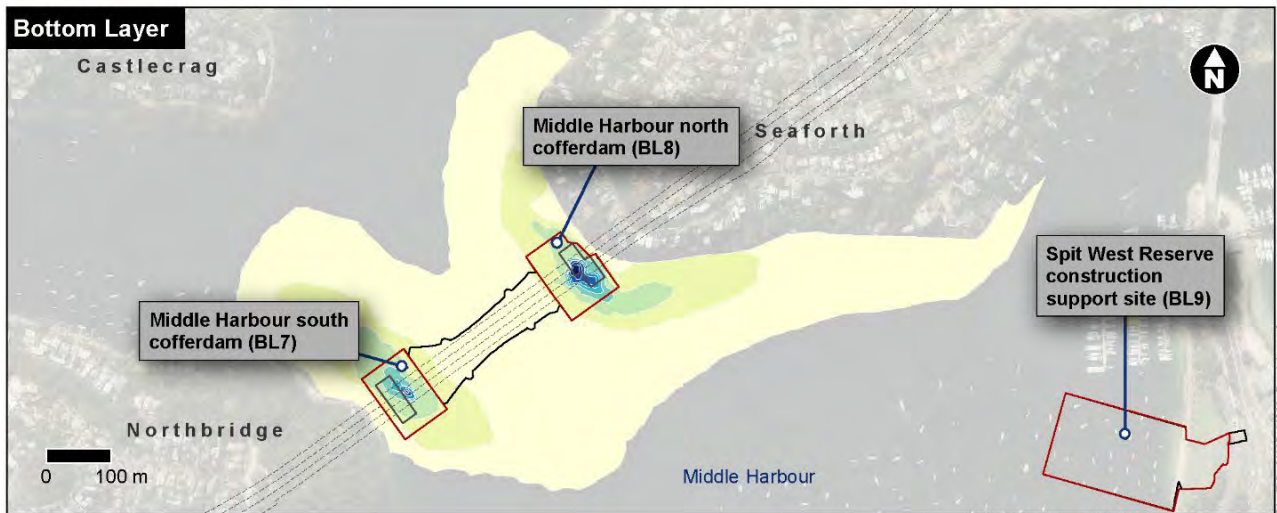
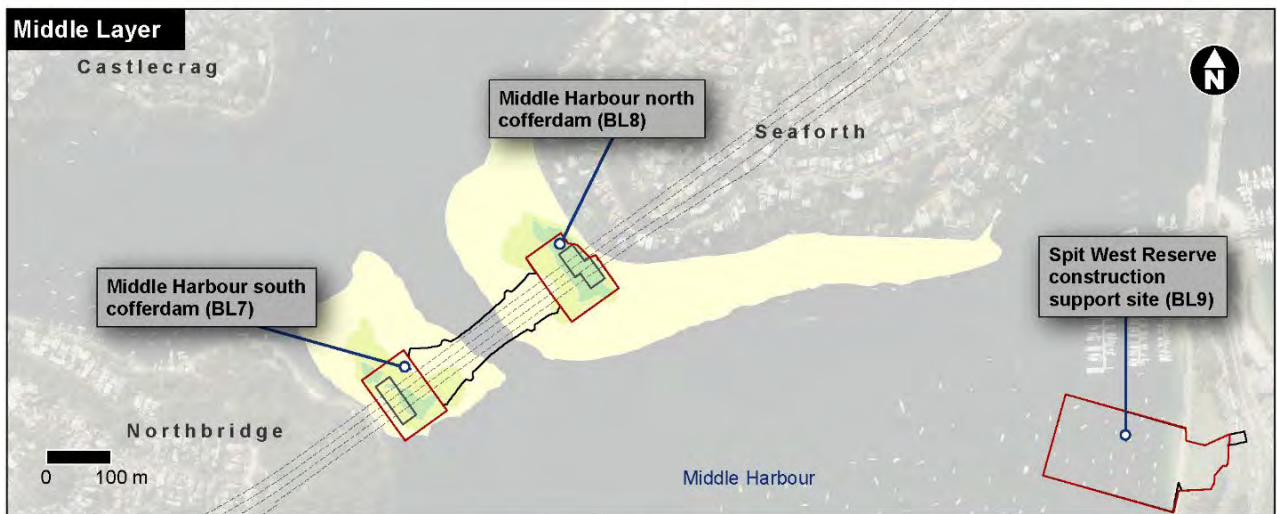
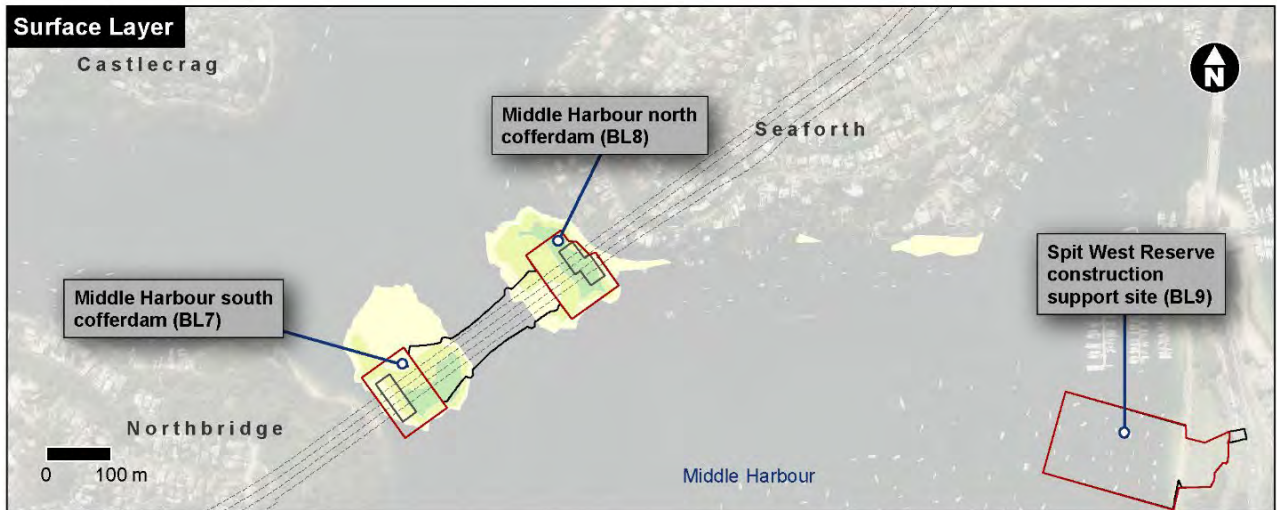


Figure 17-5 Dredge plume impacts within Middle Harbour during dredging activities

Deposition of mobilised sediment

Deposition of dredged material would be contained within the silt curtains proposed to be used during dredging activities and limited to a thickness of less than five millimetres.

Modelling of sediment deposition on the bed of the harbour two weeks after the completion of dredging activities indicated the following (refer to Figure 17-6):

- The majority of deposition would occur within and adjacent to the dredging footprint due to the low current speeds throughout the area and the use of deep draft silt curtains. Deposits would be concentrated in front of each cofferdam where most of the rock dredging and rehandling would occur
- Low levels of sedimentation (one to five millimetres) would mostly occur downstream of the dredge footprint due to stronger currents during the ebb tide, with some deposition reaching beyond Spit Bridge near Clontarf. Low level sedimentation would occur upstream about 600 metres from the immersed tube tunnel crossing of Middle Harbour
- Deposition is not predicted to accumulate in the area around Spit Bridge where tidal currents and bed shear stresses are high
- Deposition rates at the Middle Harbour south cofferdam (BL7) would remain low throughout the dredge period, despite its location close to the dredge footprint, due to the effectiveness of the deep and shallow draft silt curtains.

In summary, the effects of sedimentation as a result of dredging are expected to be minor. Short term effects of turbidity and deposition would likely be less than the effects from significant rainfall events.

Mobilisation of contaminants

Sediment sampling carried out for the project within Middle Harbour identified levels of selected contaminants within the top 0.5 metres to one metre of sediments from the bed of the harbour, which would, if mobilised, exceed guideline criteria. Dredging and other construction activities within Middle Harbour have the potential to mobilise these contaminants.

The behaviour of sediment-bound contaminants when resuspended into the water column has been previously assessed (Geotechnical Assessments, 2015) for other construction projects (Sydney Metro City & Southwest) which determined that contaminants are likely to remain bound to sediment particles and not be released into the water column.

A backhoe dredge with a closed environmental clamshell bucket would be used to remove the top layer of sediment. This would reduce the potential for release of contaminated sediments into the water (refer to Chapter 6 (Construction work)). On the basis of this proposed methodology, plume modelling has shown it is therefore unlikely that marine water quality would be substantially affected.



BL_EIS_CH15_M004_SoilDeposition_v6

Legend

Construction features

- Beaches Link (tunnel section)
- ▭ Construction footprint
- ▭ Construction support site

Soil deposition depth

- 1 to 5 (mm)
- 5 to 10 (mm)
- 10 to 50 (mm)
- 50 to 100 (mm)
- Above 100 (mm)

Figure 17-6 Sediment deposition two weeks after completion of dredging activities

Discharges, runoff, spills and leaks

Land based construction activities occurring immediately adjacent to Middle Harbour could result in the release of sediment via runoff to the harbour. There is also potential for spills or leaks of fuels and/or oils from maintenance or re-fuelling of construction plant or equipment or vehicle incidents, which could result in discharges to surrounding waterways and Middle Harbour. The discharge of treated water from onshore construction areas may also affect water quality in Middle Harbour.

These potential impacts would be effectively managed through the implementation of environmental management measures and procedures such that impacts on marine water quality would be minimised.

17.4.3 Surface water quality

Surface activities

A summary of potential impacts to surface water quality as a result of surface construction works is provided in Table 17-14. Identified surface water quality impacts would be managed via standard erosion and sediment control management and mitigation measures for all work sites including surface works areas.

Table 17-14 Summary of potential surface construction impacts on surface water quality

Construction activities/ incidents	Potential impacts
Temporary construction support sites	<p>Establishment of temporary construction support sites may result in erosion and mobilisation of exposed soils by stormwater runoff and wind leading to sedimentation of waterways.</p> <p>Temporary construction support sites may include activities that have a high potential to impact downstream water quality, if unmitigated, through spills of pollutants flowing to downstream watercourses. Typical activities that pose a risk include:</p> <ul style="list-style-type: none"> • Storage of chemicals • Vehicle wash down areas • Vehicle refuelling areas. <p>Further, the movement of construction vehicles may transfer soil and pollutants to adjacent roads, which may then be conveyed via stormwater runoff into waterways.</p>
Earthworks	<p>Exposure of soils during earthworks (including stripping of topsoil, excavation, removal of existing paved areas, stockpiling and transport of materials) can result in soil erosion and off-site movement of eroded sediments by wind and/or stormwater into receiving waterways. Once sediments enter waterways, they can directly and indirectly impact on the aquatic environment.</p> <p>If not appropriately managed, direct impacts would include reducing light penetration (limiting the growth of macrophytes), clogging fish gills, altering stream geomorphology, smothering benthic organisms and reducing visibility for fish. Indirect impacts of increased sediments occur over the longer term and include accumulation and the release of attached pollutants such as nutrients and heavy metals.</p> <p>The waterways at most risk of being impacted by earthworks would be:</p> <ul style="list-style-type: none"> • Willoughby Creek • Flat Rock Creek • Burnt Bridge Creek

Construction activities/ incidents	Potential impacts
	<ul style="list-style-type: none"> Manly Creek and Manly Dam.
Stockpiling	<p>Storage of earthworks materials, crushed rock, mulch and vegetation in stockpiles on construction sites and within temporary construction support sites have the potential to impact water quality and impact the aquatic environment if not appropriately managed.</p> <p>Stockpiles within 500 metres of a waterway that could potentially present a risk to water quality would be located at:</p> <ul style="list-style-type: none"> Flat Rock Drive (BL2) and Punch Street (BL3) construction support sites (Flat Rock Creek) Balgowlah Golf Course (BL10) and Kitchener Street (BL11) construction support sites (Burnt Bridge Creek) Wakehurst Parkway south and east construction support sites (BL12 and BL13) (Manly Creek and Manly Dam) Wakehurst Parkway north (BL14) construction support site (Trefoil Creek) Surface connection at Balgowlah (Burnt Bridge Creek) Realignment and upgrade of Wakehurst Parkway (Manly Creek and Trefoil Creek).
Demolition	<p>Demolition works have the potential to disturb and/or spread sources of pollutants including asbestos and other building materials, pollutant-laden soils, or heavy metals and chemicals that could affect water quality if not appropriately managed. Demolition can also generate dust and airborne pollutants. These pollutants once mobilised can be picked up by stormwater runoff and distributed to downstream receiving waterways via the drainage network.</p>
Contamination and acid sulfate soils	<p>If not appropriately managed, disturbance of contaminated land or groundwater, or acid sulfate soils during construction could result in the mobilisation of contaminants or acid sulfate soils by stormwater runoff and subsequent transportation to downstream waterways, potentially increasing contaminant concentrations in the receiving environment (refer to Chapter 16 (Geology, soils and groundwater)).</p> <p>The project is located within areas of low or extremely low probability of acid sulfate soils (refer to Appendix M (Technical Working Paper: Contamination)). There is the possibility of acid sulfate soils being present within sediments within Middle Harbour and/or The Spit.</p>
Spills and leaks	<p>If not appropriately managed, accidental spills or leaks could occur from spillage of diesel during refuelling, and leakage of hydraulic and lubricating oil from plant and equipment. Washdown water from plant washing and concrete slurries also have the potential to enter waterways if not appropriately managed.</p>
Relocation of utilities	<p>The relocation of utilities would involve soil disturbance as a result of trench excavation and underboring and construction of new utility routes. The disturbance of soil by machinery would increase the potential for soil erosion which has the potential to impact on downstream water quality if not appropriately managed.</p>

Construction activities/ incidents	Potential impacts
Removal of vegetation	<p>The removal of vegetation has the potential to increase the risk of erosion and sedimentation within the surrounding waterways if not appropriately managed.</p> <p>The majority of vegetation that would be removed for the project is located along the Wakehurst Parkway. Additionally, a small area of riparian vegetation and instream habitat would be removed for the localised adjustment and drainage works at Burnt Bridge Creek and the existing aboveground watercourse within the northern extent of Flat Rock Reserve. The removal of riparian vegetation and instream habitat at both creeks has the potential to impact bank stability and surface water quality if environmental management measures are not implemented. Vegetation removal for the localised adjustment of a small section of Burnt Bridge Creek would be mitigated by constructing a naturalised channel comprising of new plantings and retaining walls.</p>

Tunnelling activities

Sources of wastewater

During construction, tunnelling works would result in large volumes of wastewater being generated from the following sources:

- Groundwater infiltration into tunnelling works
- Rainfall runoff into tunnel portals and ventilation outlet tunnels
- Wash down runoff
- Heat and dust suppression water.

Most of this wastewater would be collected from groundwater infiltration into the tunnelling works. Estimated volumes of construction wastewater are included in Section 17.4.5. Water volumes generated during the construction of the project would vary based on construction activities both above and below the ground surface, the amount of groundwater infiltrating into the tunnels and the length of tunnels that have been excavated. Groundwater infiltration into tunnelling works has been estimated as a worst case without consideration of the progressive installation of tunnel linings designed to reduce infiltration to an average of one litre per second per kilometre of tunnel.

The reuse of wastewater would be maximised during construction works (eg dust suppression and compaction of earthworks and pavements). Despite this reuse, there is expected to be a surplus of wastewater, which would need to be treated appropriately before discharge to the local stormwater system or directly to a local surface watercourse.

Wastewater treatment

The wastewater collected from tunnelling activities would be tested and treated at construction wastewater treatment plants prior to reuse or discharge. Discharges from construction wastewater treatment plants would be required to meet the following discharge criteria:

- The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and
- The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 95 per cent species protection levels, and
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) of which public comments are under consideration as of November 2020.

Temporary construction wastewater treatment plants would generally consist of settling tanks/ponds, flocculation tanks (which bind small particles suspended in the water together to make them easier to remove) and filtration.

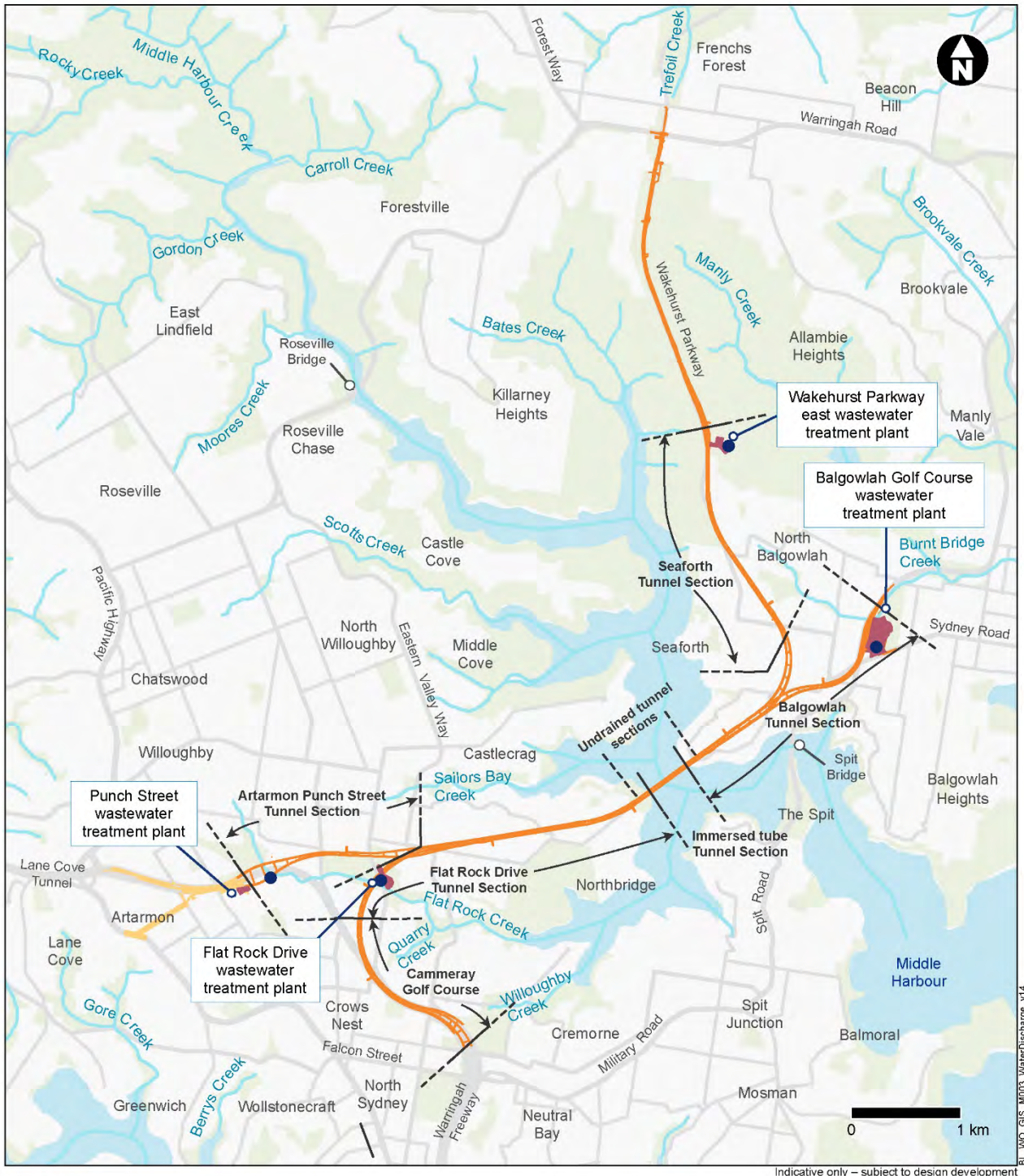
Indicative construction wastewater treatment discharges and approximate duration of operation of the treatment plants are presented in Table 17-15. Discharge quantities are presented as a worst case, excluding progressive installation of tunnel linings to reduce infiltration to below one litre per second per kilometre. Therefore, the predicted tunnel infiltration, and discharge volumes, would be less than predicted by the modelling. Wastewater treatment plants and discharge locations are shown in Figure 17-7.

Table 17-15 Construction wastewater treatment plants

Plant location	Approximate duration of operation	Discharge quantity (kL/d)	Discharge location	Ultimate receiving waters
Cammeray Golf Course construction support site (BL1)	Three years and three months	296	Local stormwater system	Willoughby Creek
Cammeray Golf Course construction support site (BL1) and Western Harbour Tunnel and Warringah Freeway Upgrade project Cammeray Golf Course construction support site (WHT10) (cumulative discharge) ¹	Six months	321	Local stormwater system	Willoughby Creek
Flat Rock Drive construction support site (BL2)	Four years	711	Local stormwater system	Flat Rock Creek
Punch Street construction support site (BL3)	Three years and nine months	308	Local stormwater system	Flat Rock Creek
Balgowlah Golf Course construction support site (BL10)	Four years	428	Local stormwater system	Burnt Bridge Creek
Wakehurst Parkway east construction support site (BL13)	Three years and six months	10	Drainage channel to be formed at the eastern section of the temporary construction support site	Wakehurst Golf Course dam for reuse by the golf course (via overland flow)

Note 1: Cumulative impact during the time the two wastewater treatment plants would be discharging concurrently into the local stormwater system.

The wastewater treatment plants at Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Punch Street (BL3), Balgowlah Golf Course (BL10) and Wakehurst Parkway east (BL13) construction support sites would treat wastewater generated from tunnelling activities to a standard suitable for discharge based on ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines. Construction wastewater treatment plants would be designed to maintain the water quality outcomes of the receiving ambient environment so that water quality objectives are achieved and impacts on water quality of affected catchments would be low compared to the existing pollutant loads.



Indicative only – subject to design development

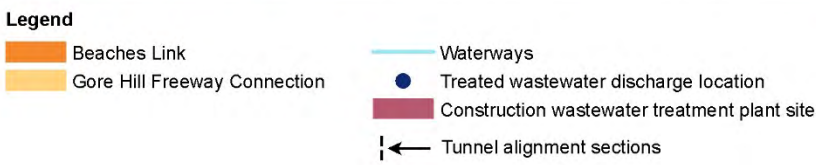


Figure 17-7 Construction wastewater treatment plants and discharge locations

Impacts on NSW water quality objectives during construction

The project would treat wastewater from tunnelling activities and implement standard erosion and sediment control measures for all work sites and surface works areas. With the implementation of these standard, environmental management measures, potential pollutant loading to the receiving waterways is considered to be low compared to the existing pollutant loading from Willoughby Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and Trefoil Creek catchments.

As a consequence, the project construction is likely to have a negligible influence on whether the NSW water quality objectives of receiving waters are protected (if currently met) or achieved (if currently not met).

17.4.4 Impacts on geomorphology

Construction of the project has the potential to impact on geomorphology due to:

- Treated water discharges from construction wastewater treatment plants have the potential to impact creek channel bed and bank conditions due to changes in baseline volumes and velocities
- Temporary changes in downstream creek flows and velocities as a result of increased surface runoff
- Mobilised sediment build up in the streams if not appropriately managed
- Impervious surfaces created by the project increasing the volume and rate of runoff, causing erosion within the instream channel
- Potential subsidence below watercourses, potentially impacting on channel bed and bank conditions.

Groundwater infiltration to the tunnels would be collected, treated and reused as required or discharged to local waterways including Willoughby Creek, Flat Rock Creek and Burnt Bridge Creek. This is expected to largely offset baseflow reduction to these waters, as the additional creek flows could partially feed the surrounding groundwater system.

Treated wastewater discharges into Willoughby Creek are not anticipated to change the creek geomorphology as the modified concrete and rock channel would be able to handle greater flows during frequent flood events. The susceptibility of Willoughby Creek to degradation as a result of increased flows is considered to be low based on assessment of its current stability and the relatively low level of project discharges when compared to existing flows.

Cumulative average daily treated wastewater discharges into Flat Rock Creek would be 0.012 kilolitres per second for about four years. This cumulative flow is considered minor when compared to creek flows experienced during a two-year average recurrence interval (ARI) event (0.02 kilolitres per second). Construction wastewater treatment plant discharges into Flat Rock Creek are not anticipated to change the form of the creek channel and banks as Flat Rock Creek is able to handle greater flows during frequent flood events. The overall predicted maximum total flow reduction in Flat Rock Creek at the end of construction is 20 per cent, increasing to 39 per cent after 100 years of operation, however given the circular nature of water flows (treatment of groundwater infiltration and discharge back into local waterways), discharges may partially offset this impact. There is also little potential for further incision of the concrete-lined sections and rocky riffle/runs at Flat Rock Creek. Baseflow impacts are modelled conservatively without tunnel linings designed and installed to reduce groundwater inflows into the tunnels. Baseflow impacts are therefore likely to be lower than that predicted. Refer to Section 17.4.5 for further discussion on water availability and flows.

Average daily treated wastewater discharges into Burnt Bridge Creek would be about 0.005 kilolitres per second for about four years. This flow is considered negligible when compared to creek flows experienced during a two-year ARI event (29.7 kilolitres per second) and is not expected to change the stability or form of Burnt Bridge Creek channel or banks.

Most of the treated wastewater generated at the Wakehurst Parkway east construction support site (BL13) wastewater treatment plant would be reused. The small amount discharged would be into the drainage channel to be formed at the eastern section of the site which would naturally drain towards Wakehurst Golf Course and the golf course dam. Therefore, geomorphology impacts from treated wastewater discharges at the Wakehurst Parkway east construction support site are not expected.

If not appropriately managed, impacts to geomorphology as a result of increased mobilised sediment or increased surface runoff (volume or velocity) could occur where activities are near watercourses. This includes Willoughby Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek and along drainage lines that pass under Wakehurst Parkway. Impacts to Flat Rock Creek are considered to have low potential of occurring given the concrete-lined or piped nature of the creek.

Drainage works associated with an existing aboveground watercourse within Flat Rock Reserve at the Flat Rock Drive construction support site (BL2) and localised adjustment of Burnt Bridge Creek as part of surface connections at Balgowlah would be staged to ensure creek flows and velocities are not substantially changed and to avoid downstream erosion and bed and bank stability impacts. The potential for watercourse geomorphology impacts would be mitigated through environmental management measures outlined in Section 17.6.

Works along the Wakehurst Parkway, the Wakehurst Parkway south construction support site (BL12), Wakehurst Parkway east construction support site (BL13) and Wakehurst Parkway north construction support site (BL14) are unlikely to change the bed and bank conditions of the existing drainage lines within the Garigal National Park and Manly Dam Reserve provided environmental management measures outlined in Section 17.6 are implemented. Refer to Chapter 6 (Construction work) for further details regarding the scope and extent of stormwater drainage works.

17.4.5 Water balance, environmental water availability and flows

Water balance

The expected construction water balance, based on average groundwater infiltration, and the estimated treated discharge quantities are shown in Table 17-16. The actual water usage during construction is expected to show considerable variation during this period depending on the nature and extent of construction activities taking place. Non-potable water uses would include earthworks and pavement compaction, landscape watering, roadheader supply, dust suppression, plant wash-down and rock bolting, amongst other activities. Some activities are consumptive such as concrete batching and the water used in the offices, with some consumptive demand assumed to be discharged directly into the sewerage network. There would also be minor losses in the system due to evaporation. The remainder would be treated and either reused or discharged at the proposed discharge locations listed in Table 17-15.

Non-potable sources (eg treated wastewater and harvested rainwater) may be used to meet construction water demand requirements. The deficit for the non-potable demand and any potable demand would be sought from the Sydney Water supply network. The use of non-potable water over potable would be preferred, however this is dependent on the location and nature of the water use activity as well as the quantity and quality of available water at the time. Water availability would vary as construction progresses as well as seasonally due to climate. It is expected that the potential for treated wastewater reuse would also show variability.

Table 17-16 Construction water balance

Activity ¹	Total water demand (kL/d)	Consumptive use (kL/d)	Groundwater infiltration (kL/d)	Harvested rainwater (kL/d)	Treated wastewater reused (kL/d)	Sydney water supply (kL/d)	Discharge quantity (kL/d)
Surface works ²	368	368	0	0	185	183	0
Tunnelling							
Cammeray Golf Course (BL1)	159	15	278	1	127	32	296
Flat Rock Drive (BL 2)	635	61	440	1	305	331	711
Punch Street (BL 3)	125	40	347	1	130	0	308
Balgowlah Golf Course (BL 10)	810	457	521	1	263	547	428
Wakehurst Parkway east (BL 13)	548	370	30	1	199	349	10
Total	2645	1311	1616	5	1209	1442	1753

Note 1. Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve (BL9) construction support sites are not included in the water demand estimates

Note 2. Surface works estimates include works along the existing Gore Hill Freeway, surface works between the mainline tunnels at Balgowlah and Killarney Heights, and surface works at Wakehurst Parkway.

Water availability and flows

Water extraction from surface water is not proposed during construction. However, surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during construction of the project. Baseflow impacts are modelled conservatively without tunnel linings designed and installed to reduce groundwater infiltration into the tunnels. Baseflow impacts are likely to be lower than that predicted in Appendix N (Technical working paper: Groundwater) due to conservative modelling assumptions.

The assessment of groundwater impacts for the project indicate that the maximum predicted groundwater drawdown at Willoughby Creek during construction is up to three metres in the upper reaches. Baseflow impacts are not expected as the creek is lined in this area. There is the potential for baseflow reductions of more than five per cent to occur at Flat Rock Creek and Quarry Creek at the end of construction. The drawdown beneath Burnt Bridge Creek is estimated to be up to five metres. There would be maximum of 79 per cent reduction in baseflow at the end of construction. Due to the very low existing baseflows along Burnt Bridge Creek and Quarry Creek and the existing geomorphologies, the predicted baseflow reductions are unlikely to have any substantial hydrodynamic or water quality impacts. An estimated drawdown of less than one metre is expected at Manly Dam, resulting in maximum baseflow reduction of two per cent. Other creeks would be unaffected by changes to baseflow conditions. As discussed below, it is expected that the additional creek flows from treated water from the construction wastewater treatment plants could partially feed the surrounding groundwater system. Further details regarding the potential impacts of baseflow reductions and measures to minimise potential impacts on ecological conditions are provided in Chapter, 16 (Geology, soils and groundwater), Chapter 19 (Biodiversity) and Appendix S (Technical working paper: Biodiversity development assessment report).

Stormwater harvesting schemes

The project would not impact the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at the Cammeray Golf Course. However, the existing storage dam at the Cammeray Golf Course would be impacted by the Western Harbour Tunnel and Warringah Freeway Upgrade project.

As part of the Western Harbour Tunnel and Warringah Freeway Upgrade project and subject to a timely agreement with Cammeray Golf Club and North Sydney Council regarding a suitable alternative location, Transport for NSW would install a new permanent replacement storage dam (and associated infrastructure) within the golf course prior to decommissioning of the existing dam.

The reinstatement and management of impacts to North Sydney Council prior to the reinstatement of the permanent solution form part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

The project would impact the Balgowlah Golf Course stormwater harvesting dam as part of constructing the new access road between Sydney Road and Burnt Bridge Creek Deviation. The Balgowlah Golf Course Stormwater Harvesting dam will initially be retained and maintained as construction water and irrigation of Balgowlah Oval by Northern Beaches Council. As construction progresses the stormwater harvesting dam would be removed. The ongoing need for a stormwater harvesting water quality basin at Balgowlah would be assessed and determined during further design development. If the stormwater harvesting water quality basin is considered to be required, a suitable alternate location and future use would be determined as part of the dedicated consultation process regarding the final layout of the new and improved public open space and recreation facilities at Balgowlah.

17.4.6 Residual impacts during construction

With the implementation of the management measures outlined in Section 17.6, and in the context of the overall catchment, any potential short-term impacts are unlikely to have any material impact on ambient water quality within the receiving waterways.

The residual risk to sensitive receiving environments and environmental values identified in Section 17.3.8 and Section 17.3.9 is expected to be low provided the proposed management measures are implemented, maintained and monitored.

Construction activities are not expected to result in a substantial change to the sediment dynamics in the vicinity of the Middle Harbour crossing. The use of floating silt curtain enclosures immediately around dredging plant and associated deep draft silt curtains is expected to effectively contain any mobilised sediments.

17.5 Assessment of potential operational impacts

17.5.1 Hydrodynamic environment of Middle Harbour

The immersed tube tunnels would be installed as a series of pre-cast units. Due to the profile of the harbour bed, the units would sit both partially within a trench closer to the shore and above the bed of the harbour towards the centre of the harbour crossing. The middle sections would be placed with the tops of the tunnel units being about 9.2 metres above the existing level of the bed of the harbour, creating a sill-like feature over a length of around 250 metres and around 40 metres wide. The water depth above the immersed tube tunnels would vary between 16 metres and 22 metres, depending on the distance from the shore.

Hydrodynamic modelling of the potential impacts on tidal currents and tidal flushing indicates:

- The changes to currents for both flood and ebb tides as a result of the project would be small and less than those seen through natural variations such as wind driven circulation
- Water levels upstream of the Middle Harbour crossing would not be affected
- The tidal prism of Middle Harbour (ie the volume of water between mean high tide and mean low tide) would be marginally reduced (0.4 per cent decrease)
- Tidal flushing (replacement of water via tidal fluctuations) would take slightly longer for water located upstream and below the level of the sill; however, flushing would remain relatively rapid.

Due to the existing low energy hydrodynamic environment at the proposed Middle Harbour crossing, little to no bedload transport or resuspension of existing sediment is expected to occur where the immersed tube tunnels would be located above the bed of the harbour. Localised increases in current speed are not expected to result in a change to the sediment dynamics near the proposed Middle Harbour crossing. Figure 17-8 to Figure 17-11 show the changes to tidal flows as a result of the project during peak flood and peak ebb tides at the top of the sill and at the surface.

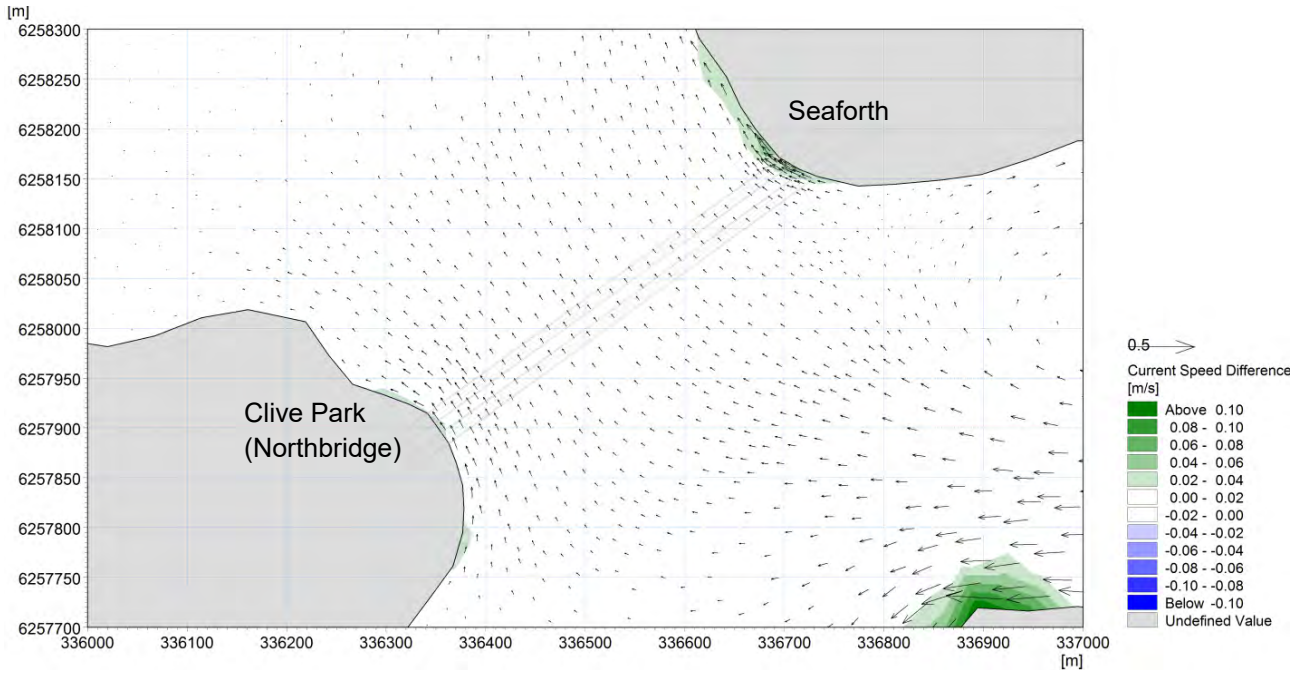


Figure 17-8 Current speed difference: project design less existing conditions (Peak flood tide: surface layer)

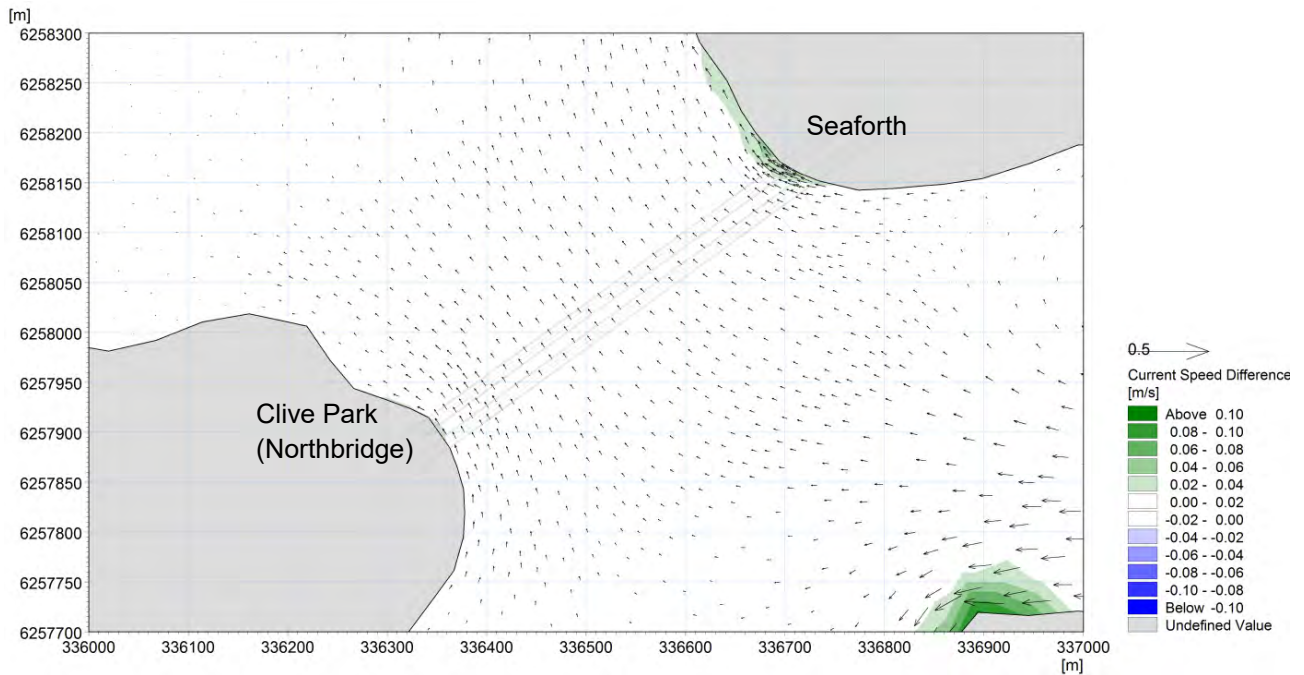


Figure 17-9 Current speed difference: project design less existing conditions (Peak flood tide: layer just above the crown of the tunnel)

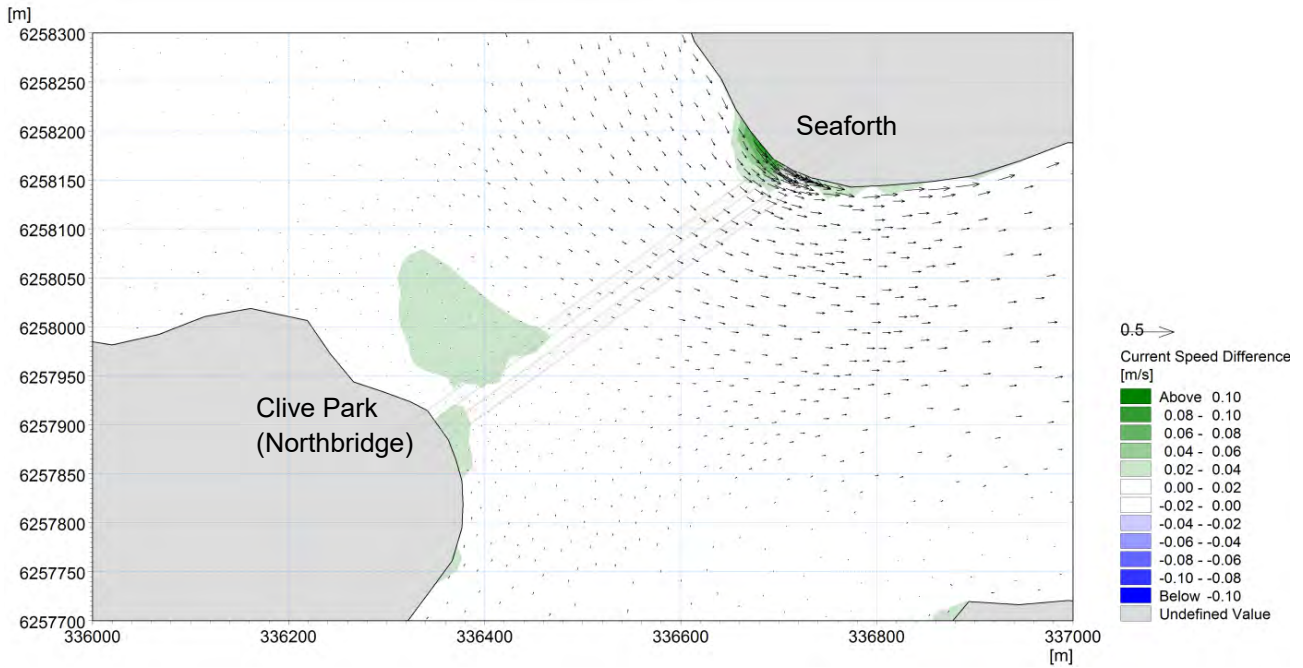


Figure 17-10 Current speed difference: project design less existing conditions (Peak ebb tide: surface layer)

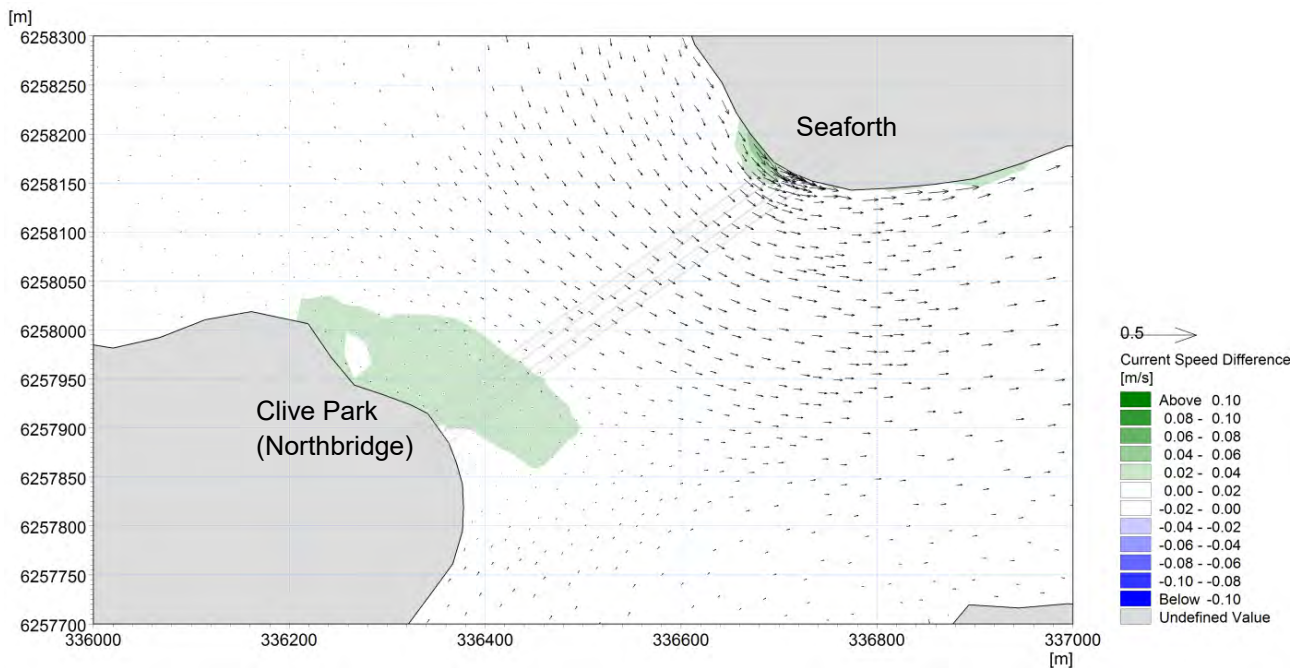


Figure 17-11 Current speed difference: project design less existing conditions (Peak ebb tide: layer just above the crown of the tunnel)

17.5.2 Marine water quality

Tidal flushing upstream of the Middle Harbour crossing has the potential to be affected by the permanent sill-like feature that would be created by the project. The longer term effects of the sill have the potential to reduce water exchange and therefore increase residence times in the near-bed waters for about one kilometre upstream of the sill from 1.6 days to 2.4 days. Increased residence time of the deep water upstream may lead to longer periods of low dissolved oxygen concentrations in the near-bed waters below the sill level and/or increased siltation behind the sill. Lower dissolved oxygen concentrations may lead to a nutrient release from the sediments and its subsequent vertical mixing, potentially stimulating algal growth near the surface.

When dissolved oxygen concentrations are reduced there may be mortality to some benthic infauna and epifauna in soft sediment habitat in the deepest parts of the harbour, but fish and sharks would generally be able to avoid these bottom layers. It would be expected that recolonisation of affected deep water soft sediment habitat would occur through natural processes of recruitment of planktonic larvae and from movement of fauna from shallower unaffected areas of soft sediment.

Based on average annual rainfall patterns, the conditions leading to dissolved oxygen depletion to about 50 per cent saturation concentrations are likely to naturally occur a few times per year, particularly during the warmer late summer and autumn period. While the project would potentially result in low dissolved oxygen events lasting slightly longer at a slightly lower dissolved oxygen concentration than currently occurs, any depletion of dissolved oxygen in deeper waters would be rapidly mixed vertically resulting in the project having a negligible effect on dissolved oxygen in surface waters in which Type 1 and Type 2 Key Fish Habitats are located. The potential impacts of the likely slightly longer periods of low dissolved oxygen concentrations in the deep waters to the marine ecology of Middle Harbour are discussed further in Chapter 19 (Biodiversity).

17.5.3 Surface water quality

Surface water runoff

During operation of the project, all road surfaces would be sealed, and embankments landscaped. Suitable stabilisation and management measures would be implemented during periods of vegetation establishment to minimise the potential for erosion and sedimentation impacts at nearby waterways including Flat Rock Creek and Burnt Bridge Creek. Provided appropriate controls are implemented, short-term impacts during the vegetation establishment period would be expected to be manageable with negligible impacts on receiving water quality.

Runoff from upgraded road pavement would typically contain pollutants such as sediments, litter, nutrients, oils and greases, petrochemicals and heavy metals, which could potentially impact on water quality when discharged into receiving waterways and sensitive receiving environments (Trefoil Creek, Manly Creek, Manly Dam, Burnt Bridge Creek and Flat Rock Creek). Potential impacts on the water quality of nearby watercourses and drainage lines would include increased sedimentation, erosion, and mobilisation of contaminated sediments resulting in potential impacts to aquatic flora and fauna if not appropriately managed.

Where possible, surface water quality controls for the project would be provided so that water is treated to a standard that would meet the design targets for the project. Where the design targets are not able to be met due to site constraints, water quality treatment to meet existing conditions would be provided such that impacts on surface water quality would be minimal.

MUSIC modelling was carried out to assess the performance of the proposed surface water quality treatment measures against the pollutant reduction targets outlined in Section 17.1.3.

The modelling results for the main locations where stormwater would be discharged (ie Gore Hill Freeway Connection, surface connections at Balgowlah and the realigned and upgraded Wakehurst Parkway) indicate that while the project would not meet the design targets in all locations, it would still meet or improve the existing water quality. On this basis impacts on surface water quality are expected to be minimal.

Chapter 5 (Project description) and Appendix O (Technical working paper: Surface water quality and hydrology) provide further details of the stormwater drainage infrastructure and proposed stormwater quality treatment systems.

Tunnel drainage and wastewater treatment

The tunnels, when operational, would include drainage infrastructure to capture groundwater and stormwater ingress, spills, maintenance wastewater, fire suppressant deluge and other potential water sources.

Water intercepted by the tunnel drainage systems would be collected and pumped to the Gore Hill Freeway wastewater treatment plant for treatment. Following treatment, the water would then be discharged into Flat Rock Creek via a new drainage pipe connecting with Flat Rock Creek at a flow rate of about 16 litres per second (refer to Figure 17-12).

The wastewater treatment plant would be designed to meet the following discharge criteria:

- The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and
- The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 99 per cent species protection levels, and
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) of which public comments are under consideration as of November 2020.

Impacts on NSW water quality objectives during operation

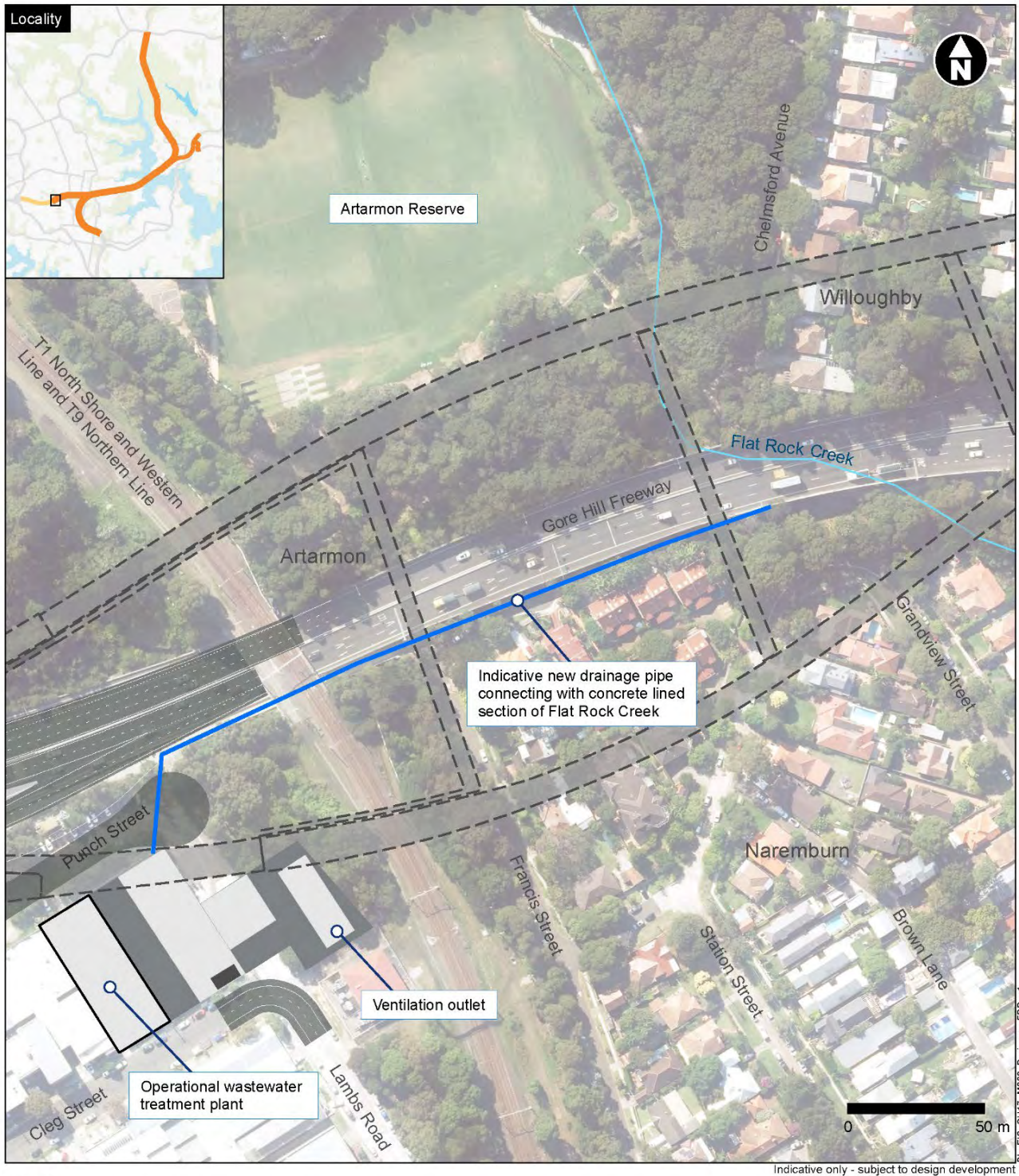
During operation, the project would treat tunnel infiltration and road tunnel runoff at the Gore Hill Freeway operational wastewater treatment plant. The plant would be designed to treat key indicators of concern to a level that is consistent with the ANZG (2018) water quality guidelines and the NHMRC (2008b) recreational water quality guidelines.

Runoff from the Gore Hill Freeway Connection, surface connections at Balgowlah and the realigned and upgraded Wakehurst Parkway is predicted to meet or improve the existing water quality of receiving waters (Flat Rock Creek, Burn Bridge Creek, Manly Dam, Manly Creek or Bantry Bay).

The overall impacts to ambient water quality are likely to be negligible. The project is considered to have a negligible influence on goals to achieve the NSW water quality objectives.

17.5.4 Impacts to the local stormwater system

Treated wastewater from the Gore Hill Freeway operational wastewater treatment plant would discharge into Flat Rock Creek via a new drainage pipe at a flow rate of about 0.016 kilolitres per second (16 litres per second) (refer to Figure 17-12). This discharge rate is unlikely to have a material impact on the operation of the local stormwater system.



Legend



-  Beaches Link driven tunnel
-  Surface road

Figure 17-12 Operational wastewater treatment discharge location

17.5.5 Impacts on geomorphology

The potential impact to the geomorphology of watercourses from surface water runoff is considered negligible given that project stormwater discharges would be via the stormwater network. Drainage works would be designed to include velocity flow dissipation structures so as to prevent scouring of creeks and drainage lines.

The Gore Hill Freeway wastewater treatment plant discharge volumes would be ultimately received into Flat Rock Creek via the local stormwater system at a flow rate of about 0.016 kilolitres per second. This rate is lower than the creek flow rate under a two-year ARI flood event (0.02 kilolitres per second). It is therefore considered that Flat Rock Creek bed and banks would be able to handle expected wastewater treatment plant flow rates without impacting the creek form and geomorphic processes.

The upgrade of the concrete lined drainage line between Punch Street and Flat Rock Creek via Chelmsford Avenue would be located on existing flow paths and sized to not restrict the free flow of water. It would be designed with low gradient and scour protection to minimise impacts to geomorphology. Additionally, installation of culverts would be in accordance with the *Temporary Stormwater Drainage for Road Construction technical guideline* (Roads and Maritime Services, 2011b).

The proposed localised adjustment of Burnt Bridge Creek would be designed considering the susceptibility of the creek to scour from increased flow and runoff. The extension to the existing culvert would be designed with low gradient and scour protection to minimise impacts to geomorphology. The extent of scour protection would be minimised during further design development as far as practicable. The gradient, sinuosity and channel capacity would remain consistent with upstream and downstream sections of the creek. Where required, grade controls and bank stabilisation works would be implemented to manage anticipated high velocity conditions.

Cumulative long-term surface settlement from tunnelling works and groundwater drawdown have been assessed for the project (Arup and WSP, 2020). Cumulative long-term surface settlement is expected to be nil or very minor at creeks intersected or in proximity to the tunnels. The risk of rock cracking from such surface settlement is negligible because the ground movement would be insufficient to cause any noticeable change in permeability of the rock cover. The exception to this is the cumulative long-term surface settlement predicted at Flat Rock Creek within poorly consolidated fill beneath Flat Rock Baseball Diamond. At this location, settlement is predicted to be up to 85 millimetres under a worst case (conservative) modelling scenario. With the inclusion of proposed tunnel lining for around 300 metres beneath Flat Rock Reserve, modelling indicates that predicted settlement at Flat Rock Reserve reduces from 85 millimetres without the lined tunnel to 35 millimetres with the lined tunnel.

Contours of calculated surface angular distortion have been developed based on the calculated surface settlement data (Arup and WSP, 2020). The calculated maximum settlement is at the north east section of the link at Balgowlah Connection, Burnt Bridge Creek, Wakehurst Parkway Connection and north of the Warringah Freeway portal with the maximum settlement being 35 to 40 millimetres in these areas.

Settlement is not expected to have noticeable impact on Flat Rock Creek or Burnt Bridge Creek form and geomorphology as the existing creek drainage infrastructure along both these creeks would be designed as culverts and would mitigate some of the predicted settlement impacts.

17.5.6 Water balance, environmental water availability and flows

Water balance

Operation of the project has the potential to alter the water balance of surface and groundwater systems. The Gore Hill Freeway wastewater treatment plant would treat all groundwater infiltration during operation of the project. Any non-potable water demand during operation of the project would be sourced from this facility. The operational stage water balance is shown in Table 17-17.

Table 17-17 Operational water balance

Wastewater treatment plant location	Water demand		Average groundwater infiltration (kL/d)	Treated groundwater re-used (kL/d)	Discharge quantity (kL/d)
	Washdown (kL/d)	Deluge testing (kL/d)			
Gore Hill Freeway	2	8	1435	10	1425

Water availability and flows

Water extraction from waterways is not proposed during operation of the project. However, surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during operation of the project. This has the potential to result in impacts to groundwater dependant ecosystems and other surrounding riparian ecosystems reliant on surface water (refer to Appendix N (Technical working paper: Groundwater)).

The assessment of groundwater impacts for the project identified that the project has the potential to result in a worst case groundwater drawdown of up to 29 metres beneath Flat Rock Creek after 100 years of operation. The modelling indicates that there would be a maximum total flow reduction of about 39 per cent in Flat Rock Creek after 100 years of operation, noting operational wastewater treatment plant discharges to Flat Rock Creek may offset this impact. Potential impacts would also be experienced at Quarry Creek and Burnt Bridge Creek, where maximum total flows would be reduced by 69 and 96 per cent respectively after 100 years of operation.

While these reductions could be considered significant, in particular for Burnt Bridge Creek and Quarry Creek, they are unlikely to result in a complete loss of aquatic habitat. Pools would be retained and there would still be high flows within the waterways immediately after rainfall events. Between rainfall events there would still be some (low) flow along the waterways. Further consideration to the potential impacts of baseflow reduction on aquatic ecosystems is provided in Appendix S (Technical working paper: Biodiversity development assessment report).

It is noted that groundwater modelling provides a conservative assessment which excludes the designed tunnel linings. Additional modelling was carried out for a scenario in which the section of tunnel beneath Flat Rock Creek is lined. With the linings assumed, the predicted water table drawdown after 100 years of operation was predicted to be up to eight metres less than the drawdown predicted without the lining, demonstrating that implementation of tunnel lining would help mitigate potential groundwater drawdown impacts and that potential baseflow impacts would be lower than predicted (refer to Chapter 16 and Appendix N (Technical working paper: Groundwater)).

A minor flow reduction of two per cent would be experienced at Manly Creek/Manly Dam, however other watercourses including Willoughby Creek would be unaffected by changes to baseflow and would experience a negligible total flow reduction after 100 years of operation.

Environmental management measures to minimise potential impacts due to reduced groundwater baseflow to creeks are provided in Chapter 16 (Geology, soils and groundwater). Monitoring of surface water flows and groundwater levels would occur in the vicinity of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, both prior to and during construction to confirm potential baseflow loss to these surface water features.

Stormwater harvesting schemes

The stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course would not be impacted by the project as the storage dam would be reinstated as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project.

The ongoing need for a stormwater harvesting water quality basin at Balgowlah would be assessed and determined during further design development. If a basin is considered to be required, a suitable alternate location and future use will be determined as part of the dedicated consultation process regarding the final layout of the new and improved public open space and recreation facilities at Balgowlah.

17.5.7 Residual impacts on water quality during operation

As discussed in Section 17.3, receiving waterways near the project have existing elevated levels of some heavy metals, nutrients, turbidity and pH, and low dissolved oxygen.

Tunnel water would be treated to comply with (ANZECC/ARMCANZ, 2000) and ANZG (2018) guidelines (refer to Section 17.1.3). MUSIC model results for several areas, including the Gore Hill Freeway Connection stormwater catchment, combined stormwater sub-catchments at Balgowlah and stormwater catchments at Wakehurst Parkway, show that the proposed water quality strategy would achieve general reductions on annual pollutant exports when compared to existing conditions. However, the water quality strategy at Balgowlah would not achieve the operational water quality design targets for total suspended solids and total phosphorus, while the water quality strategy for the Wakehurst Parkway would not achieve the operational water quality design target for nitrogen. Spill controls and water quality monitoring would be implemented to identify and manage operational impacts on ambient water quality within the receiving waterways.

For locations where stormwater would be discharged (ie Gore Hill Freeway, Balgowlah and Wakehurst Parkway), water quality treatment to meet existing conditions would be provided, at a minimum, such that impacts on surface water quality would be minimal.

Impacts to the baseflow of Quarry Creek and Flat Rock Creek would occur because of groundwater drawdown that occurs due to the project. Provided controls are implemented, maintained and monitored, impacts on downstream receivers would be minimal.

With the proposed treatment and management measures, residual impacts on ambient water quality are expected to be negligible.

The residual risk to sensitive receiving environments and environmental values identified in Section 17.3.8 and Section 17.3.9 respectively is expected to be low provided the proposed management measures are implemented, maintained and monitored.

17.6 Environmental management measures

Environmental management measures relating to water quality impacts are outlined in Table 17-18. No specific measures are required for hydrodynamics during construction given the methodology to be implemented during construction; activities in Middle Harbour (refer to Chapter 6 (Construction work)) and the minimal hydrodynamic impacts expected as a result of the project.

Table 17-18 Environmental management measures – hydrodynamics and water quality

Ref	Phase	Impact	Environmental management measure	Location
WQ1	Design	Stormwater harvesting	The need for a stormwater harvesting water quality basin at Balgowlah will be assessed and determined during further design development. If the stormwater harvesting water quality basin is considered to be required, a suitable alternate location and future use will be determined as part of the dedicated consultation process regarding the final layout of the new and improved public open space and recreation facilities at Balgowlah.	BL (Balgowlah)

Ref	Phase	Impact	Environmental management measure	Location
WQ2	Design	Spill containment	<p>Spill containment controls along surface roads will be confirmed during further design development and determined with consideration of:</p> <ul style="list-style-type: none"> • The environmental sensitivity of the receiving waterways • The likelihood of vehicle accidents, informed by the annual average daily traffic (AADT) loading along the surface road • Where implementation of controls measures may have a negative impact on other areas of environmental importance, such as biodiversity and heritage. 	BL/GHF
WQ3	Design and operation	Local stormwater system capacity	<p>The capacity for the local stormwater system to receive operational wastewater treatment plant discharge will be confirmed during further design development. If there is a stormwater infrastructure capacity issue with existing infrastructure, mitigation measures such as storage detention to control water outflow during wet weather events will be implemented within the motorway facility site.</p>	GHF
WQ4	Design and operation	Burnt Bridge Creek geomorphology	<p>The localised adjustment of Burnt Bridge Creek will be designed with consideration of existing channel conditions and an understanding of existing hydrology to minimise alterations to, and erosion of, the bed and banks. The gradient, sinuosity and channel capacity will be consistent with upstream and downstream sections.</p> <p>The extension to the existing culvert will be designed with a low gradient and scour protection to minimise impacts to geomorphology. Where required, the adjustment will include grade controls and bank stabilisation works to manage anticipated high velocity conditions.</p>	BL

Ref	Phase	Impact	Environmental management measure	Location
WQ5	Design and operation	Water sensitive urban design	Opportunities for water sensitive urban design will be considered during the development of the design for the stormwater management system for the new and upgraded road infrastructure and during development of the urban design and landscape plans. Identified water sensitive urban design features will be implemented where practical and with consideration to best management practice guidelines including Transport for NSW's <i>Water sensitive urban design guideline</i> (Roads and Maritime Services, 2017d).	BL/GHF
WQ6	Design and operation	Surface water discharge	Water quality treatment controls for stormwater will meet the design targets, where possible. Where the design targets cannot be met due to site constraints, water quality treatment controls will be provided to meet or improve existing surface water quality.	BL/GHF
WQ7	Design and operation	Connection to Sydney Water stormwater assets	The need for direct connection to Sydney Water stormwater assets will be reviewed during further design development and in consultation with Sydney Water. Where direct connection to a Sydney Water stormwater asset is required, the project will install and operate water treatment devices during operation to achieve the Sydney Water pollutant load reduction targets where feasible and reasonable.	BL/GHF
WQ8	Design and construction	Watercourse geomorphology	The potential for scour and erosion of watercourse bed and banks will be considered during the design of new discharge outlets. Construction work activities within or next to the watercourses and drainage lines will be minimised as much as reasonably practical to minimise disturbance of sediments in or near the waterway.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
WQ9	Design and construction	Local stormwater system capacity	Further design development will confirm the local stormwater system capacity to receive construction wastewater treatment plant inflows. If there is a stormwater infrastructure capacity issue with existing infrastructure, mitigation measures such as storage detention to control water outflow during wet weather events will be considered and implemented within the construction support site where feasible and reasonable.	BL/GHF
WQ10	Pre-construction and construction	Freshwater quality monitoring	<p>A freshwater quality monitoring program for the construction of the project will be developed and implemented, with consideration of the freshwater monitoring being carried out for the Western Harbour Tunnel and Warringah Freeway Upgrade project and the completed Northern Beaches Hospital road upgrade project.</p> <p>The program will be developed in consultation with the Environment Protection Authority, Department of Planning, Industry and Environment (Natural Resources Access Regulator), Department of Planning, Industry and Environment (Water), and relevant councils.</p> <p>Sampling locations and monitoring methodology including frequency and indicators will be in accordance with the <i>Guideline for Construction Water Quality Monitoring</i> (RTA, 2003a) and ANZG (2018).</p> <p>If exceedances of the criteria established under the freshwater monitoring program are detected, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented.</p>	BL

Ref	Phase	Impact	Environmental management measure	Location
WQ11	Construction	Wastewater discharge	<p>Discharges from wastewater treatment plants during the construction phase will be required to meet the following discharge criteria:</p> <ul style="list-style-type: none"> • The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and • The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 95 per cent species protection levels, and • The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water). 	BL/GHF
WQ12	Construction	Dredge plumes	<p>Monitoring of dredge plumes will be carried out during dredging activities to validate the dredge plume dispersion predictions. Exceedances of the predicted dredge plume extents and intensities will trigger subsequent management responses that will include a range of strategies including, assessing whether secondary impacts are occurring (eg seagrass stress) and if so then further levels of management actions will be implemented, such as adjustments to the dredging process.</p>	BL
WQ13	Construction	Watercourse geomorphology	<p>During construction, the drainage and adjustment works associated with Burnt Bridge Creek and an existing aboveground constructed drainage line within Flat Rock Reserve will be staged to ensure creek flows and velocities are not substantially changed and to avoid downstream erosion and bed and bank stability impacts.</p>	BL/GHF
WQ14	Construction	Sediment basin discharge	<p>Sediment basin discharge impact assessments, commensurate with the potential risk and consistent with the <i>National Water Quality Guidelines</i> (ANZG (2018)) and <i>Managing Urban Stormwater – Soils and Construction, Volume 1</i> (Landcom, 2004) will be prepared to inform the criteria for discharge from sediment basins.</p>	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
WQ15	Construction	Erosion and sedimentation	Disturbed floodplain environments next to the watercourses and/or along overland drainage lines should be stabilised as soon as practical following disturbance.	BL/GHF
WQ16	Construction	Marine water quality	<p>Management measures that will be implemented during dredging activities to minimise impacts on marine water quality, vegetation and habitats will include:</p> <ul style="list-style-type: none"> • Use of a backhoe dredge with a closed environmental clamshell bucket operated within a localised floating silt curtain enclosure to a depth of two to three metres to dredge the top layer of marine sediments • Implementation of 10 to 12 metre deep-draft silt curtains around the dredge works • Implementation of silt curtains in accordance with environmental management measures B31 to B33. 	BL
WQ17	Operation	Wastewater discharge	<p>The Gore Hill Freeway wastewater treatment plant will be designed to treat wastewater generated from tunnel groundwater ingress and rainfall runoff in tunnel portals and the following discharge criteria:</p> <ul style="list-style-type: none"> • The relevant physical and chemical stressors set out in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), and • The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels, and • The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water). 	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
WQ18	Operation	Operational monitoring	<p>Operational phase monitoring of surface water quality of sensitive receiving environments will be described in the operational surface water quality monitoring program and carried out in line with the post construction phase requirements of the <i>Roads and Maritime Guideline for Construction Water Quality Monitoring</i> (RTA, 2003a).</p> <p>As a minimum, monthly monitoring will be carried out for the first year of operation or until a suitably qualified and experienced independent expert determines that a site has adequately stabilised and stormwater basin discharge criteria are achieved.</p> <p>Should discharge criteria from operational stormwater basins be exceeded, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented.</p>	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 18

Flooding

18 Flooding

This chapter outlines the potential flooding impacts associated with the project and identifies measures to address these impacts. Detailed flooding assessments have been carried out for the project and are included in Appendix R (Technical working paper: Flooding).

The Secretary’s environmental assessment requirements as they relate to flooding, and where in the environmental impact statement these have been addressed, are detailed in Table 18-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. The environmental management measures proposed to minimise the potential impacts in relation to flooding are included in Section 18.8.

Table 18-1 Secretary’s environmental assessment requirements – flooding

Secretary’s requirement	Where addressed in EIS
<p>1. The EIS must map the following features relevant to flooding as described in the <i>NSW Floodplain Development Manual 2005</i> (NSW Government, 2005) including:</p> <ul style="list-style-type: none"> a. Flood prone land; b. Flood planning areas, the area below the flood planning level; c. Hydraulic categorisation (floodways and flood storage areas); d. Flood Hazard. 	<p>Figures containing maps of features relevant to flooding are listed below:</p> <ul style="list-style-type: none"> a. Flood prone land – Figure 4.4 of Appendix R (Technical working paper: Flooding) b. Flood planning areas, the area below the flood planning level – Figure 4.7 of Appendix R (Technical working paper: Flooding) c. Hydraulic categorisation (floodways and flood storage areas) – Figure 4.5 of Appendix R (Technical working paper: Flooding) d. Flood Hazard – Figure 4.6 of Appendix R (Technical working paper: Flooding).
<p>2. The Proponent must assess (and model where required), the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including:</p>	<p>Section 18.3 sets out the approach that was adopted to assess the impact the project would have on flood behaviour during both its construction and operation. Section 18.5 and Section 18.6 detail the findings of the impact assessment for construction and operation respectively.</p>
<ul style="list-style-type: none"> a. How the tunnel entries and cut-and-cover sections of the tunnels would be protected from flooding during construction works; 	<p>Section 18.5.1 summarises the findings of the assessed flood risk at the temporary construction support sites that would be used to support tunnel excavation and the construction of cut and cover sections of tunnel, while Section 18.8 contains a set of measures which are aimed at managing the flood risk during tunnel construction.</p>

Secretary's requirement	Where addressed in EIS
b. Any detrimental increases in the potential flood affectation of the project infrastructure and other properties, assets and infrastructure;	Sections 18.5 and Section 18.6 present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project, respectively.
c. Consistency (or inconsistency) with applicable Council floodplain risk management plans;	Section 18.6.3 presents the findings of a review of the project in terms of its consistency with council floodplain risk management plans.
d. Compatibility with the flood hazard of the land;	Section 18.4 describes the existing flood behaviour in the vicinity of the project, including an overview of the provisional flood hazard for a 1% Annual Exceedance Probability (AEP) flood. Section 18.5.1 includes discussion on the potential flood hazard at proposed temporary construction support sites, Section 18.5.2 includes discussion of potential flood risk at temporary construction support sites, while Section 18.6 includes discussion on the findings of the assessment in terms of the impact that the operation of the project would have on the hazard categorisation of the floodplain.
e. Compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land;	Section 18.4 describes the existing flood behaviour in the vicinity of the project, including the hydraulic categorisation of the floodplain into floodways, flood storage and flood fringe for a 1% AEP flood. Sections 18.5 and Section 18.6 describe the impacts on flood behaviour as a result of changes to flow conveyance and flood storage across the floodplain.
f. Whether there will be adverse effect to beneficial inundation of floodplain environment, on, or adjacent to or downstream of the site;	Due to the urbanised nature of the floodplain, no areas have been identified where there would be an adverse effect caused by a reduction in inundation. Section 18.5 and Section 18.6 present the findings of an assessment of more general impacts of the project on flood behaviour, including changes in the extent of inundation.
g. Downstream velocity and scour potential;	Section 18.5 identifies potential impacts that the construction of the project could have on velocity and scour potential, while Section 18.6 presents the findings of the assessment of impacts during the operation of the project.
h. Impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the	Section 18.6 provides an assessment of the proposed works and its impact on transport infrastructure that may be relied upon as part of community emergency management arrangements.

Secretary's requirement	Where addressed in EIS
State Emergency Services and Council;	<p>Section 18.8 sets out environmental management measures, including consultation with State Emergency Services and relevant councils and incorporation of flood emergency management measures into the relevant project environmental and/or safety documentation.</p> <p>Appendix E (Community consultation framework) identifies councils and State Emergency Services as key stakeholders, with engagement to continue into the next phases of the project.</p>
i. Any impacts the development may have on the social and economic costs to the community as consequence of flooding;	<p>Section 18.5 and Section 18.6 present the findings of an assessment of the potential impacts on flood behaviour during the construction and operational phases of the project respectively, including consideration of social impacts (such as impacts on emergency response arrangements and disruption to the community) and economic impacts (such as the potential for increases in flood damages in adjacent development due to an increase in above floor inundation).</p>
j. Whether there will be direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and	<p>Section 18.5 identifies potential impacts that the construction of the project could have on erosion, siltation and the stability of watercourses, while Section 18.6 presents the findings of an assessment of the corresponding impacts during the operation of the project.</p>
k. Any mitigation measures required to offset potential flood risks attributable to the project (these mitigation measures must be discussed with the State Emergency Services and Council where appropriate).	<p>Section 18.8 outlines potential measures to mitigate construction and operational related impacts of the project on flooding conditions (and therefore the potential for increased flood risk) in adjacent development and to manage the risk of flooding to the project.</p> <p>Appendix E (Community consultation framework) identifies councils and State Emergency Services as key stakeholders, with engagement to continue into the next phases of the project.</p>
3. The assessment should take into consideration any flood studies undertaken by local government councils, as available.	<p>Section 18.3 identifies the flood studies used in the assessment of flooding impacts.</p>
4. The EIS must assess and model the effect of the proposed development (including fill) on current flood behaviour for the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in	<p>Section 18.6.5 provides an assessment of the impact the project would have on flood behaviour under future climate change conditions.</p>

Secretary's requirement	Where addressed in EIS
rainfall intensity of flood producing rainfall events due to climate change.	

18.1 Flooding terminology and concepts

18.1.1 Annual exceedance probability

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (AEP). For example, for a flood magnitude having 10% AEP, there is a 10 per cent probability (or 1 in 10 chance) that there would be floods of greater magnitude each year. Similarly, for a flood magnitude having 1% AEP, there is a one per cent probability (or 1 in 100 chance) that there would be floods of greater magnitude each year.

18.1.2 Probable maximum flood

The Probable Maximum Flood (PMF) occurs as a result of the Probable Maximum Precipitation on the study catchments. The PMF is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism in regard to rainfall production. Meaning, the PMF is defined as the upper limiting value of floods that could reasonably be expected to occur and defines the extent of flood prone land (ie the floodplain).

18.2 Legislative and policy framework

The assessment of potential flooding impacts of the project on existing flood regimes has been conducted in accordance with relevant national, state and local government legislation, policies and technical guidelines. The assessment has adhered to:

- National-level:
 - *Australian Rainfall Runoff (ARR) 1987* (Institution of Engineers Australia, 1987), with a sensitivity analysis of the recently released ARR 2019 edition (Ball et al., 2019)
 - *Australian Disaster Resilience Handbook 7: Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR) 2017 edition (Australian Institute for Disaster Resilience, 2017)
- State-level:
 - *Floodplain Development Manual (FDM) 2005* (NSW Government, 2005)
 - *Guideline on Development Controls on Low Risk Flood Areas 2007* (Department of Planning, 2007)
 - *Environmental Planning and Assessment Act 1979*
 - *Floodplain Risk Management Guidelines: Practical Considerations of Climate Change 2007* (DECC, 2007)
- Local-level:
 - Warringah Local Environmental Plan (LEP) 2011
 - Manly LEP 2013
 - Willoughby LEP 2012
 - North Sydney LEP 2013
 - Mosman LEP 2012.

18.3 Assessment methodology

The key tasks comprising the flooding and drainage assessment are broadly described as follows:

- Review of available data including existing flood studies and associated hydrologic and hydraulic models (collectively referred to as 'flood models') within the catchment that are crossed by the project, including:
 - Manly Lagoon Floodplain Risk Management Study and Plan (WMA, 2018)
 - *Flat Rock Creek Catchment Flood Study and Overland Flow Mapping Volume 1* (Lyll and Associates, 2018)
 - North Sydney Flood Study (WMA, 2016)
 - Fort Denison Sea Level Rise Vulnerability Study (Watson & Lord, 2008)
- Update of the existing flood models where required to more accurately define flooding and drainage behaviour in the vicinity of the project
- Application of the ARR 1987 methodology (and recently released 2019 ARR sensitivity analysis) for design flood estimation
- Preparation of figures showing flood behaviour under present day conditions for design floods with AEPs of 10%, 1%, 0.5% and 0.2%, as well as the PMF
- Assessment of the potential flood risks during construction and the operational features of the project
- Assessment of the impact future climate change would have on flood behaviour while under construction and during operational conditions
- Assessment of the impact a partial blockage of the local stormwater drainage system would have on flood behaviour under operational conditions
- Assessment of potential measures which are aimed at mitigating the risk of flooding to the project and its impact on existing flood behaviour
- Development of hydrologic models to assess the impact the upgrade of the Wakehurst Parkway would have on peak flows and hence scour potential in the receiving drainage lines that drain to Bantry Bay and Manly Creek
- Assessment of potential measures which are aimed at mitigating the risk of scour in the aforementioned receiving drainage lines.

Further detail and information in respect to the methodology for each of the key tasks above is outlined in Appendix R (Technical working paper: Flooding).

18.4 Existing environment

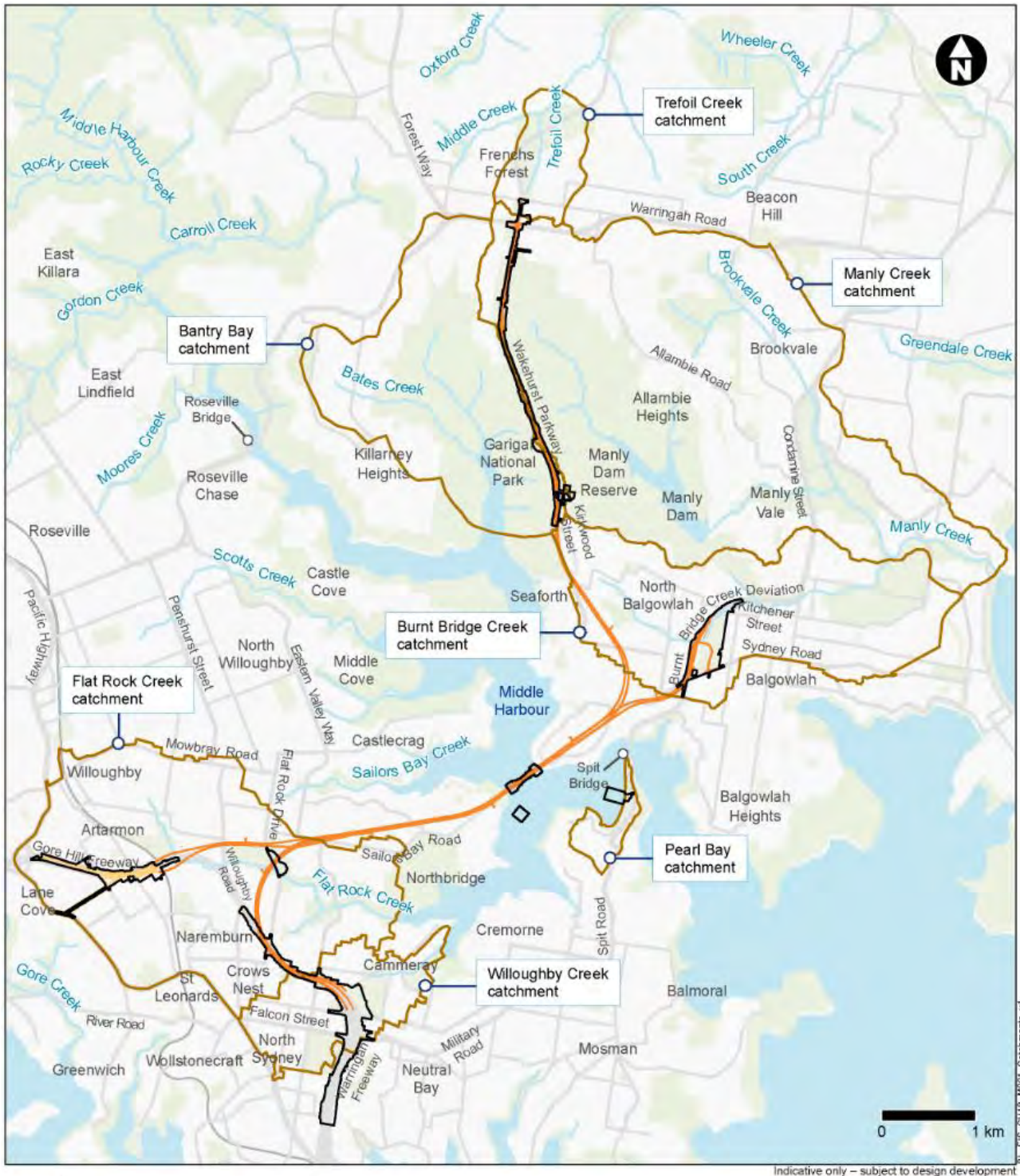
18.4.1 Overview

The following catchments contribute runoff to the existing drainage systems and waterways that are located within the project footprint (Figure 18-1):

- Willoughby Creek
- Flat Rock Creek
- Pearl Bay (within Middle Harbour)
- Burnt Bridge Creek (a sub-catchment of Manly Lagoon)
- Bantry Bay
- Manly Creek (a sub-catchment of Manly Lagoon)

- Trefoil Creek (a sub-catchment of Narrabeen Lagoon).

The catchments outlined above drain to either Middle Harbour, Manly Lagoon or Narrabeen Lagoon. Section 18.4.2 provides a brief overview of each catchment, while Section 18.4.3 provides a description of the nature of mainstream flooding and major overland flow in the vicinity of the project under present day (ie pre-project) conditions. Mainstream flooding, major overland flow and ocean storm tide flooding have collectively been termed ‘flooding’ within this chapter.



Legend

- | | | |
|------------------------------|------------------------------|---------------------------------|
| Operational features | Construction features | Catchments and waterways |
| Beaches Link | Construction footprint | Catchment boundary |
| Gore Hill Freeway Connection | | Waterways |

Figure 18-1 Catchment areas

A general description of the geomorphology and water quality of the existing catchment and watercourse environments is provided in Chapter 17 (Hydrodynamics and water quality). Chapter 17 (Hydrodynamics and water quality) also details the existing drainage infrastructure and surface water and surface water management infrastructure of the study area. This section outlines:

- Catchments and their drainage characteristics
- The existing flood behaviour of each catchment.

18.4.2 Catchment areas

The following sections provide an overview of each catchment that drains to and from the project corridor, including information regarding key drainage features, as well as the source of flows for the existing drainage lines that cross the project.

Figure 18-1 shows an overview of the catchment areas subject to the project, while Figure 4.1 of Appendix R (Technical working paper: Flooding) shows more detail of the existing drainage systems and catchment features along the project corridor and should be read in conjunction with the information detailed below.

Willoughby Creek

The Willoughby Creek catchment drains in a north-easterly direction, extending from the Pacific Highway in North Sydney and has a total catchment area of about 1.5 square kilometres (150 hectares) at Grafton Street. The catchment is located within the North Sydney local government area and includes the suburbs of North Sydney, Crows Nest, Neutral Bay, Cremorne and Cammeray.

The Warringah Freeway runs north-south through the middle reaches of the catchment, which predominantly comprises medium density residential development with areas of higher density residential and commercial development also present within its upper reaches. Areas of open space in the catchment include St Leonards Park, ANZAC Park, Cammeray Golf Course and Green Park. ANZAC Park School is located on the western (upstream) side of the Warringah Freeway, immediately north of ANZAC Park.

A series of drainage systems comprising pipe and box culvert sections control runoff from the catchment upstream of the Warringah Freeway and converge at ANZAC Park where they discharge into twin 2000 millimetre wide by 1500 millimetre high box culvert where the drainage line crosses under the Warringah Freeway. A series of piped drainage systems that control runoff from the Warringah Freeway discharge directly into the box culvert. This drainage line continues downstream through Cammeray Golf Course as a 2500 millimetre wide by 1500 millimetre high box culvert. At Grafton Street the box culvert outlets into a steep gully in the north-east corner of Primrose Park where it runs along the northern side of the park as a grassed channel before ultimately discharging into Middle Harbour.

Flat Rock Creek

The Flat Rock Creek catchment drains in an easterly direction from the Pacific Highway in Artarmon and has a total catchment area of about 3.9 square kilometres (390 hectares) at Willoughby Road. The catchment is located within the Willoughby local government area and includes the suburbs of Artarmon, St Leonards, Naremburn, Willoughby, Northbridge and Cammeray.

The catchment is completely urbanised and the natural drainage characteristics have been altered by industrial, residential and commercial development. The construction of the Gore Hill Freeway in 1991 along the route of the original creek has altered the natural drainage system and its flood storage characteristics. The T1 North Shore and Western Line and T9 Northern Line runs north-south through the middle reaches of the catchment.

A new trunk drainage system was constructed in conjunction with the Gore Hill Freeway, extending from the Pacific Highway to the T1 North Shore and Western Line and T9 Northern Line. The Gore Hill Freeway and its drainage system were later upgraded as part of the Lane Cove Tunnel project in 2006.

The trunk drainage system is piped where it runs along the southern side of Gore Hill Freeway from Marsden Street and crosses under the freeway at Hampden Road, via an existing transverse drainage structure. This drainage structure discharges into an open channel that continues along the northern side of the Gore Hill Freeway to a brick arch culvert under the T1 North Shore and Western Line and T9 Northern Line. Two existing transverse drainage structures control runoff from the north of the Gore Hill Freeway discharge into the trunk drainage system along this section. Two existing drainage structures that control runoff from the southern side of Gore Hill Freeway discharge into an open channel between Hampden Road and the T1 North Shore and Western Line (refer to Figure 17-2 of Chapter 17 (Hydrodynamics and water quality) for further details on the characteristics of Flat Rock Creek).

The trunk drainage system downstream of the T1 North Shore and Western Line and T9 Northern Line culvert to Willoughby Road was constructed in the 1930's and was not altered by the construction of the freeway. Between the railway and Chelmsford Avenue, the trunk drainage comprises a low level conduit running beneath a vegetated floodway which caters for surcharge (overflow) flows. A concrete and brick lined channel with a waterway area of 6.5 to 7.3 square metres comprises the main arm of Flat Rock Creek where it runs from Chelmsford Avenue to Willoughby Road.

As part of the trunk drainage for the Gore Hill Freeway, Artarmon Reserve was converted to a dual purpose playing field/retarding basin. The objective was to reduce the peaks of major stormwater flows which originate from the northern portion of the catchment, to offset the increase in peak flows generated by the freeway. The retarding basin was later modified as part of the Lane Cove Tunnel project to offset the impact that the widening of the Gore Hill Freeway would otherwise have had on peak flows in Flat Rock Creek.

At Willoughby Road, flows are conveyed through a stone arch bridge. During major flood events, the Willoughby Road bridge conveys flows derived from the Flat Rock Creek catchment, as well as surcharges from one of its tributaries. A major box culvert commences at the downstream face of the bridge and runs beneath Hallstrom Park before discharging to an open channel 150 metres to the east of Flat Rock Drive.

Pearl Bay

The Pearl Bay catchment drains in a westerly direction, extending from Spit Road in Mosman and has a total catchment area of about 0.27 square kilometres (27 hectares). The catchment is located within the Mosman local government area.

The Spit West Reserve construction support site (BL9) is proposed to be located at the northern end of the catchment within Spit West Reserve.

Burnt Bridge Creek

The Burnt Bridge Creek catchment drains in an easterly direction from the Wakehurst Parkway and has a total catchment area of about 3.4 square kilometres (340 hectares) at Condamine Street. The catchment covers the Northern Beaches local government area and includes the suburbs of Seaforth, North Balgowlah, Balgowlah, Manly Vale and Fairlight.

Burnt Bridge Creek Deviation runs north-south from Sydney Road to Condamine Street through the middle reaches of the catchment which predominantly comprises low and medium density residential development. Commercial development is mainly located along Condamine Street and Sydney Road. Open space is predominantly located within the middle and lower reaches of the catchment and includes Balgowlah Golf Course, Manly Golf Club, Manly West Park and LM Graham Reserve.

The main arm of Burnt Bridge Creek comprises a vegetated channel that extends from Clontarf Street in the west to Condamine Street in the east and includes culvert crossings at Brook Road, Burnt Bridge Creek Deviation and Kitchener Street. The culvert crossing of Burnt Bridge Creek Deviation comprises twin 3600 millimetre wide by 3600 millimetre high box culverts and twin 2400 millimetre wide by 2400 millimetre high box culverts. East (downstream) of Condamine Street the creek is drained by a box culvert that discharges into a vegetated channel that runs along the northern side of Manly West Park and through the Manly Golf Club before discharging into Manly Lagoon at Pittwater Road (refer to Figure 17-3 of Chapter 17 (Hydrodynamics and water quality) for further details on the characteristics of Burnt Bridge Creek).

A series of piped drainage lines cross Burnt Bridge Creek Deviation between Serpentine Crescent and Abingdon Street. The piped drainage lines control runoff from the catchment to the north of Burnt Bridge Creek Deviation and discharge into Burnt Bridge Creek along its northern bank.

Bantry Bay

The Bantry Bay catchment drains in a southerly direction from Warringah Road and has a total catchment area of about 4.8 square kilometres (480 hectares). Residential development is located in the upper northern and western portions of the catchment, while the Garigal National Park covers the majority of the middle and lower portions of the catchment.

The section of the project that runs along the Wakehurst Parkway between Grattan Crescent and Kirkwood Street generally follows the catchment divide between Bantry Bay and Manly Creek. Three minor drainage lines presently control runoff from this section of the Wakehurst Parkway which would be upgraded as part of the project.

Manly Creek

The Manly Creek catchment drains in a south easterly direction, extending from Warringah Road in the north and has a total catchment area of about 18.2 square kilometres (1820 hectares) at Manly Lagoon.

Manly Creek runs in a southerly direction to the east of Wakehurst Parkway. A series of piped crossings along the Wakehurst Parkway control runoff from the residential development and nature reserve to the west of the road. The largest of these piped drainage systems comprises a 2400 millimetre wide by 1800 millimetre high box culvert and a 750 millimetres diameter pipe located about 140 metres south of Warringah Road, and a 1200 millimetre diameter pipe located immediately south of Yarraman Avenue. The piped crossings discharge into receiving drainage lines that feed into Manly Creek.

Manly Dam was originally constructed across Manly Creek in the late 1800's to supply drinking water to the local area. The dam continued to supply drinking water until 1936, after which time it became an important recreational facility for the local area and beyond. The dam has a capacity of approximately 2000 megalitres and its water body is sheltered and deep (in most parts) with a surface area of approximately 0.3 square kilometres (30 hectares).

Trefoil Creek

A relatively small section of the project along the Wakehurst Parkway at its connection to Frenchs Forest Road East is located within the headwaters of the Trefoil Creek catchment, runoff from which discharges into Middle Creek. The Trefoil Creek catchment is about 0.97 square kilometres (97 hectares) at its confluence with Middle Creek.

Trefoil Creek is fed by several piped drainage systems which discharge to the steep sided valley to the east of the Wakehurst Parkway and north of Frenchs Forest Road East. These piped drainage systems control runoff from sections of Frenchs Forest Road East, the Wakehurst Parkway and Bantry Bay Road, as well as the north east portion of the Northern Beaches Hospital.

18.4.3 Existing flooding and drainage characteristics

A brief description of patterns of both mainstream flooding and major overland flow is provided below with respect to present day (ie pre-project) conditions within areas in the vicinity of construction and/or operational components of the project.

The patterns of mainstream flooding and major overland flow are classified using Annual Exceedance Probability and Probable Maximum Flood which, as outlined in Section 18.1 above, are defined as follows:

- Annual Exceedance Probability (AEP)
 - 10% AEP – there is a 10 per cent probability (or 1 in 10 chance) that there would be floods of greater magnitude each year
 - 1% AEP – there is a one per cent probability (or 1 in 100 chance) that there would be floods of greater magnitude each year
- Probable Maximum Flood (PMF) – the upper limiting value of floods that could reasonably be expected to occur (the result of the most severe combination of meteorological conditions) and defines the extent of flood prone land (ie the floodplain).

Flooding behaviour has been defined using the hydrologic and hydraulic models that were developed as part of the studies informing this assessment (see Appendix R (Technical working paper: Flooding) for more information). It should be noted the discussion below considers flooding patterns for the AEP and PMF in catchment areas for which impacts are predicted. As such, the existing AEP and PMF flood impacts are not reported for all catchment areas. A discussion of flooding patterns is provided for those catchments where the AEP and PMF flood impacts are not reported.

Figure 18-2 to Figure 18-8 show the flooding behaviour for each of the catchments in the 1% AEP event (for the existing flooding behaviour in the 10% AEP, 1% AEP and PMF events for all catchments, refer to Figures 4.2 to 4.4 in Appendix R (Technical working paper: Flooding)).

Willoughby Creek

Up to 1% AEP

During a 10% AEP event, flow would surcharge the trunk drainage system that forms the main arm of Willoughby Creek and overtop the sag in Ernest Street to the east of Lytton Street to a maximum depth of about 0.5 metres, increasing to 0.7 metres during a 1% AEP. Existing residential development located on the southern side of Ernest Street is also affected by flooding due to surcharge of the trunk drainage system. The main flow path which runs between St Leonards Park and ANZAC Park principally operates as a low hazard floodway, although high hazard areas are located near ANZAC Park, principally due to the depth of ponding that occurs in this area.

Flow that surcharges the tributary branch of Willoughby Creek that runs between Miller Street and ANZAC Avenue along the northern boundary of ANZAC Park Public School would overtop ANZAC Avenue to a maximum depth of about 0.2 metres during a 10% AEP event, increasing to 0.5 metres during a 1% AEP event.

Overland flow from Ernest Street and ANZAC Avenue would collect at the low point in ANZAC Park before entering the trunk drainage system that runs under the Warringah Freeway. The depth of ponding in ANZAC Park would occur to a maximum of 2.1 metres and 3.5 metres during a 10% and 1% AEP event, respectively, which is sufficient to result in hazardous flooding conditions to persons and property.

Floodwaters that collect in ANZAC Park would pond against the noise wall that runs along the western side of the Warringah Freeway to a maximum depth of about three metres during a 1% AEP event. If the noise wall were to fail under this weight of water, then floodwater would inundate the Miller Street off-ramp to a maximum depth of about two metres and extend across the northbound carriageways of the freeway.

During a 1% AEP storm event, a low and high hazard floodway would form to the north (downstream) of the road corridor near Cammeray Golf Course. The floodway area also extends east into an existing residential development which is located along Fall Street and Grafton Street.

PMF

Floodwaters that collect in ANZAC Park would build up to a level that overtops the noise wall that is located along the western side of the Warringah Freeway, where it would pond across the full width of the freeway before surcharging across its eastern side and into Cammeray Golf Course.

ANZAC Park would be inundated to a maximum depth of seven metres, while the carriageways of the Warringah Freeway would be inundated over a length of about 350 metres and to a maximum depth of five metres. The flood walls associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project (subject to separate environmental impact assessment and approval) would prevent the ingress of floodwater to the road tunnels for events up to the PMF.

Flat Rock Creek

Up to 1% AEP

During a 10% AEP event flow in excess of the capacity of the existing stormwater drainage system would pond in the cul-de-sac of George Place to a maximum depth of about one metre. During a 1% AEP event, flow would pond to a maximum depth of 1.5 metres before discharging in a south-easterly direction through the adjoining industrial development and onto the eastbound carriageway of the Gore Hill Freeway.

The eastbound carriageway of the Gore Hill Freeway acts as an overland flowpath during a 1% AEP event, conveying flows that surcharge the existing transverse drainage structures located in the vicinity of George Place and Reserve Road. Depths of overland flow would typically be less than 0.2 metres but would reach up to 0.4 metres at two locations.

During a 10% AEP event, flow that surcharges the trunk drainage system in McLachlan Avenue would travel in an easterly direction along the shared bicycle path to the south of the Gore Hill Freeway before discharging onto the westbound carriageway north of Hotham Street.

The westbound carriageway of the Gore Hill Freeway acts as an overland flowpath during a 1% AEP event, conveying flow that surcharges the drainage systems in McLachlan Avenue, Hotham Parade and Whiting Street. Flow along the eastbound carriageway would collect at the sag below the Reserve Road overpass and ponds to a maximum depth of 0.7 metres before continuing in a southerly direction.

During a 1% AEP event, flow that surcharges the existing transverse drainage structures located between Herbert Street and the T1 North Shore and Western Line and T9 Northern line also contributes to overland flow travelling east along the eastbound carriageway of the Gore Hill Freeway.

PMF

The main carriageways and various existing entry and exit ramps of the Gore Hill Freeway are inundated by floodwater that discharges from the north at George Place, Reserve Road, and Simpson Street, and from the south at McLachlan Avenue, Hotham Parade Whiting Street, Herbert Street and Punch Street.

While the majority of flow that discharges from George Place is conveyed in an easterly direction along the eastbound carriageway, a portion of this flow discharges onto the central carriageways where it enters the Lane Cove Tunnel.

Similarly, while the majority of flow that discharges from McLachlan Avenue is conveyed in an easterly direction along the westbound carriageway, a portion of the flow discharges onto the central carriageways where it would enter the Lane Cove Tunnel.

The section of Gore Hill Freeway between Reserve Road and the T1 North Shore and Western Line and T9 Northern Line is inundated across its full width. Depths of flow are typically 1.2 metres or less but would reach a maximum of 1.8 metres at one location.

Flood levels upstream (west) of the T1 North Shore and Western Line and T9 Northern Line are controlled by the rail underpass, which constricts overland flow travelling along the Gore Hill Freeway.

Pearl Bay

The area of Spit West Reserve where the Spit West Reserve construction support site (BL9) is proposed to be located would be inundated by overland flow that is conveyed along the southbound carriageway of Spit Road and discharges into the reserve via the carpark entry from Spit Road for events up to the PMF.

Burnt Bridge Creek

Up to 1% AEP

The existing culvert crossing of Burnt Bridge Creek at Burnt Bridge Creek Deviation has a hydrologic standard in excess of 1% AEP under ideal flow conditions.

While flow would generally be confined to the incised valley through which Burnt Bridge Creek runs between Brook Road and Kitchener Street, residential development located on the southern overbank of the creek in Brook Road, Hope Street and Burnt Bridge Creek Deviation would be inundated by floodwater during a 1% AEP event.

Flow that surcharges existing transverse drainage structures would pond behind the noise wall located along the western side of Burnt Bridge Creek Deviation between Serpentine Crescent and Kitchener Street, with a portion of this flow discharging onto Burnt Bridge Creek Deviation via openings which are present in the noise wall adjacent to Kitchener Street during a 10% AEP event.

Flow would overtop the western bank of Burnt Bridge Creek immediately upstream of Kitchener Street and discharge onto the southbound carriageway of Burnt Bridge Creek Deviation during a 10% AEP event.

PMF

Flow in excess of the existing transverse drainage structure (culvert crossing of Burnt Bridge Creek at Burnt Bridge Creek Deviation) would overtop Burnt Bridge Creek Deviation to a maximum depth of about one metre. A portion of this flow would re-enter Burnt Bridge Creek to the east of the road corridor, while the remaining flow would travel in a northerly direction along both the northbound and southbound carriageways.

Flow that surcharges the existing transverse drainage structures would pond behind the noise wall that runs along the western side of Burnt Bridge Creek Deviation before discharging onto the road in the vicinity of the Kitchener Street bridge.

Flow would overtop the western bank of Burnt Bridge Creek immediately upstream of Kitchener Street where it discharges onto both the northbound and southbound carriageways of Burnt Bridge Creek Deviation. The depth of flow along Burnt Bridge Creek Deviation would reach a maximum of about two metres near the Kitchener Street bridge.

Bantry Bay

The section of the Wakehurst Parkway between Grattan Crescent and Kirkwood Street generally follows the catchment divide between Manly Creek and Bantry Bay and is not affected by mainstream flooding or major overland flow.

Manly Creek

Up to 1% AEP

During a 1% AEP event, flow that surcharges the piped drainage system in the Wakehurst Parkway at its intersection with Warringah Road would inundate the road to relatively shallow depths that are typically 0.1 metres or less.

Flow that discharges from the drainage system at the northern end of Bantry Bay Road would pond at the inlet of the 1050 millimetre diameter pipe that crosses the Wakehurst Parkway about 140 metres south of Warringah Road. During a 1% AEP event, this ponding would have a maximum depth of over two metres but would not surcharge onto the road.

During a 1% AEP event, flow that surcharges the two pipe crossings of the Wakehurst Parkway between Garner Avenue and Yarraman Avenue would inundate the road to depths typically 0.2 metres or less.

Flow that discharges from the drainage system at the eastern end of Yarraman Avenue would pond at the inlet of the 1200 millimetre diameter pipe that crosses Wakehurst Parkway immediately to its south. During a 1% AEP event, this ponding would have a maximum depth of over two metres but would not surcharge onto the road.

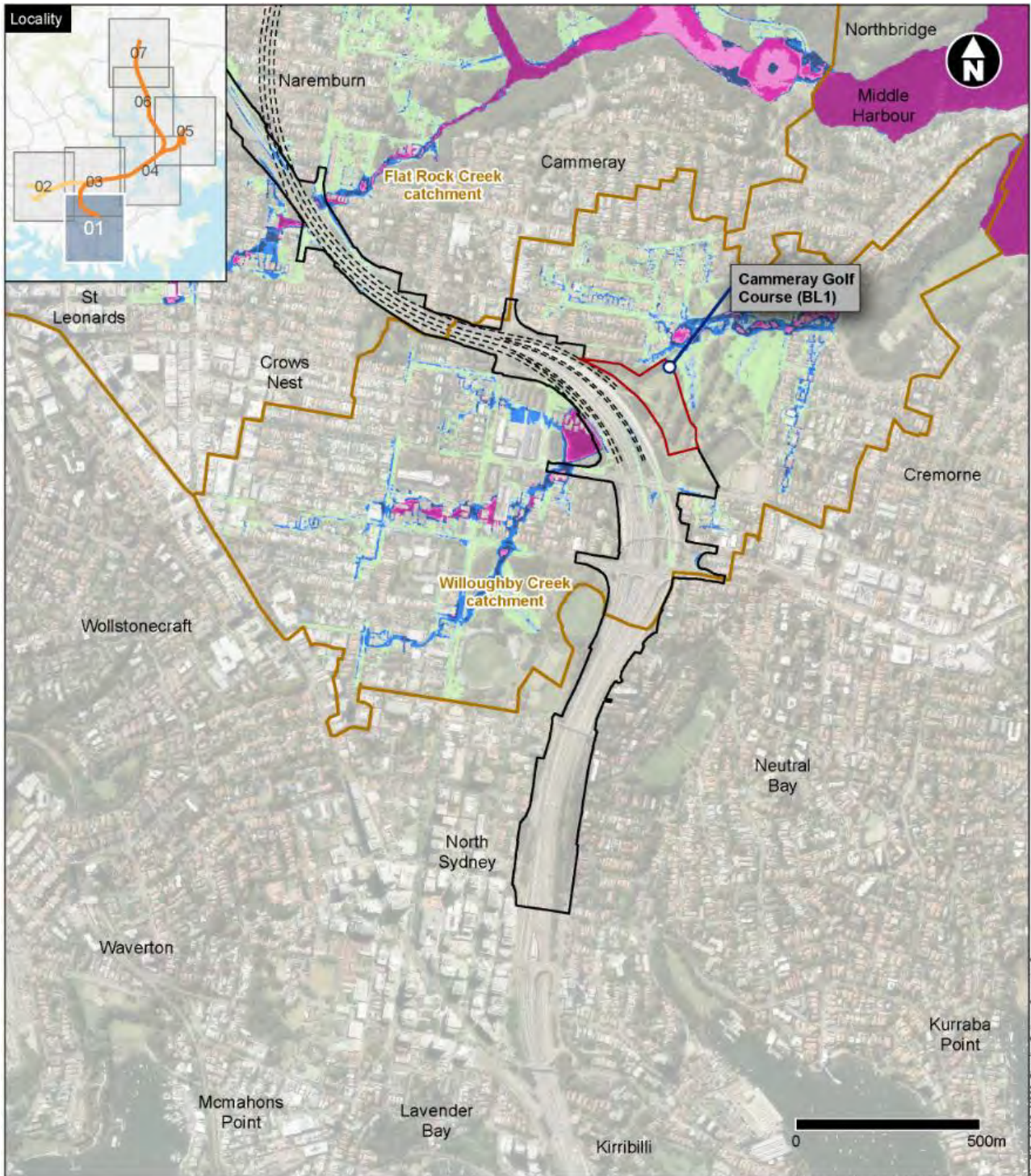
PMF

The hydraulic model developed as part of the Manly Lagoon Floodplain Risk Management Study and Plan (WMA, 2018) has been configured in a way that applies inflows downstream of Wakehurst Parkway and therefore does not show flooding to the road corridor or any of the areas upstream during a PMF event. Flow would, however, inundate the Wakehurst Parkway at the locations described above to a greater depth during more extreme storm events.

Trefoil Creek

The section of the project along the Wakehurst Parkway that is located within the Trefoil Creek catchment is not impacted by mainstream flooding or major overland flow.

The Wakehurst Parkway was recently upgraded as part of the Northern Beaches Network Connectivity and Enhancements project. Figure 4.1 of Appendix R (Technical working paper: Flooding) shows the layout of the upgraded drainage system along the Wakehurst Parkway, which has been designed to control runoff from the local catchment during storms up to 10% AEP in magnitude. During a 1% AEP event, overland flow would occur along the kerbside lanes of the Wakehurst Parkway due to surcharge of the drainage system.



Indicative only – subject to design development

BL_EIS_CH18_M002_Flooding/attenuation/v2

Legend

- Construction footprint
 - Construction support site
 - Tunnel section
 - Catchment boundary
- Indicative depth of inundation (m)**
- < 0.05
 - 0.05 - 0.10
 - 0.10 - 0.30
 - 0.30 - 0.50
 - 0.50 - 0.70
 - 0.70 - 1.00
 - > 1.00

Figure 18-2 Flood behaviour under present day conditions – 1% AEP event (map 1)

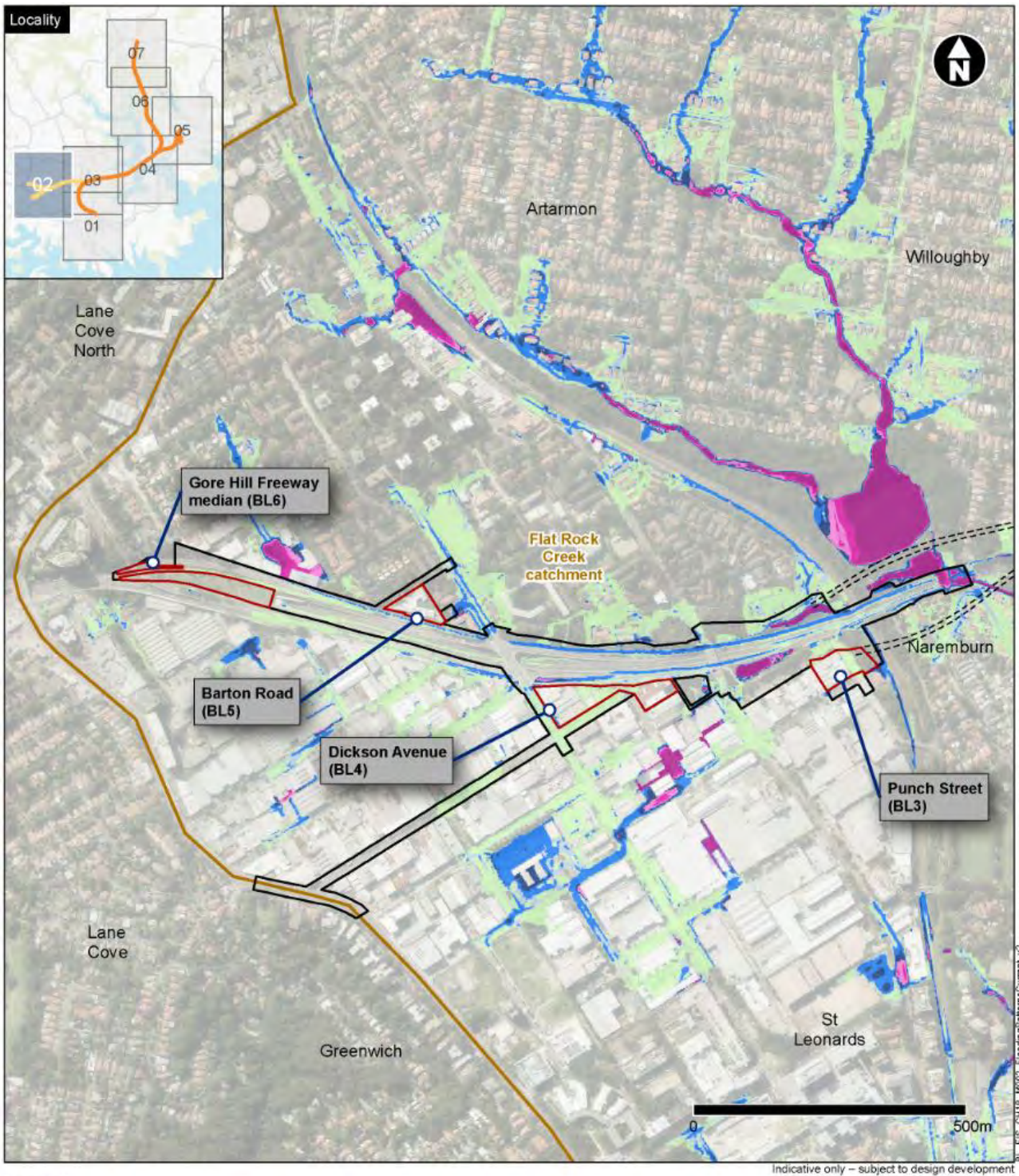
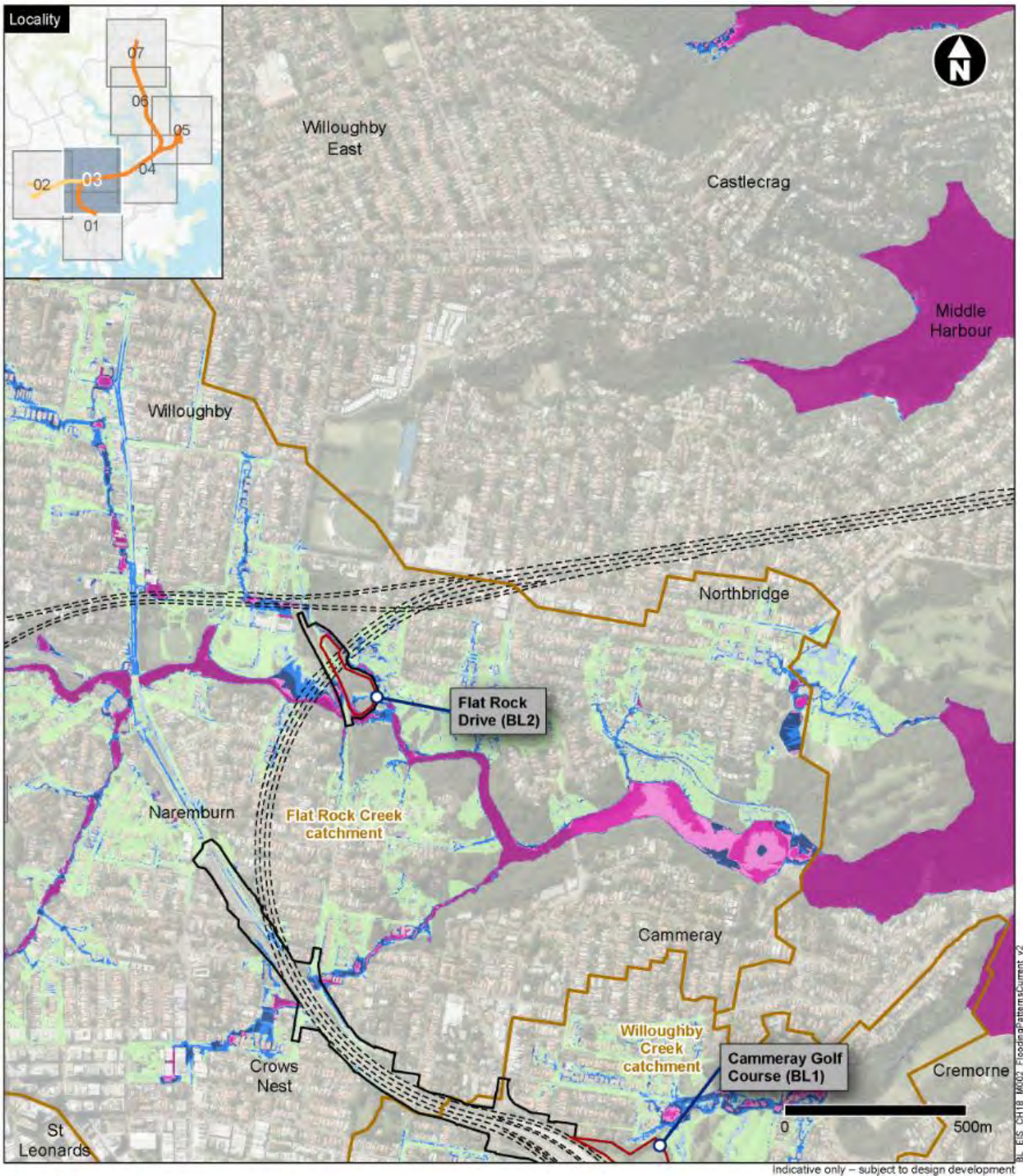


Figure 18-3 Flood behaviour under present day conditions – 1% AEP event (map 2)



Indicative only – subject to design development



Figure 18-4 Flood behaviour under present day conditions – 1% AEP event (map 3)

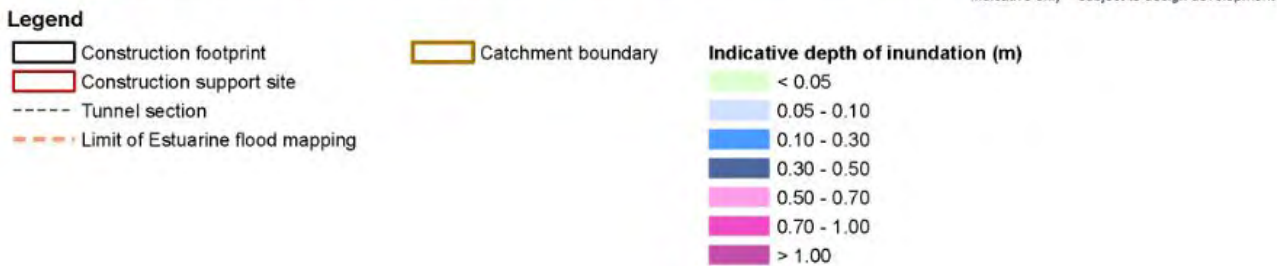
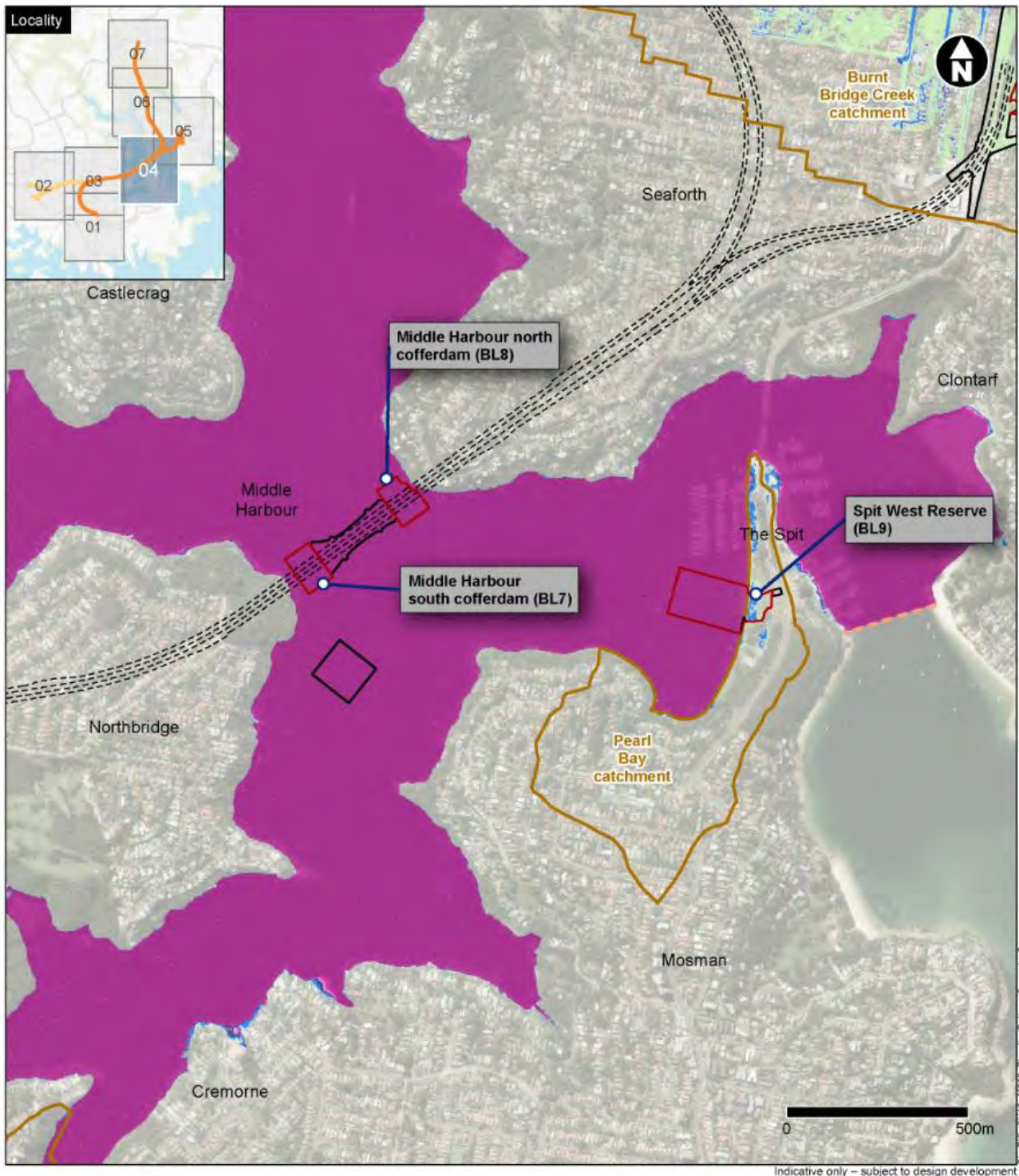


Figure 18-5 Flood behaviour under present day conditions – 1% AEP event (map 4)

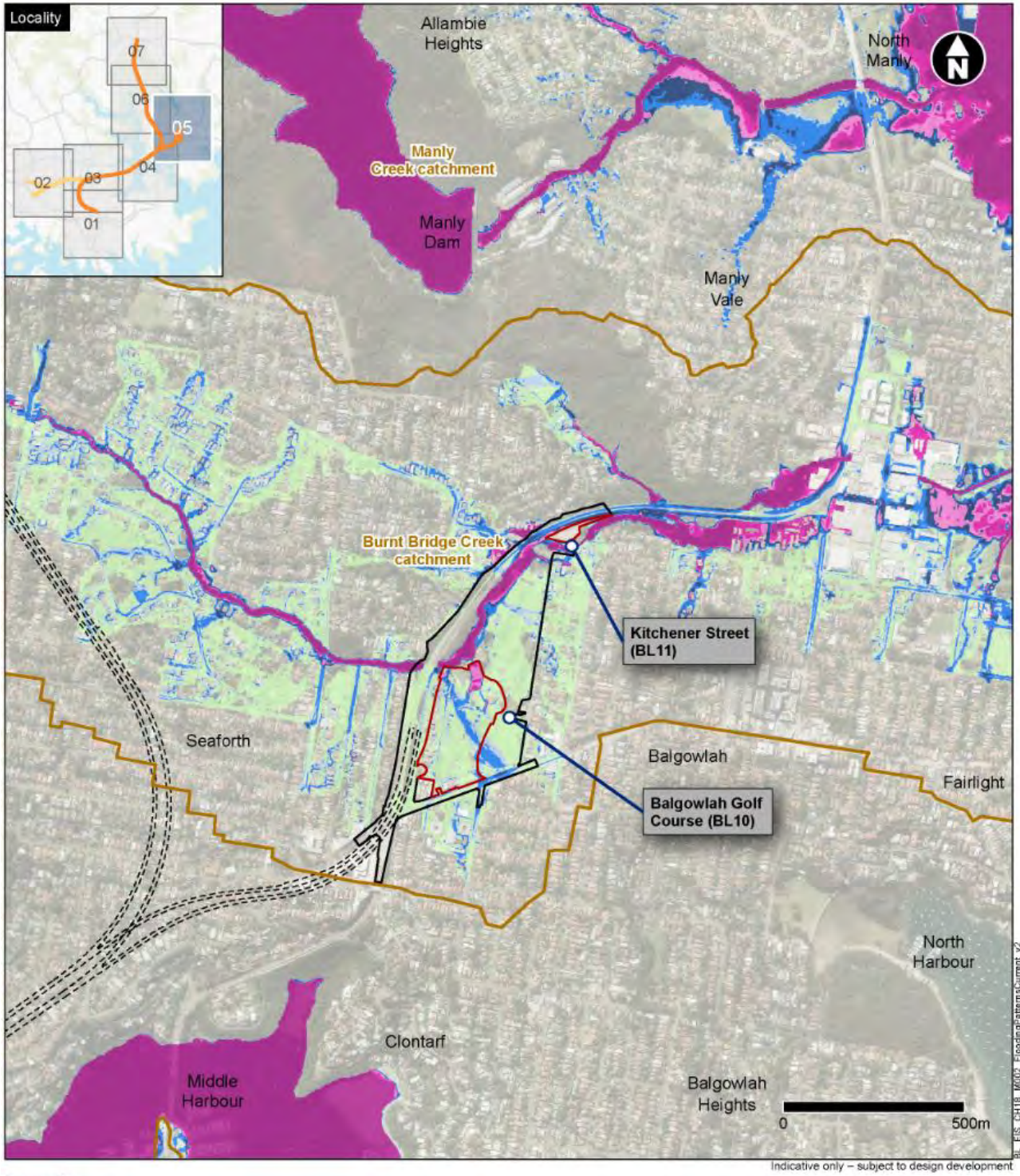


Figure 18-6 Flood behaviour under present day conditions – 1% AEP event (map 5)

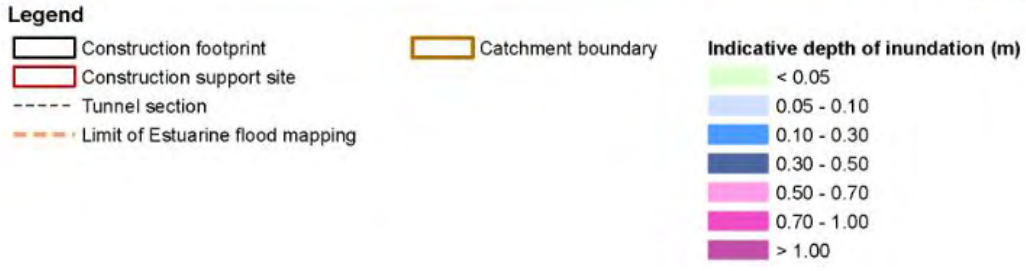
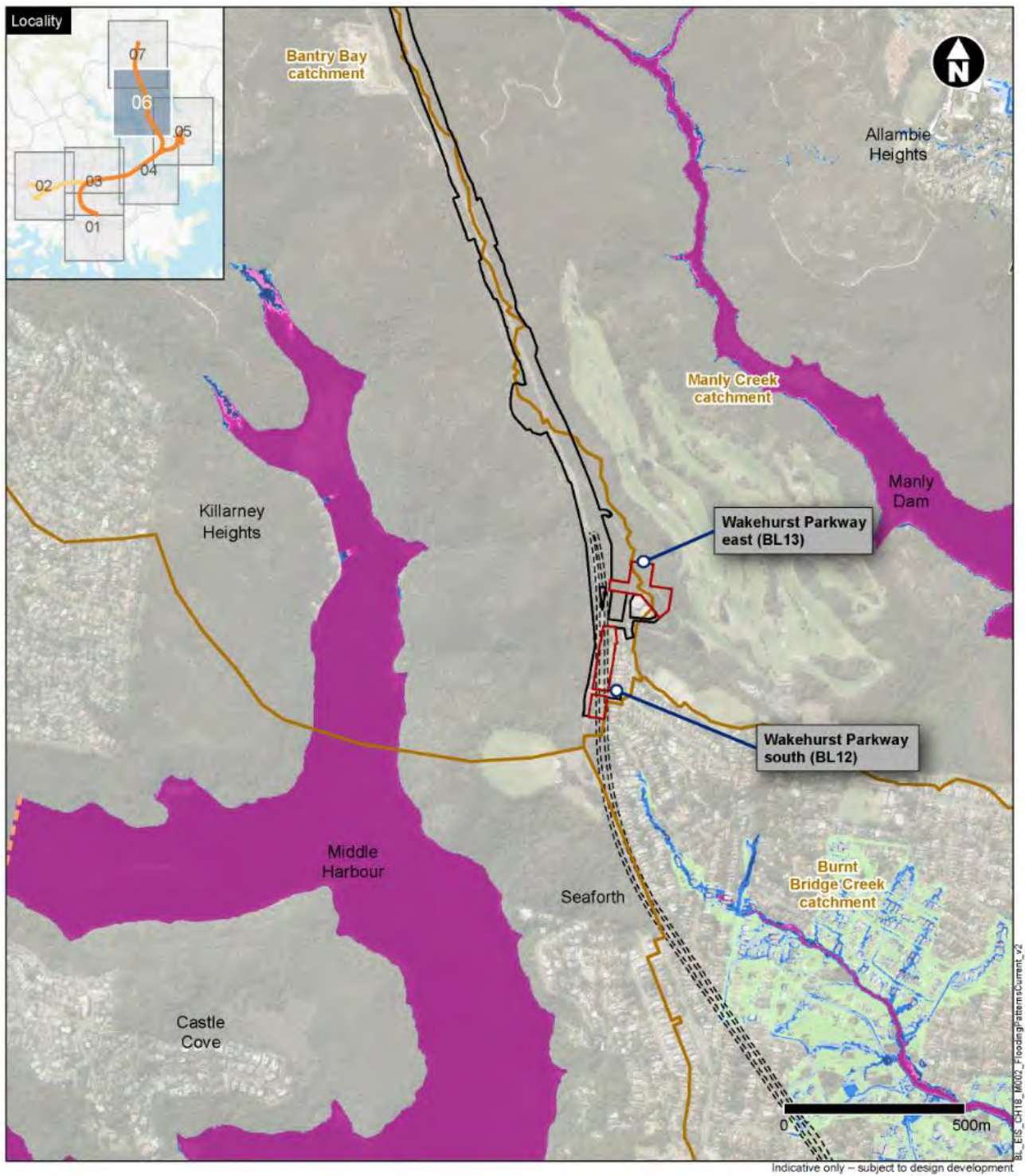
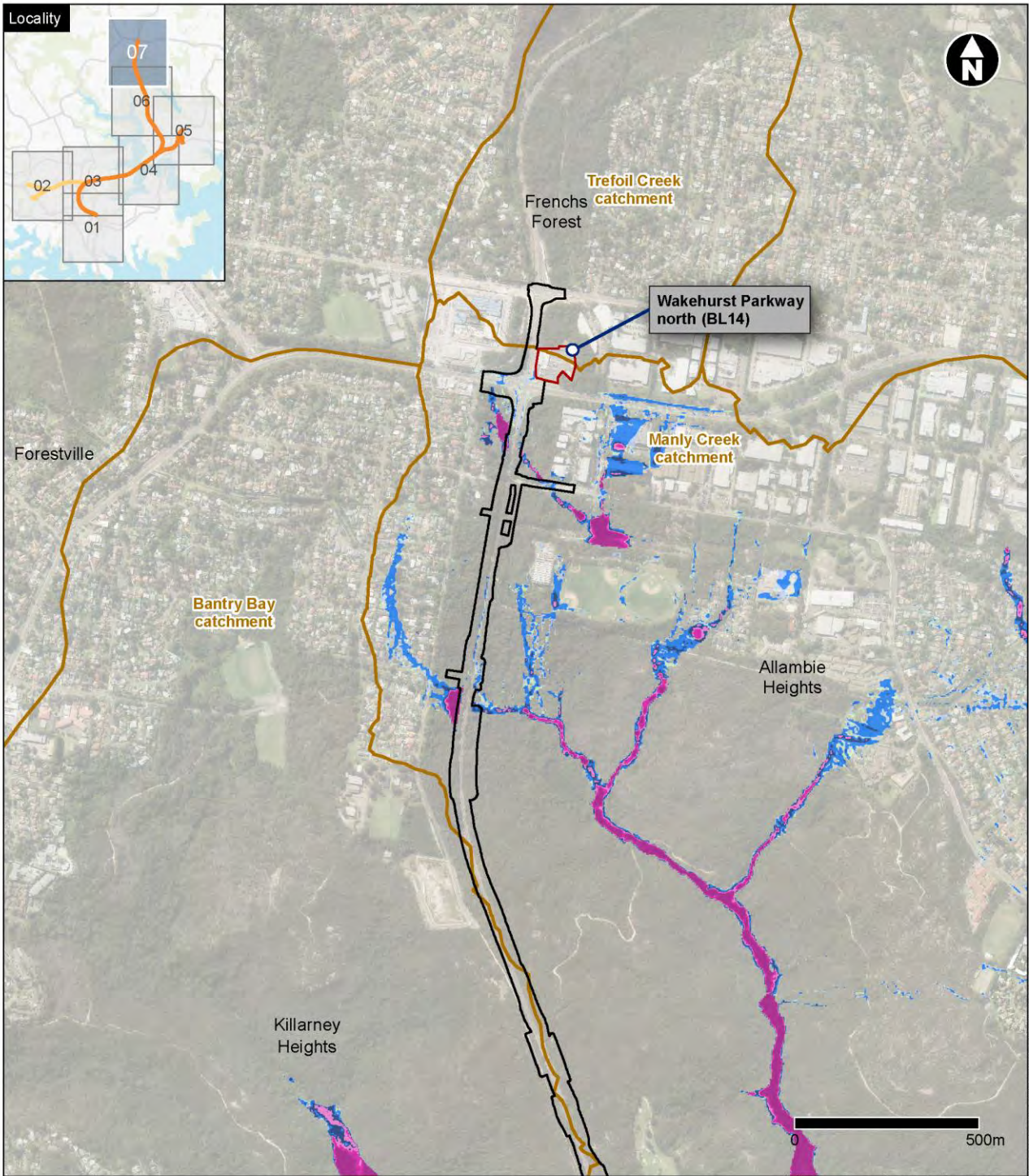


Figure 18-7 Flood behaviour under present day conditions – 1% AEP event (map 6)



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Indicative only – subject to design development

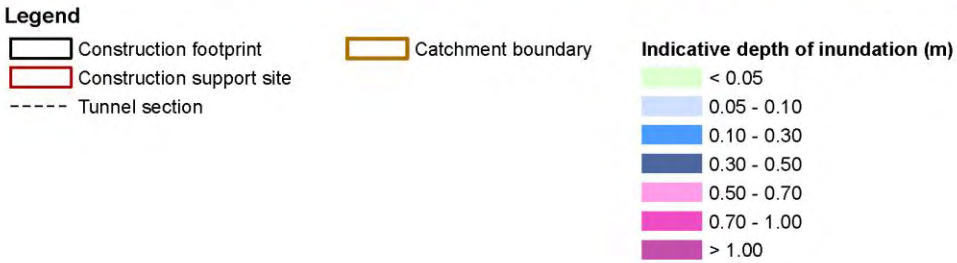


Figure 18-8 Flood behaviour under present day conditions – 1% AEP event (map 7)

18.5 Assessment of potential construction impacts

This section provides an assessment of the flood risk at the proposed temporary construction support sites which are associated with the construction of the Beaches Link and Gore Hill Freeway project. Details of the proposed temporary construction support sites, including proposed activities are outlined in Chapter 6 (Construction works).

This section also provides an overview of the potential impacts that the proposed construction activities could have on flood behaviour.

18.5.1 Potential impacts of construction activities on flood behaviour

Construction activities have the potential to exacerbate flooding conditions when compared to both present day and operational conditions. This is because the construction activities typically impose a larger footprint on the floodplain due to the need to provide temporary structures outside the operational project footprint which would be removed following the completion of construction activities.

A qualitative assessment was carried out of the potential impacts construction activities could have on flood behaviour, the key findings of which are summarised in Table 18-2.

While the majority of the temporary construction support sites would involve works within the floodplain that would need to be managed, the assessment found that the greatest potential for adverse impacts on flood behaviour in adjacent development is associated with Balgowlah Golf Course construction support site (BL10) and the adjacent new and improved public open space and recreation facility works. There is also the potential for construction activities to impact local catchment runoff, which would be managed through appropriate local stormwater management controls to be implemented during the construction phase of the project.

Without mitigation the construction of the project has the potential to result in changes in flood behaviour that may result in social and economic cost impacts to the community by exacerbating the impact of flooding to property and infrastructure as well as disruption to the community.

While the findings of the assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be carried out during further design development and construction planning. Consideration would also be given to setting an appropriate hydrologic standard for mitigating the impacts of construction activities on flood behaviour, taking into account their temporary nature and therefore the likelihood of a flood of a given AEP occurring during the construction period.

Prior to construction, further investigation would be carried out to develop measures which are aimed at mitigating the impacts of construction activities on flood behaviour. A range of measures which would be implemented to mitigate the potential construction related impacts of the project are outlined in Section 18.8.

Temporary construction support site facilities

A range of site facilities including offices, staff amenities, stores and laydown, workshops and parking are proposed at the temporary construction support sites associated with the project, with the exception of Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8) construction support sites located on Middle Harbour.

Most of the locations that have been identified for the proposed construction support sites are affected by flooding, whether as a result of main stream flooding, overland flow or ocean storm tides (refer to Table 18-2), with the exception of Gore Hill Freeway median (BL6), Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.

While the majority of the temporary construction support sites would be subject to flooding during a 10% AEP storm event, depths of inundation are generally shallow and of a short duration nature. The exception is Flat Rock Drive construction support site (BL2), where depths of flow are greater

than 0.5 metres in a 10% AEP flood event. Elevated water levels in Middle Harbour could also result in the partial inundation of Spit West Reserve construction support site (BL9).

Site facilities located on the floodplain, particularly in areas of high hazard, pose a safety risk to construction personnel. It would be necessary to locate site facilities outside high hazard areas with safe evacuation routes. All temporary construction support sites include land located outside areas of high hazard that would be suitable for site facilities.

Tunnel construction

The key activities associated with tunnel construction carried out from the Beaches Link temporary construction support sites, include:

- Tunnel excavation
- Cut and cover structures.

The tunnel excavation would involve the use of pumps at the tunnel low points, and potentially mobile sumps at the cutting face to collect tunnelling water, groundwater ingress and stormwater runoff from the tunnel openings. While the tunnel excavation arrangement would be designed to accommodate a nominal amount of stormwater runoff, the potential for the ingress of floodwater to the tunnel excavations during their construction poses a significant risk to personal safety and has the potential to cause damage to machinery and delays in the project timetable if not adequately managed. The flood standard adopted at each tunnel opening during construction would be developed during further design development.

Similar to the construction of the driven tunnels, the potential for ingress of floodwater into the open excavations poses a safety risk to construction workers, as well as having the potential to cause damage to machinery and construction delays. Potential impacts to cut and cover structures that are part of the project, include:

- The ability for floodwater which ponds in ANZAC Park in the Willoughby Creek catchment to discharge onto the Warringah Freeway near the proposed cut and cover sections of the tunnel is constrained by the presence of the noise wall which runs along its southern side. Any leakage of floodwater through, or overtopping of, the noise wall (for example in a PMF event), could cause flooding of the freeway in excess of one metre in the vicinity of the cut and cover sections of tunnel
- Stormwater which surcharges the existing drainage system at the Flat Rock Creek and Burnt Bridge Creek catchments has the potential to impact cut and cover operations.

Cut and cover works at the Wakehurst Parkway are not subject to flooding due to the road being located along a natural ridgeline.

The provision of temporary barriers in combination with the permanent solid barriers/flood walls which are proposed around tunnel portals, would be required to prevent floodwater entering the open excavations.

Refer to Table 18-2 for details on the potential impacts of flooding behaviour resulting from tunnel construction activities.

Spoil management and stockpile areas

The construction of the project would generate a significant amount of spoil which, in some situations, may need to be temporarily stored in stockpile areas. Stockpiles located on the floodplain have the potential to obstruct floodwater and alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to significant quantities of material being washed into receiving drainage lines and waterways.

Some stockpiling of spoil material is proposed at all temporary construction support sites with the exception of Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8) construction support sites. Tunnel spoil is generally stockpiled within an acoustic shed. External stockpiles are generally avoided. While the majority of these sites are affected by flooding to

varying degrees, there would typically be suitable areas outside the 10% AEP flood extent that could be used to stockpile material.

Surface earthworks

While surface earthworks are associated with activities within the confines of most temporary construction support sites, the main area of surface earthworks is associated with the Gore Hill Freeway Connection component as well as the upgrades of Burnt Bridge Deviation and the Wakehurst Parkway.

Surcharge of the existing drainage along the Gore Hill Freeway occurs during a 1% AEP, when the depth of flow along the northern and southern sides of the freeway exceed about 0.3 metres.

While floodwater is generally confined to the main channel of Burnt Bridge Creek and its immediate overbank area near the project, several major overland flow paths develop during storms which result in the surcharge of the existing stormwater drainage system.

As the Wakehurst Parkway generally runs along the top of a natural ridge line, it is not subject to flooding. Rather, the road corridor is impacted by surface runoff which is generated by a number of relatively small catchments which are located on its eastern and western sides.

The inundation of the surface earthworks by floodwater has the potential to cause scouring of disturbed surfaces and transport sediment and construction materials into the receiving waterways. It would be necessary to plan, implement and maintain measures which are aimed at managing the diversion of floodwater either through or around the construction areas.

Bridge construction

New bridge works are limited to pedestrian and shared user bridge upgrades along the Wakehurst Parkway, the construction of which would be managed from the Wakehurst Parkway north construction support site (BL14).

The proposed pedestrian footbridge works along the Wakehurst Parkway are not at risk of being flooded during construction.

18.5.2 Potential flood risk at temporary construction support sites

Without the implementation of appropriate management measures, inundation of the temporary construction support sites by floodwater has the potential to:

- Cause damage to the project works and delays in construction programming
- Pose a safety risk to construction workers
- Detrimentially impact the downstream waterways through the transport of sediments and construction materials by floodwaters
- Obstruct the passage of floodwater and overland flow through the provision of temporary infrastructure such as site sheds, stockpiles, noise walls and flood walls, which in turn, could exacerbate flooding conditions at developments located outside the construction footprint.

Table 18-2 provides a summary of the proposed activities, as well as the assessed flood risk at the temporary construction support sites associated with the construction of the Beaches Link and Gore Hill Freeway Connection project. Figure 5.1 of Appendix R (Technical working paper: Flooding) shows the extent to which floods of varying magnitude affect each temporary construction support site. Figure 5.2 shows the indicative depth and extent of inundation in the vicinity of each temporary construction support site for the 10% AEP and 1% AEP flood events. Figure 5.3 of Appendix R (Technical working paper: Flooding) shows the provisional flood hazard and preliminary hydraulic categorisation of the floodplain near each temporary construction support site for a 1% AEP flood event. Further details of each temporary construction support site and its associated facilities and activities is provided in Chapter 6 (Construction work). A range of measures which would be implemented to mitigate the potential construction related impacts of the project are outlined in Section 18.8.

Table 18-2 Summary of assessed flood risks and potential impacts associated with proposed temporary construction support sites

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Cammeray Golf Course (BL1)	Willoughby Creek	PMF	✓	✓	✓	✓	✓	<p>The Cammeray Golf Course construction support site (BL1) would be subject to very shallow sheet flow during heavy rainfall events, principally due to runoff generated from within its extent. Overland flow discharging through the Cammeray Golf Course construction support site (BL1) during storms up to 1% AEP in intensity is classified as low hazard flood fringe.</p> <p>During a PMF event, floodwater would surcharge the Warringah Freeway where it would discharge through the Cammeray Golf Course construction support site (BL1) at depths of up to 0.5 metres.</p> <p>Refer to Figures 5.1 (Sheet 2), 5.2 (Sheet 1) and 5.3 (Sheet 1) of Appendix R (Technical working paper: Flooding).</p>	<p>If appropriate connections to existing trunk drainage system are not incorporated into the design of the project, then the provision of hard stand areas within the confines of the Cammeray Golf Course construction support site (BL1) has the potential to exacerbate flooding conditions in existing residential development that is located along Warringah Road, Falls Street, Cammeray Road and Grafton Street.</p> <p>Construction activities within the confines of the Cammeray Golf Course construction support site (BL1) have the potential to obstruct flow which surcharges the Warringah Freeway during a PMF, thereby exacerbating flooding conditions in existing development that is located on the western side of the freeway.</p> <p>Floodwater originating from ANZAC Park, as well as from</p>

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
									within the Warringah Freeway corridor has the potential to impact tunnel works that are proposed adjacent to Cammeray Golf Course.
Flat Rock Drive (BL2)	Flat Rock Creek	More frequent than 10% AEP	✓	✓	✓		✓	<p>The Flat Rock Drive construction support site (BL2) would be subject to flooding during storms more frequent than 10% AEP.</p> <p>Flooding occurs in the south-west corner of the Flat Rock Drive construction support site (BL2) during storms which result in the surcharge of the existing transverse drainage of Flat Rock Drive.</p> <p>The Flat Rock Drive construction support site (BL2) also spans an incised natural watercourse which drains from the north.</p> <p>Refer to Figures 5.1 (Sheet 3), 5.2 (Sheet 1) and 5.3 (Sheet 1) of Appendix R (Technical working paper: Flooding).</p>	<p>Changes in natural surface levels within the confines of the Flat Rock Drive construction support site (BL2) have the potential to alter flooding patterns in the area, which in turn could impact on construction activities, as well as the hydrologic standard of Flat Rock Drive.</p> <p>Flooding has the potential to impact the covered section of the decline and the spoil shed, both of which are located across the incised natural watercourse which drains from the north.</p> <p>Construction activities within the Flat Rock Drive construction support site (BL2) would not have an impact on flood behaviour in existing development.</p>

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Punch Street (BL3)	Flat Rock Creek	More frequent than 10% AEP	✓	✓	✓	✓	✓	Shallow overland flow discharges in a northerly direction along Lambs Road which it is intercepted by a series of kerb inlet pits that are located at the eastern end of Punch Street. Refer to Figures 5.1 (Sheet 4), 5.2 (Sheet 2) and 5.3 (Sheet 2) of Appendix R (Technical working paper: Flooding).	Alterations to existing road levels to facilitate access to the Punch Street construction support site (BL3) has the potential to cause minor flooding within the proposed acoustic shed and access decline. Due to the topography in the area, activities within the Punch Street construction support site (BL3) would not have an impact on flood behaviour in adjacent residential development.
Dickson Avenue (BL4)	Flat Rock Creek	More frequent than 10% AEP	✓	✓	✓	✓	✓	Parts of the Dickson Avenue construction support site (BL4) are subject to relatively shallow sheet flow during storms which result in the surcharge of the existing stormwater drainage system. Refer to Figures 5.1 (Sheet 4), 5.2 (Sheet 2) and 5.3 (Sheet 2) of Appendix R (Technical working paper: Flooding).	Due to the relatively shallow nature of the flow, activities within the confines of the Dickson Avenue construction support site (BL4) would not have an impact on flood behaviour in adjacent commercial and industrial development.

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Barton Road (BL5)	Flat Rock Creek	Less frequent than 1% AEP	✓				✓	The Barton Road construction support site (BL5) is subject to relatively shallow overland flow during very rare and extreme storm events. Refer to Figures 5.1 (sheet 4), 5.2 (sheet 2) and 5.3 (sheet 2) of Appendix R (Technical working paper: Flooding).	Due to the relatively shallow nature of the flow, activities within the Barton Road construction support site (BL5) would not have an impact on flood behaviour in adjacent residential development.
Gore Hill Freeway median (BL6)	Flat Rock Creek	Not flooded	✓				✓	Refer to Figures 5.1 (Sheet 4), 5.2 (Sheet 2) and 5.3 (Sheet 2) of Appendix R (Technical working paper: Flooding). The Gore Hill Freeway median construction support site (BL6) is generally flood free.	Activities within the Gore Hill Freeway median construction support site (BL6) would not have an impact on flood behaviour in adjacent residential development.
Middle Harbour south cofferdam (BL7)	-	Potentially subject to wave action during elevated water levels in Middle Harbour			✓		✓	Flooding of the Middle Harbour south cofferdam construction support site (BL7) is principally limited to elevated water levels in Middle Harbour. Wave action due to coincident high winds could exacerbate flooding conditions at the Middle Harbour south cofferdam construction support site (BL7)	Activities within the confines of the Middle Harbour south cofferdam construction support site (BL7) would not have an impact on water levels in Middle Harbour.

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								during periods of elevated water levels in Middle Harbour. Refer to Figures 5.1 (sheet 5), 5.2 (sheet 3) and 5.3 (sheet 3) of Appendix R (Technical working paper: Flooding).	
Middle Harbour north cofferdam (BL8)	-	Potentially subject to wave action during elevated water levels in Middle Harbour			✓		✓	Flooding of the Middle Harbour north cofferdam (BL8) construction support site is principally limited to elevated water levels in Middle Harbour. Wave action due to coincident high winds could exacerbate flooding conditions at the Middle Harbour north cofferdam construction support site (BL8) during periods of elevated water levels in Middle Harbour. Refer to Figures 5.1 (Sheet 5), 5.2 (Sheet 3) and 5.3 (Sheet 3) of Appendix R (Technical working paper: Flooding).	Activities within the confines of the Middle Harbour north cofferdam construction support site (BL8) would not have an impact on water levels in Middle Harbour.

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Spit West Reserve (BL9)	-	Potentially subject to wave action during elevated water levels in Middle Harbour	✓	✓	✓			<p>Flooding of the Spit West Reserve construction support site (BL9) is principally limited to elevated water levels in Middle Harbour.</p> <p>Wave action due to coincident high winds could exacerbate flooding conditions at the Spit West Reserve construction support site (BL9) during periods of elevated water levels in Middle Harbour.</p> <p>Refer to Figures 5.1 (Sheet 5), 5.2 (Sheet 4) and 5.3 (Sheet 4) of Appendix R (Technical working paper: Flooding).</p>	Activities within the confines of the Spit West Reserve construction support site (BL9) would not have an impact on water levels in Middle Harbour.
Balgowlah Golf Course (BL10)	Burnt Bridge Creek	More frequent than 10% AEP	✓	✓	✓	✓	✓	<p>The Balgowlah Golf Course construction support site (BL10) is also impacted by major overland flow which discharges through Balgowlah Oval from Sydney Road.</p> <p>Flooding is of a low hazard nature along the major overland flow path which forms in Balgowlah Golf Course.</p>	<p>Activities within the extent of the Balgowlah Golf Course construction support site (BL10) have the potential to impact flooding behaviour along Sydney Road and in adjoining parts of the golf course.</p> <p>Activities external to the Balgowlah Golf Course construction support site (BL10) have the potential to impact flood</p>

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
								Refer to Figures 5.1 (Sheet 6), 5.2 (Sheet 5) and 5.3 (Sheet 5) of Appendix R (Technical working paper: Flooding).	behaviour in existing development that is located immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek and along the eastern side of the Balgowlah Golf Course.
Kitchener Street (BL11)	Burnt Bridge Creek	More frequent than 10% AEP	✓	✓				The Kitchener Street construction support site (BL11) is located on land which generally lies above peak 1% AEP flood levels. It would be subject to shallow inundation during extreme storm events. Refer to Figures 5.1 (Sheet 6), 5.2 (Sheet 5) and 5.3 (Sheet 5) of Appendix R (Technical working paper: Flooding).	Activities within the extent of the Kitchener Street construction support site (BL11) would have a minimal effect on flood behaviour.

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Wakehurst Parkway south (BL12)	Manly Creek and Bantry Bay	Not flooded	✓	✓		✓	✓	The Wakehurst Parkway south construction support site (BL12) is not subject to flooding. Refer to Figures 5.1 (Sheet 7), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding).	The provision of hard stand areas within the confines of the Wakehurst Parkway south construction support site (BL12) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the adjacent bushland and golf course.
Wakehurst Parkway east (BL13)	Bantry Bay	Not flooded	✓	✓	✓		✓	The Wakehurst Parkway east construction support site (BL13) is not subject to flooding. Refer to Figures 5.1 (Sheet 8), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding).	The provision of hard stand areas within the confines of the Wakehurst Parkway east construction support site (BL13) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the adjacent bushland and golf course.

Temporary construction support site	Catchment	Threshold of flooding ¹	Site facilities ²	Spoil management ²	Tunnel launch and support ²	Cut and cover structures ²	Surface earthworks ²	Description of existing flood behaviour	Potential impacts of construction activities on flood behaviour
Wakehurst Parkway north (BL14)	Manly Creek	Not flooded	✓	✓			✓	<p>Refer to Figures 5.1 (Sheet 10), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding).</p> <p>The Wakehurst Parkway north construction support site (BL14) is not subject to flooding.</p> <p>Refer to Figures 5.1 (Sheet 8), 5.2 (Sheet 6) and 5.3 (Sheet 6) of Appendix R (Technical working paper: Flooding).</p>	<p>The provision of hard stand areas within the confines of the Wakehurst Parkway north construction support site (BL14) would increase the runoff potential of the area, which in turn would increase the rate at which flow discharges to the pavement drainage system of Warringah Road.</p>

Note 1: The assessed threshold of flooding is based on present day conditions

Note 2: Proposed construction activities

18.6 Assessment of potential operational impacts

This section provides an assessment of the flood risk to the project and the impact it would have on flood behaviour during operation. Consistency of the impacts with state government and local council flood plans and policies has also been carried out (Section 18.6.3). The findings of an assessment of the potential impact of future climate change and impacts of a partial blockage of the local stormwater drainage system on flooding behaviour under operational conditions are also presented. Furthermore, the application of the ARR 2019 methodology to the design flood estimation is also detailed below in Section 18.6.6.

While the project incorporates measures that are aimed at mitigating the impact that it would have on flood behaviour, there are a number of residual impacts that would need to be investigated during further design development. This section identifies and describes the nature of the residual impacts, while a range of potential measures which are aimed at managing the flood risk and further mitigating the residual impacts of the project on flood behaviour are discussed in Section 18.8.

18.6.1 Potential flood risk to the project

Tunnel portals

While a series of measures have been incorporated into the design of the project in the vicinity of the tunnel portals for all events up to the PMF, a sensitivity analysis identified that there is the potential for floodwater to enter the tunnel system via the Gore Hill Freeway and Burnt Bridge Deviation portals should the stormwater drainage system experience a partial blockage during an extreme storm event. Further details of the sensitivity analysis and studies to be carried out during further design development are set out in Section 18.6.6.

At all other tunnel locations, the ingress of floodwater would be controlled through a combination of grade changes and standard barrier types. Design of the project also includes upgrades to the existing stormwater drainage to divert local catchment runoff around the proposed tunnel portals.

Road and pedestrian bridges

The existing road bridges, upgraded as part of the project, are all high level structures that would only be subject to relatively shallow sheet flow during storms which surcharge the pavement drainage system.

The proposed pedestrian and shared user bridges over the Wakehurst Parkway are high level structures that would not be subject to flooding.

Surface road works

Willoughby Creek Catchment

Major flooding of the Warringah Freeway during storms up to 1% AEP in intensity is prevented by the presence of a continuous solid concrete noise wall which runs along the northern side of ANZAC Park (refer to Figure 6.5 (Sheet 2) of Appendix R (Technical working paper: Flooding)). Depths of ponding in ANZAC Park increase from a maximum of about two metres during a 10% AEP storm event to a maximum of about 3.2 metres during a 1% AEP storm event. Overtopping of the noise wall would occur during a PMF event, when floodwater would pond to a maximum depth of about five metres and extend across the full width of the Warringah Freeway.

Flat Rock Creek Catchment

Flooding of the surface road works during storms up to 1% AEP in intensity would occur at the location where both the Gore Hill Freeway westbound off ramp to Epping Road and Pacific Highway, and the Gore Hill Freeway eastbound entry ramp to the Beaches Link tunnel runs under Reserve Road. Depths of ponding across the westbound and eastbound lanes of the Gore Hill

Freeway at these two locations would exceed one metre and 0.6 metres, respectively, during a 1% AEP storm event.

Floodwater which ponds across the Gore Hill Freeway eastbound entry ramp to the Beaches Link tunnel would eventually reach a depth where it would commence to flow in a southerly direction beneath the Reserve Road eastbound on ramp to the Gore Hill Freeway via a new bridge structure, where it would discharge onto the eastbound carriageway of the Lane Cove Tunnel. Flow discharging onto the eastbound carriageway of the Lane Cove Tunnel at this location would discharge in an easterly direction, where it would gradually be intercepted by the proposed pavement drainage system.

Burnt Bridge Creek Catchment

The surface road works would be subject to relatively shallow sheet flow as a result of flow which surcharges the existing pavement drainage system to the south of the crossing of Burnt Bridge Creek. Greater depths of inundation would be experienced further to the north of the tunnel portals as a result of flow which surcharges both the existing and proposed stormwater drainage system. Floodwater would also discharge onto Burnt Bridge Creek Deviation at the location of the Burnt Bridge Creek crossing during storms that are more intense than about 0.2% AEP.

It is noted the Burnt Bridge Creek Deviation is subject to flooding immediately to the north of the project as a result of floodwater which surcharges Burnt Bridge Creek during storms that are more frequent than 1% AEP.

Trefoil Creek, Manly Creek and Bantry Bay Catchments

Inundation of the Wakehurst Parkway during storms up to 1% AEP would be limited to flow which surcharges the new pavement drainage system given the road generally follows the natural divide between the Manly Creek and Bantry Bay catchments.

Tunnel support facilities

Tunnel support facilities are to be constructed as part of the project at Waltham Street, Artarmon and the Wakehurst Parkway, Frenchs Forest, with finished ground levels raised above the level of the PMF.

Motorway control centre

The proposed motorway control centre at the Gore Hill Freeway, Artarmon in the Flat Rock Creek catchment is located on land which generally lies above the level of the PMF. Provision would be incorporated into the design of the motorway control centre to prevent the ingress of floodwater to the building for events up to the PMF.

18.6.2 Potential impacts of the project on flood behaviour

The changes to flood behaviour external and internal to the road corridor as a result of the project in the 1% AEP event are discussed in the subsections below, and shown in Figure 18-9 to Figure 18-14. Changes in flood depth as a result of the project, in the 1% AEP event are shown in Figure 18-15 to Figure 18-20. Appendix R (Technical working paper: Flooding) provides discussion regarding the project's effect on flood behaviour for storm events more intense than 1% AEP. Refer to Figures 6.1 to 6.6 in Appendix R (Technical working paper: Flooding) for the changes to flood behaviour resulting from the project in the 10% AEP, 1% AEP and PMF events, for all catchments.

The proposed upgrade of the Wakehurst Parkway is located in the upper reaches of the Trefoil Creek, Manly Creek and Bantry Bay catchments. Due to the minor nature of the receiving drainage lines which control runoff from the road corridor, combined with the available LiDAR survey data, the assessment for these catchments was limited to a comparative peak flow analysis, the results of which were used to identify where the project has the potential to increase the rate of flow and hence scour potential in the affected drainage lines. For this reason, flood mapping is not provided

for these areas. Refer to Appendix R (Technical working paper: Flooding) for further details on assessment methodology.

Given the minor impact that the project would have on flood behaviour under operational conditions, it is not expected that changes in flooding patterns would result in significant change to the social and economic costs of flooding.

External to the road corridor

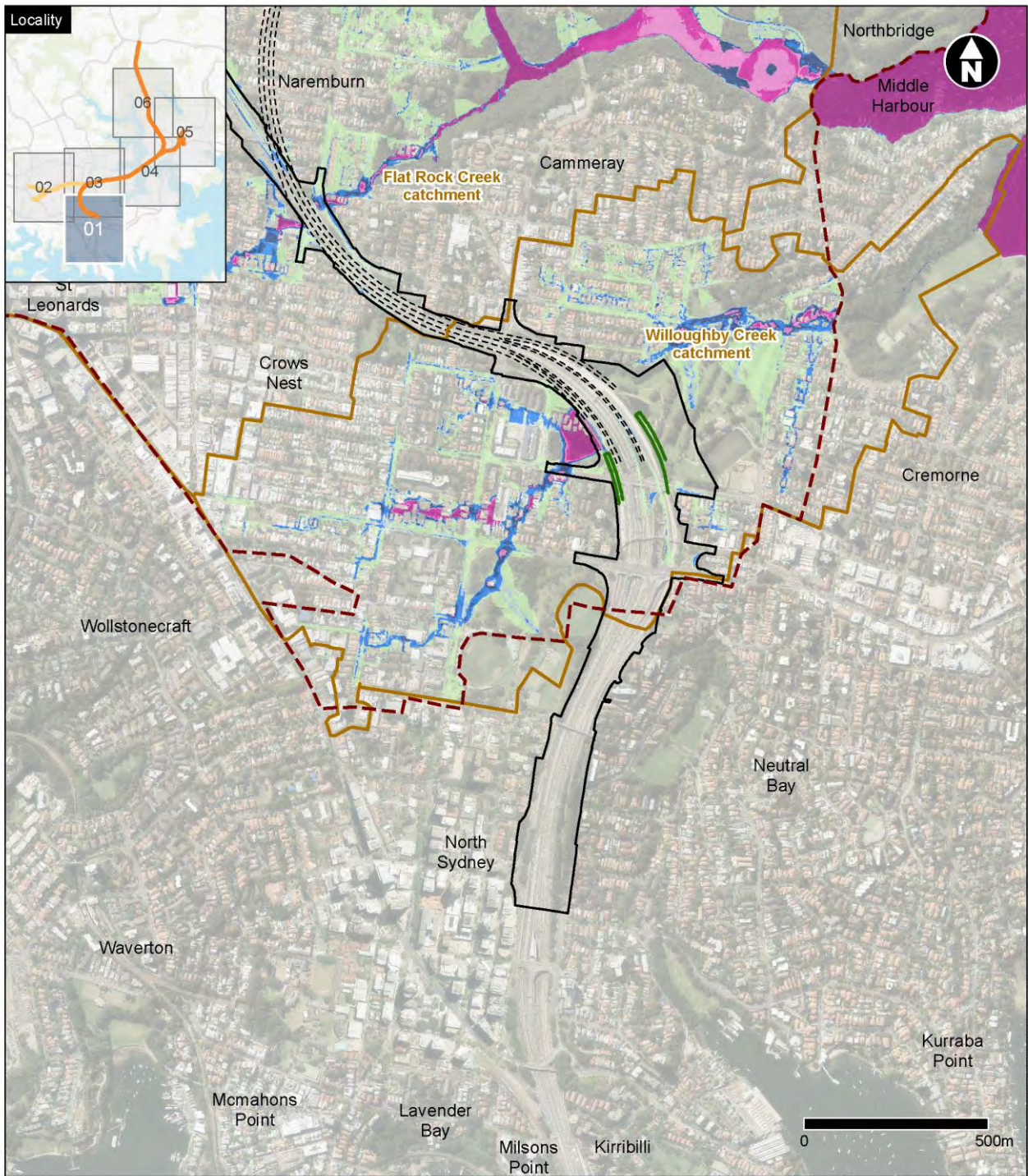
External to the road corridor, the project would generally result in a neutral or beneficial effect on flood behaviour external to the road corridor for storm events up to 1% AEP in intensity, with the following exceptions:

- Along the main arm of Burnt Bridge Creek downstream of the Kitchener Street bridge where peak 10% AEP flood levels would be increased at six residential properties in the range 10-50 millimetres
- While peak flows could potentially be increased in a number of the receiving drainage lines which run west toward Bantry Bay, there is no existing development that would be impacted by the change in flow regime
- While peak flows could potentially be increased in a number of the receiving drainage lines which run east toward the main arm of Manly Creek, there is no existing development other than the Wakehurst Golf Course that would be impacted by the change in flow regime. Increases in the rate and volume of runoff discharging to the receiving drainage lines that run through the Wakehurst Golf Course have the potential to cause prolonged inundation of parts of the golf course during periods of heavy rain
- Increases in the rate of runoff has the potential to increase the frequency of surcharge of the existing stormwater drainage system which runs across Aquatic Drive and under Aquatic Reserve, thereby increasing the frequency and depth of overland flow that is experienced across the road and in the reserve during periods of heavy rain.

In the above cases, a floor level survey would be required to determine whether the minor increase in peak flood levels attributable to the project would result in an increase in above floor inundation in existing habitable areas.

The project would have the following impacts on flow velocities and the duration of inundation external to the road corridor for storms up to 1% AEP:

- Maximum flow velocities would be increased along the main arm of Flat Rock Creek downstream of the T1 North Shore and Western Line and T9 Northern Line crossing, where maximum flow velocities would be increased by a maximum of about 0.1 metres per second
- The extension of the existing transverse drainage structure under Burnt Bridge Creek Deviation in combination with minor works within the main channel of the watercourse immediately downstream of the road crossing has the potential to increase flow velocities by up to one metre per second. The duration of inundation along the main arm of Burnt Bridge Creek Deviation would be reduced slightly when compared to present day conditions. It is noted that changes in landform in this area would also alter the nature of flows
- The concentration of flow at discrete locations along the widened section of the Wakehurst Parkway has the potential to increase peak flows, and hence flow velocities and the duration of inundation, in a number of receiving drainage lines which run to the east of the road corridor. Conversely, in a number of different receiving drainage lines which run to the east of the road corridor, the upgrade of the Wakehurst Parkway also has the potential to decrease peak flows.

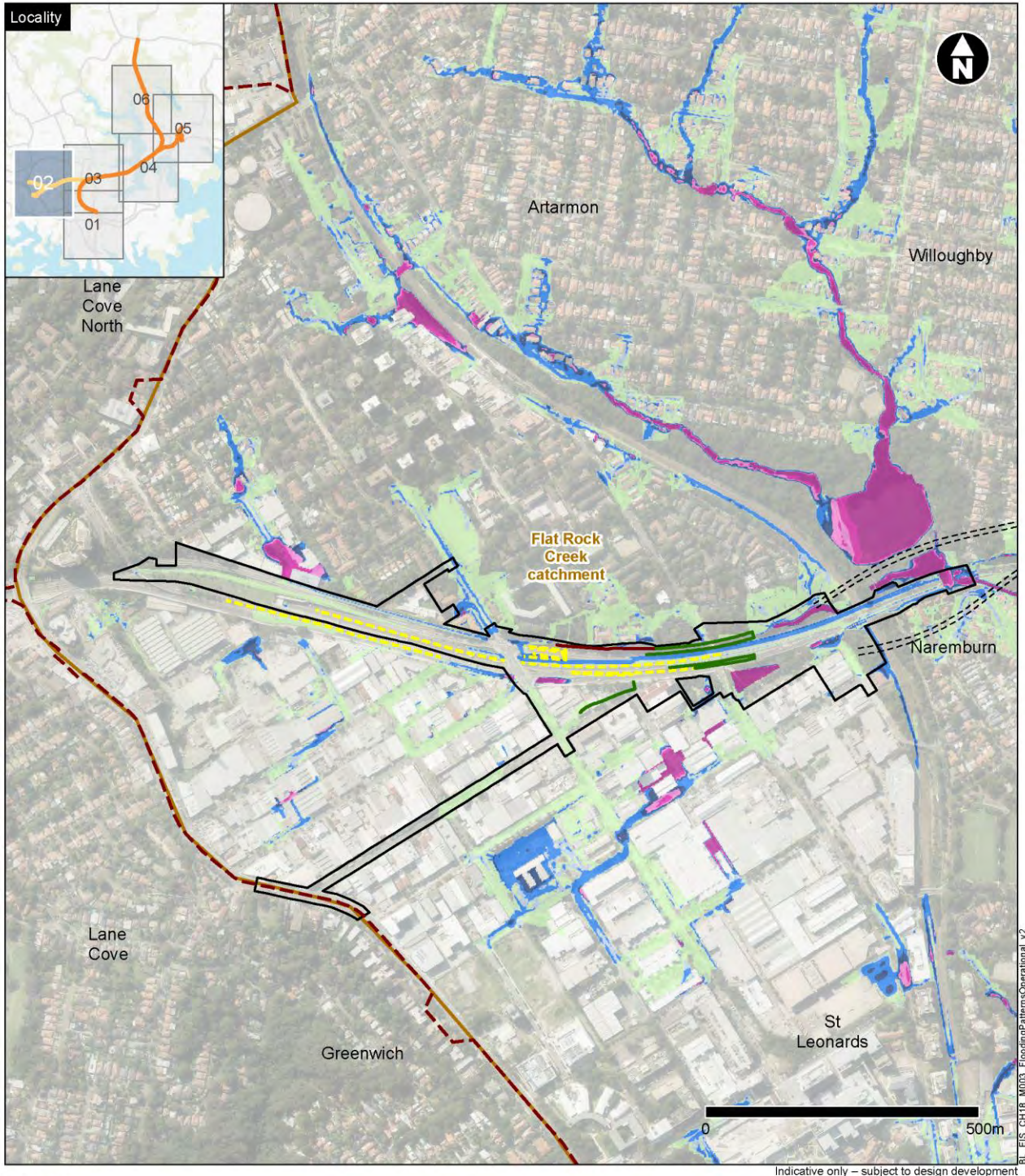


Indicative only – subject to design development

Legend

- | | | |
|--|--------------------|---|
| Construction footprint | Catchment boundary | Indicative depth of inundation (m) |
| Tunnel section | | < 0.05 |
| Limit of main stream flood mapping and major overland flow mapping | | 0.05 - 0.10 |
| Portal walls | | 0.10 - 0.30 |
| | | 0.30 - 0.50 |
| | | 0.50 - 0.70 |
| | | 0.70 - 1.00 |
| | | > 1.00 |

Figure 18-9 Flood behaviour under operational conditions – 1% AEP event (map 1)

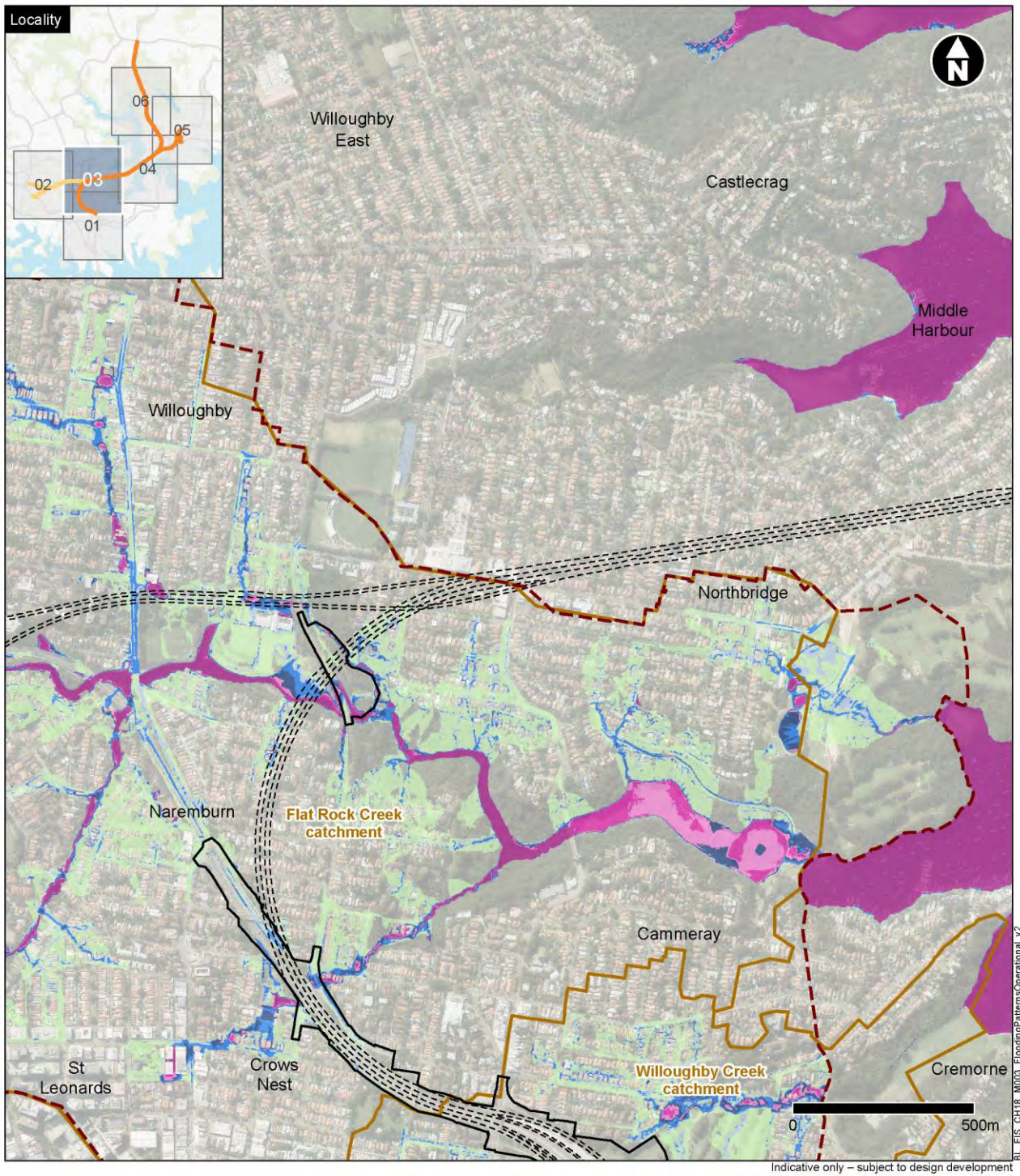


Indicative only – subject to design development

Legend

- Construction footprint
 - Tunnel section
 - Limit of main stream flood mapping and major overland flow mapping
 - Flood walls
 - Traffic barriers
 - Portal walls
 - Catchment boundary
- | Indicative depth of inundation (m) | |
|------------------------------------|-------------|
| | < 0.05 |
| | 0.05 - 0.10 |
| | 0.10 - 0.30 |
| | 0.30 - 0.50 |
| | 0.50 - 0.70 |
| | 0.70 - 1.00 |
| | > 1.00 |

Figure 18-10 Flood behaviour under operational conditions – 1% AEP event (map 2)



Legend

- | | | |
|--|--------------------|---|
| Construction footprint | Catchment boundary | Indicative depth of inundation (m) |
| Tunnel section | | < 0.05 |
| Limit of main stream flood mapping and major overland flow mapping | | 0.05 - 0.10 |
| | | 0.10 - 0.30 |
| | | 0.30 - 0.50 |
| | | 0.50 - 0.70 |
| | | 0.70 - 1.00 |
| | | > 1.00 |

Figure 18-11 Flood behaviour under operational conditions – 1% AEP event (map 3)

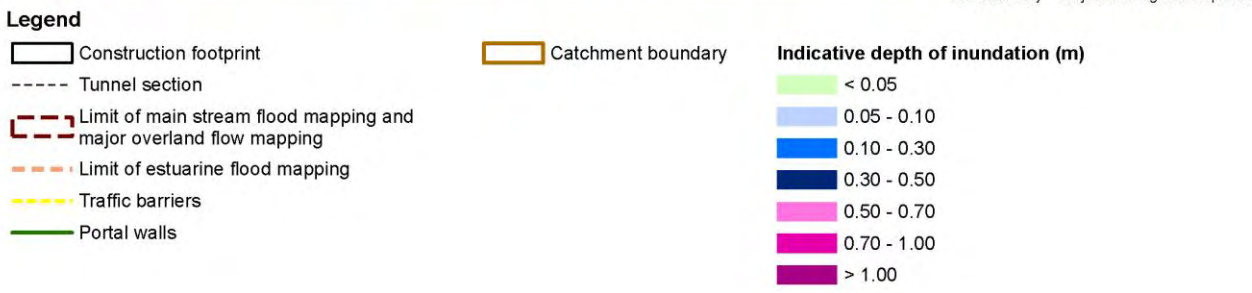
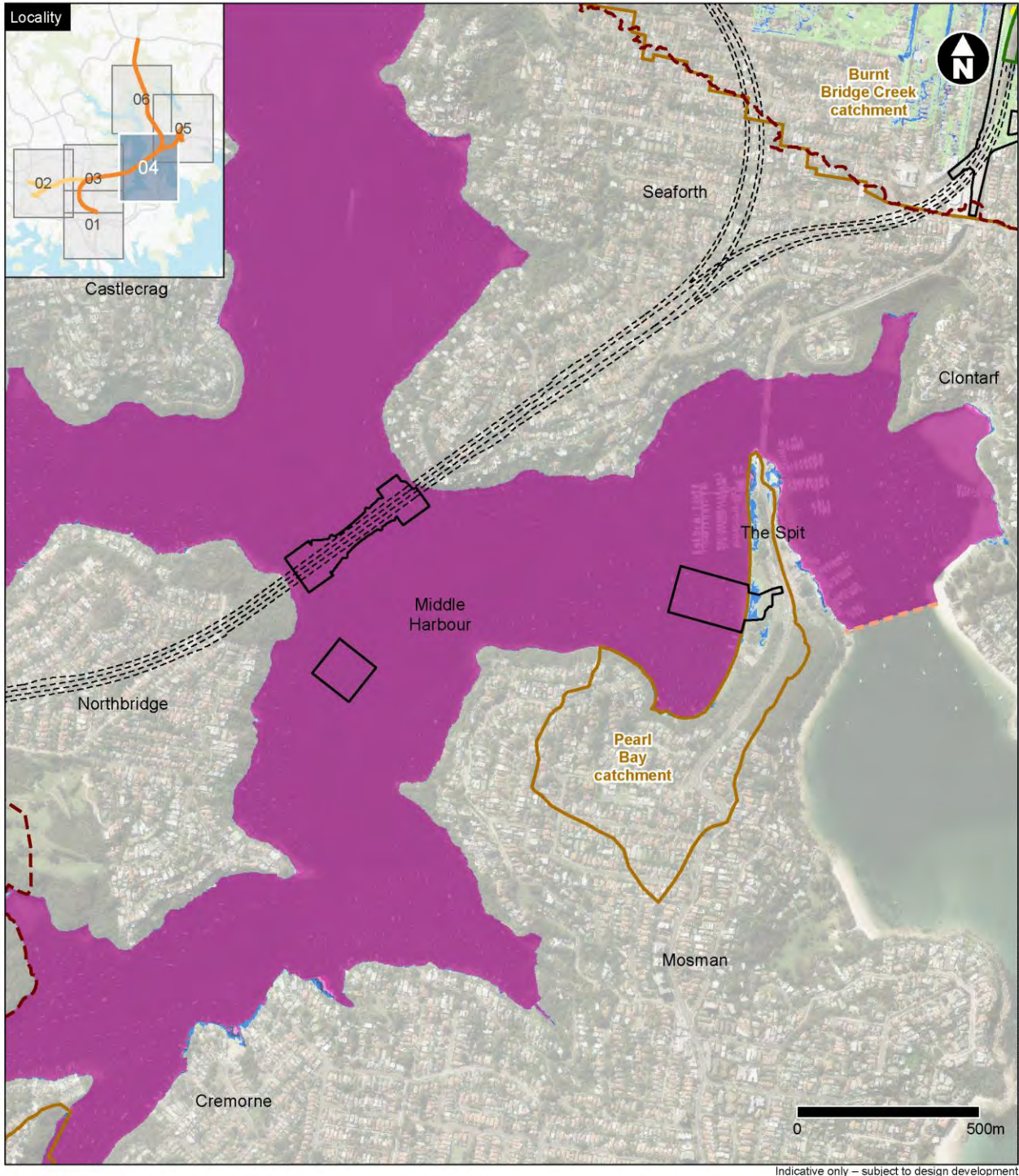
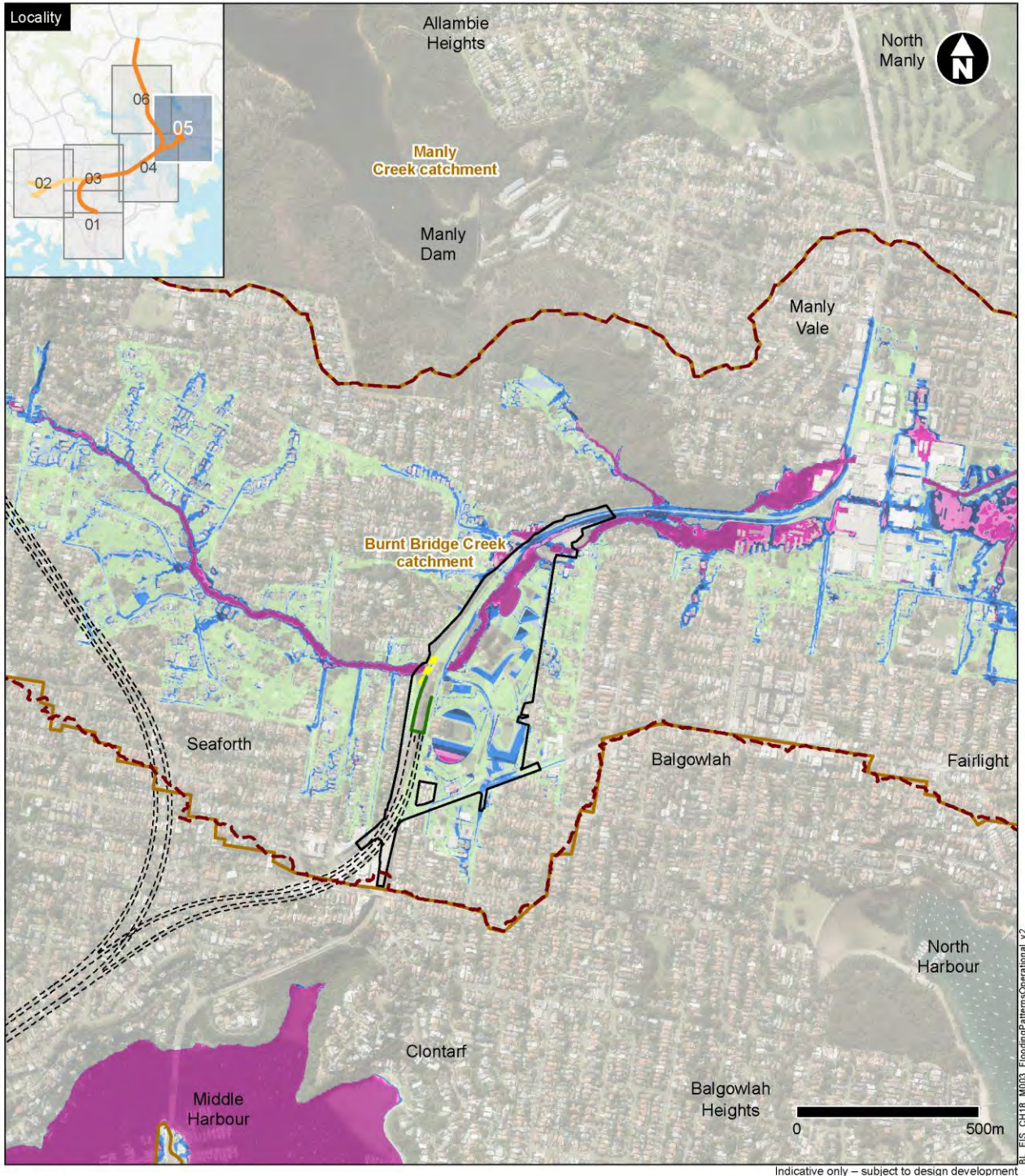


Figure 18-12 Flood behaviour under operational conditions – 1% AEP event (map 4)

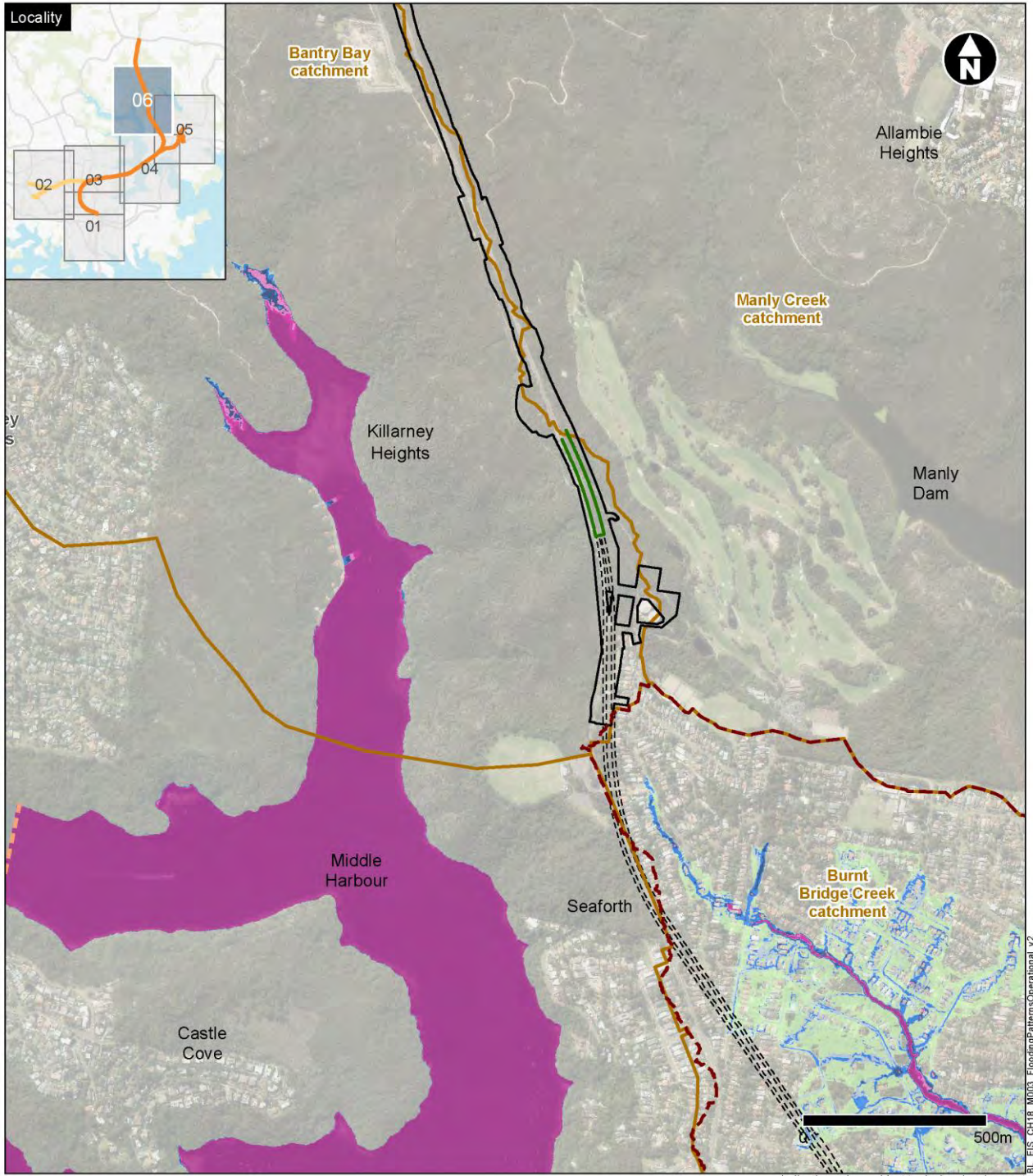


Indicative only – subject to design development

Legend

- Construction footprint
 - Tunnel section
 - Limit of main stream flood mapping and major overland flow mapping
 - Traffic barriers
 - Portal walls
 - Catchment boundary
- | Indicative depth of inundation (m) |
|--|
| < 0.05 |
| 0.05 - 0.10 |
| 0.10 - 0.30 |
| 0.30 - 0.50 |
| 0.50 - 0.70 |
| 0.70 - 1.00 |
| > 1.00 |

Figure 18-13 Flood behaviour under operational conditions – 1% AEP event (map 5)



Legend

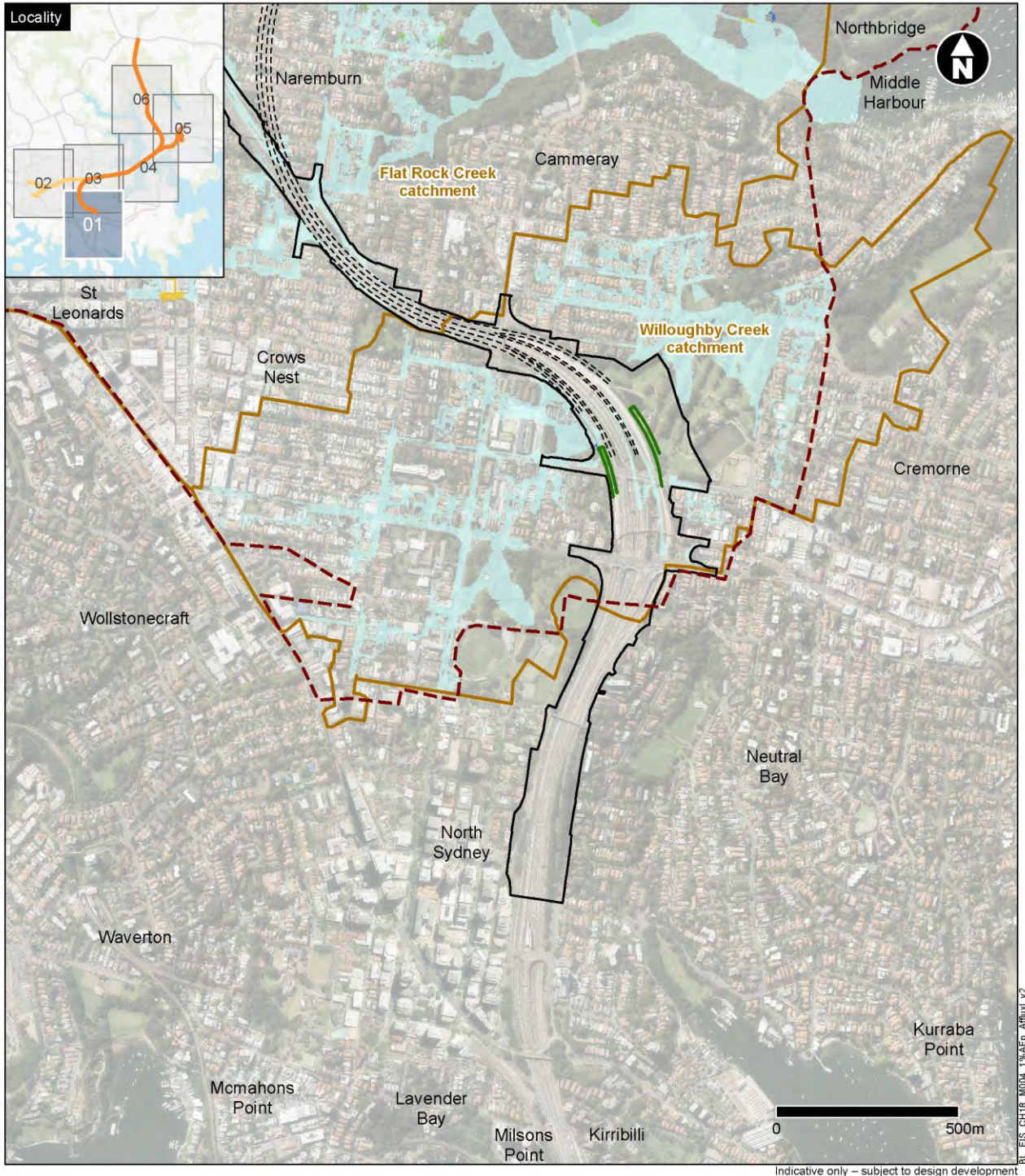
- Construction footprint
- Tunnel section
- Limit of main stream flood mapping and major overland flow mapping
- Limit of estuarine flood mapping
- Portal walls

Catchment boundary

Indicative depth of inundation (m)

- <math>< 0.05</math>
- 0.05 - 0.10
- 0.10 - 0.30
- 0.30 - 0.50
- 0.50 - 0.70
- 0.70 - 1.00
- > 1.00

Figure 18-14 Flood behaviour under operational conditions – 1% AEP event (map 6)



Indicative only – subject to design development

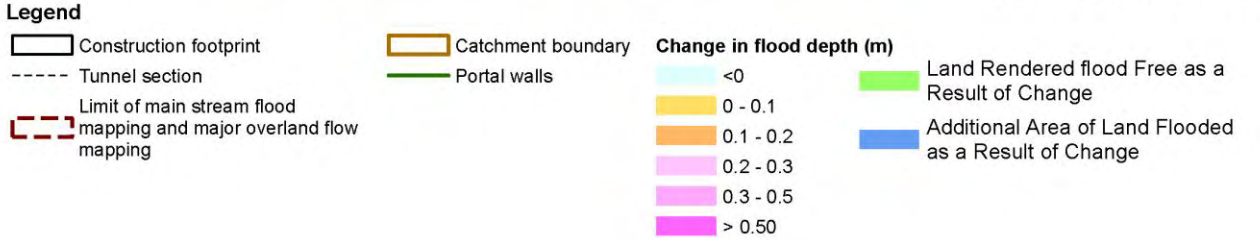


Figure 18-15 Change in flood depth under operational conditions – 1% AEP event (map 1)

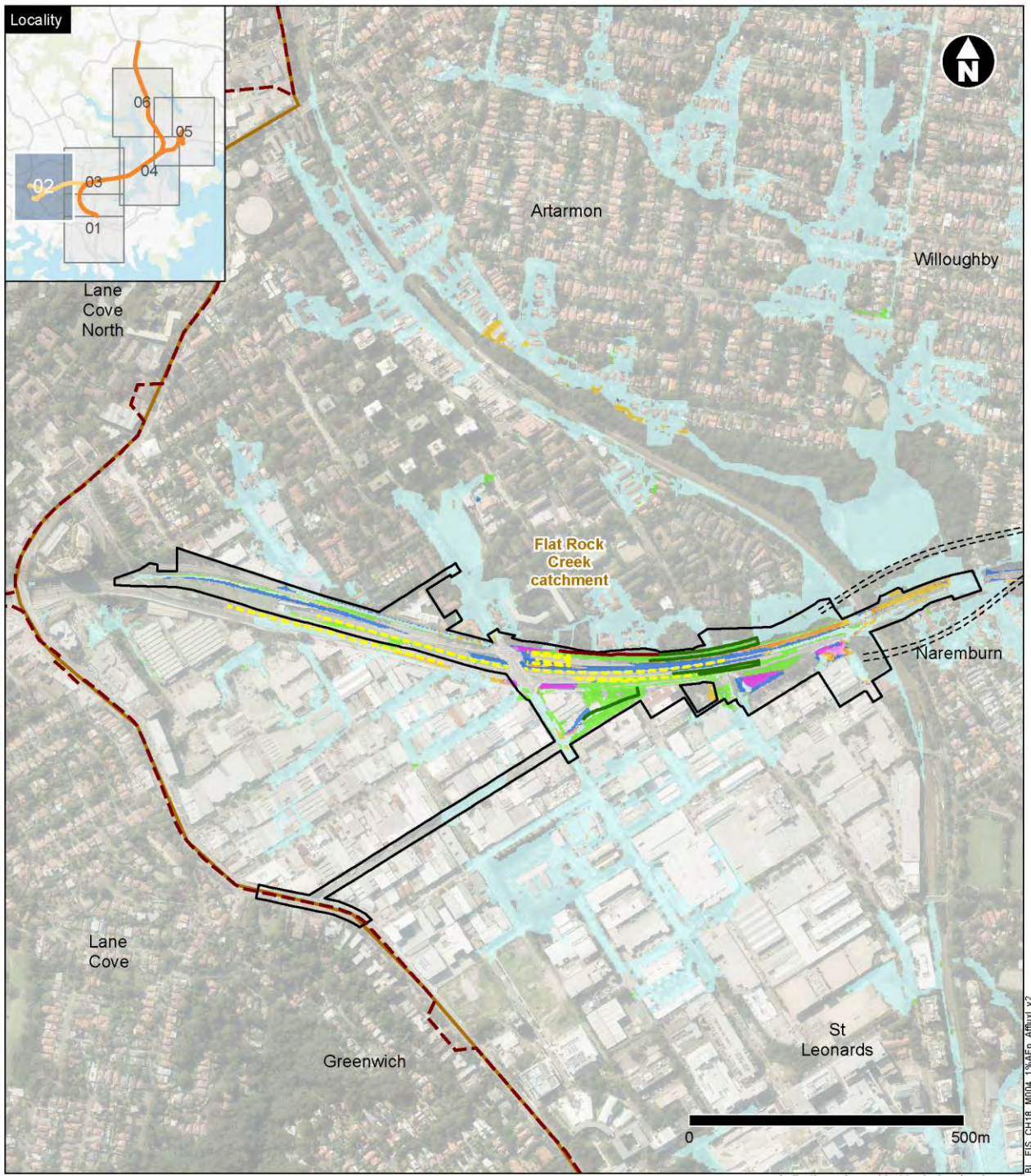


Figure 18-16 Change in flood depth under operational conditions – 1% AEP event (map 2)

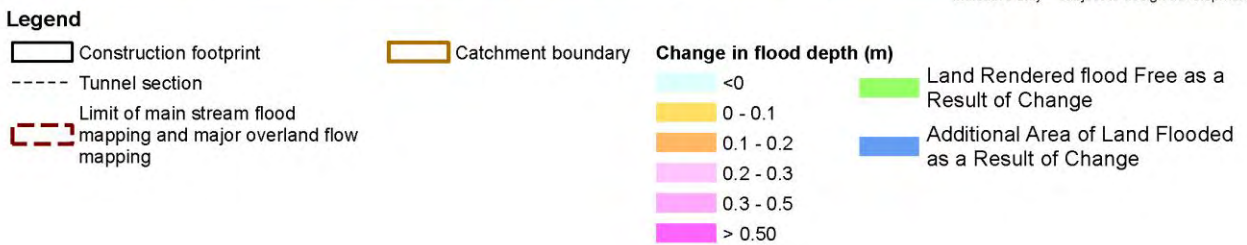
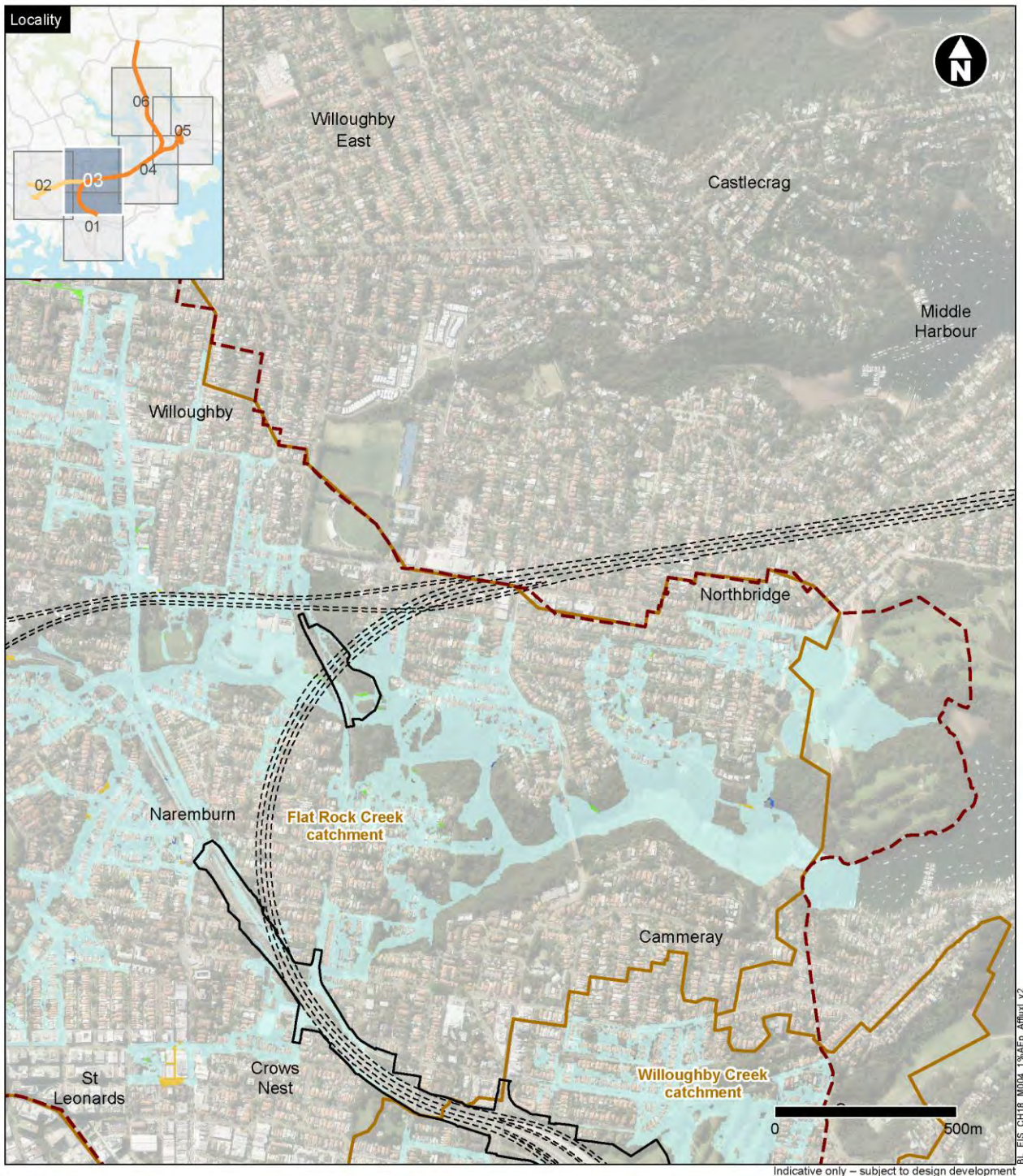
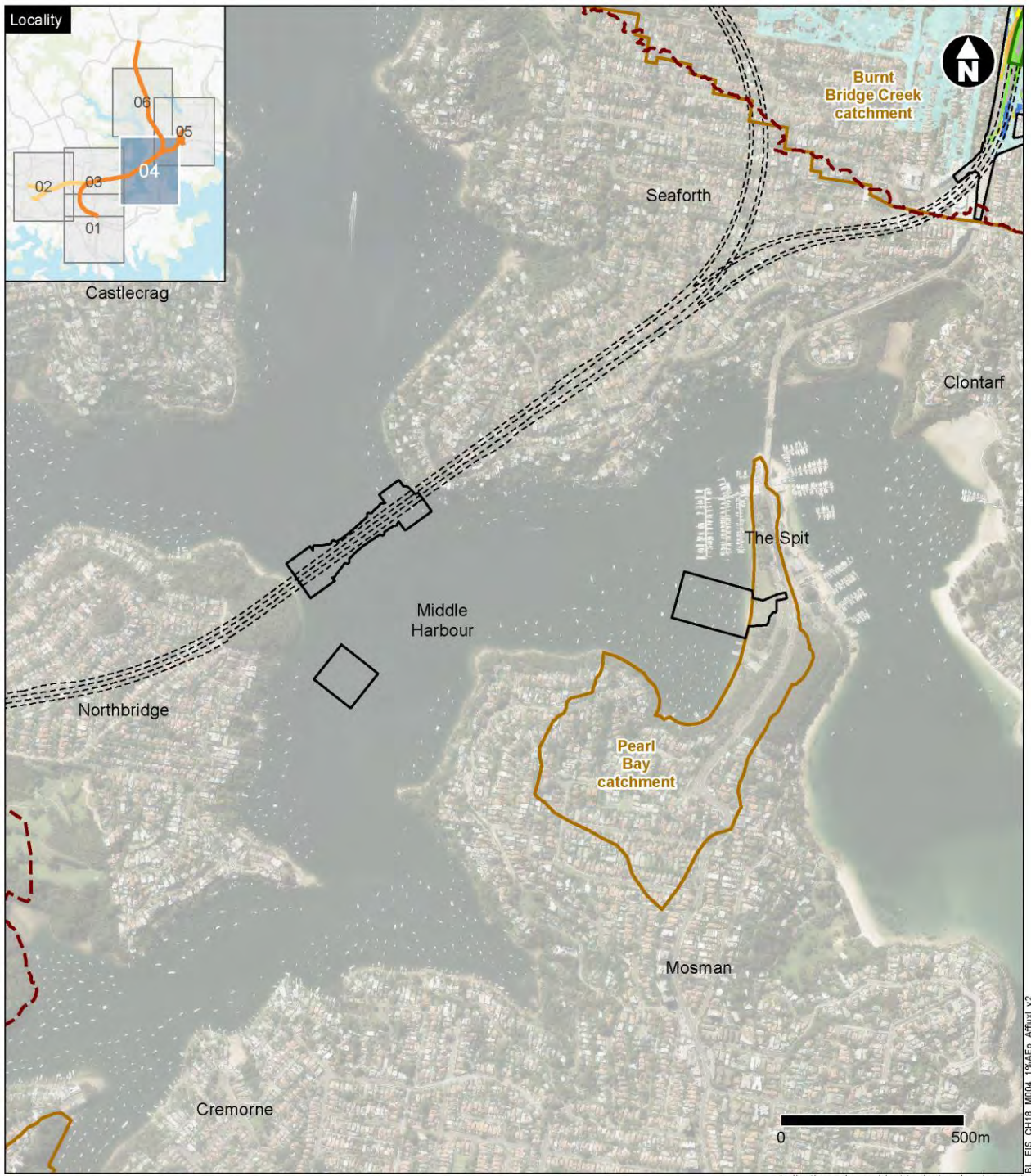


Figure 18-17 Change in flood depth under operational conditions – 1% AEP event (map 3)

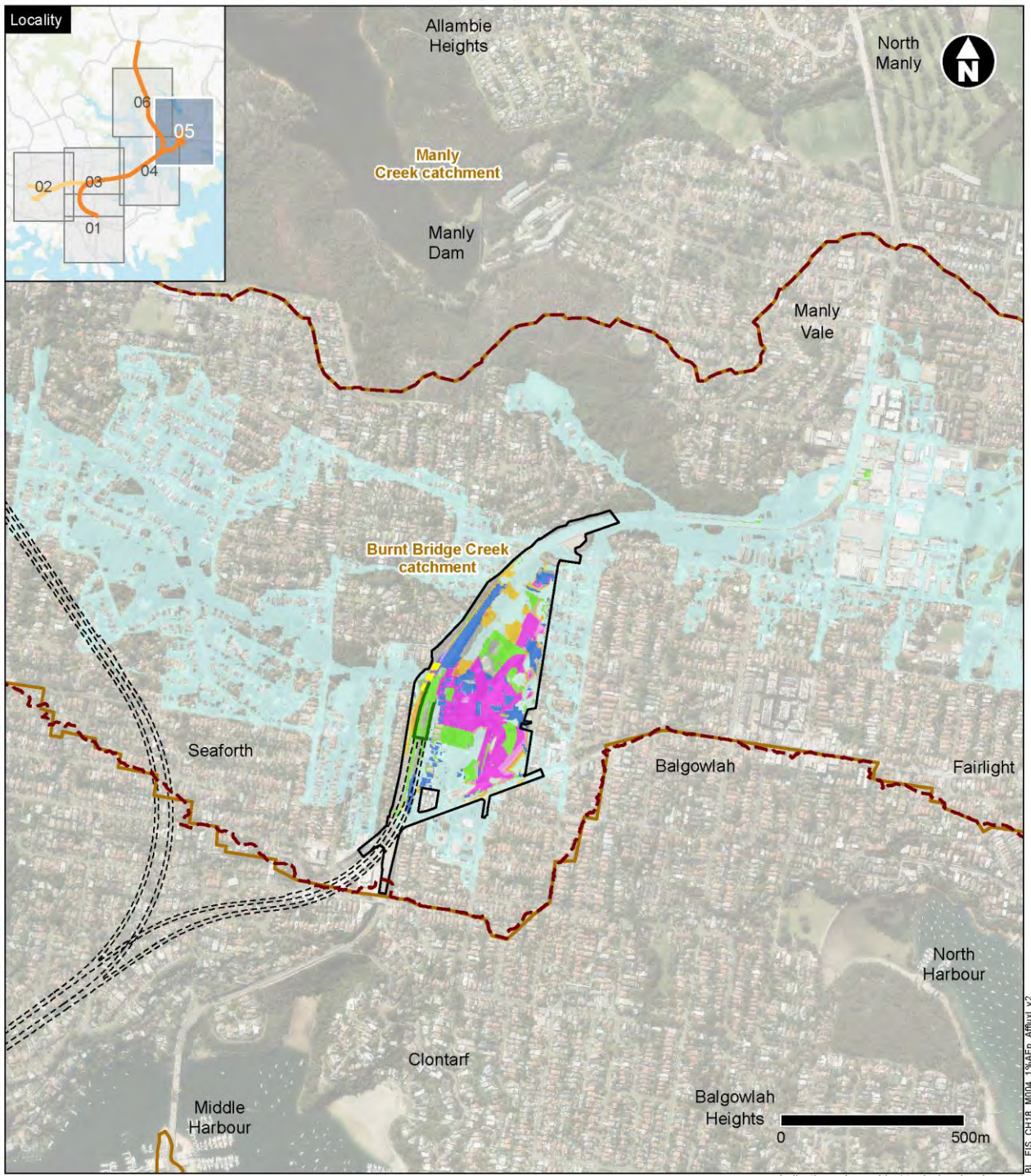


Indicative only – subject to design development

Legend

- | | | | |
|--|--------------------|----------------------------------|---|
| Construction footprint | Catchment boundary | Change in flood depth (m) | Land Rendered flood Free as a Result of Change |
| Tunnel section | Traffic barriers | <0 | Additional Area of Land Flooded as a Result of Change |
| Limit of main stream flood mapping and major overland flow mapping | Portal walls | 0 - 0.1 | |
| | | 0.1 - 0.2 | |
| | | 0.2 - 0.3 | |
| | | 0.3 - 0.5 | |
| | | > 0.5 | |

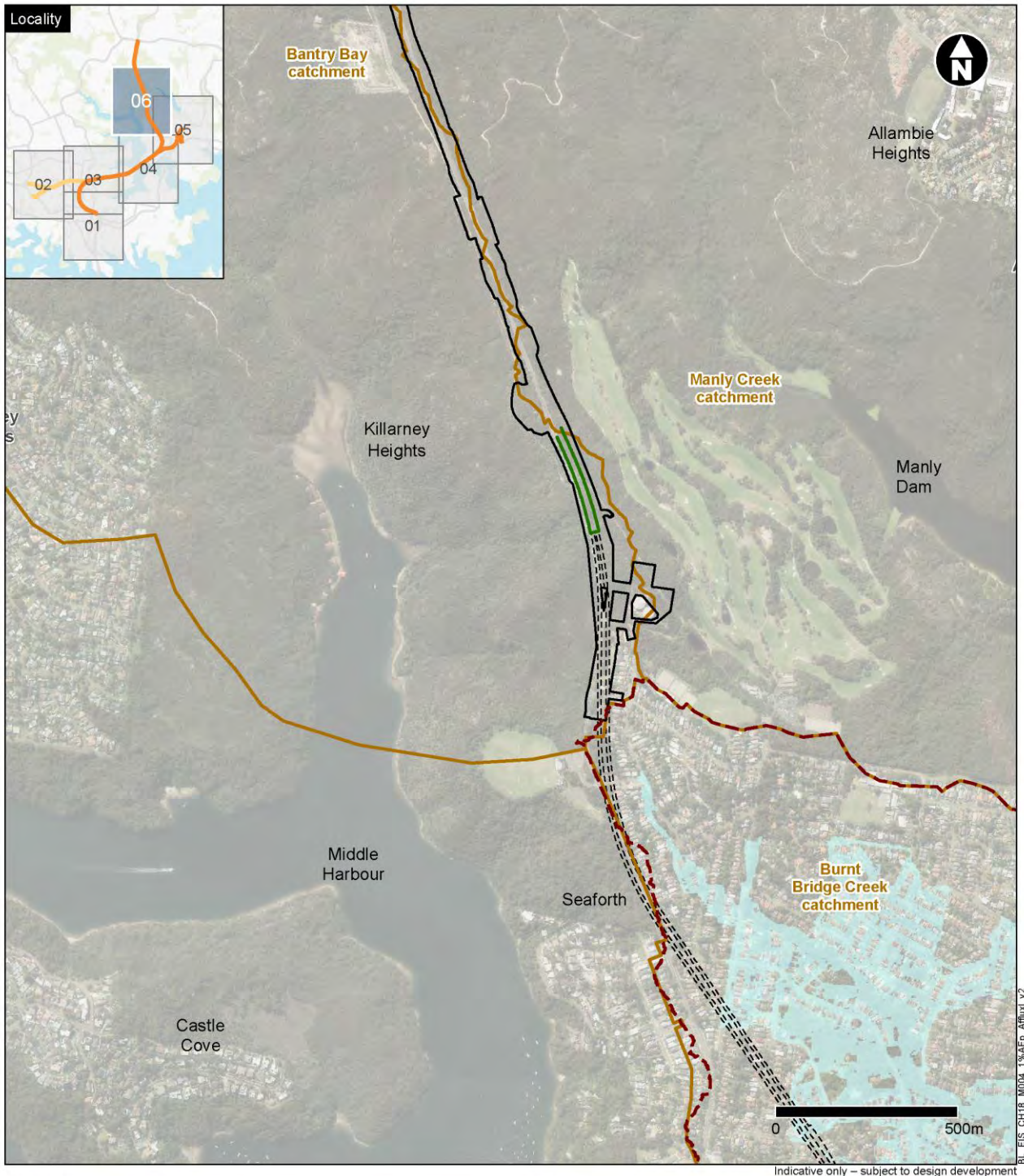
Figure 18-18 Change in flood depth under operational conditions – 1% AEP event (map 4)



Legend

- | | | | |
|--|--------------------|----------------------------------|---|
| Construction footprint | Catchment boundary | Change in flood depth (m) | Land Rendered flood Free as a Result of Change |
| Tunnel section | Traffic barriers | <0 | Additional Area of Land Flooded as a Result of Change |
| Limit of main stream flood mapping and major overland flow mapping | Portal walls | 0 - 0.1 | |
| | | 0.1 - 0.2 | |
| | | 0.2 - 0.3 | |
| | | 0.3 - 0.5 | |
| | | > 0.50 | |

Figure 18-19 Change in flood depth under operational conditions – 1% AEP event (map 5)



Indicative only – subject to design development

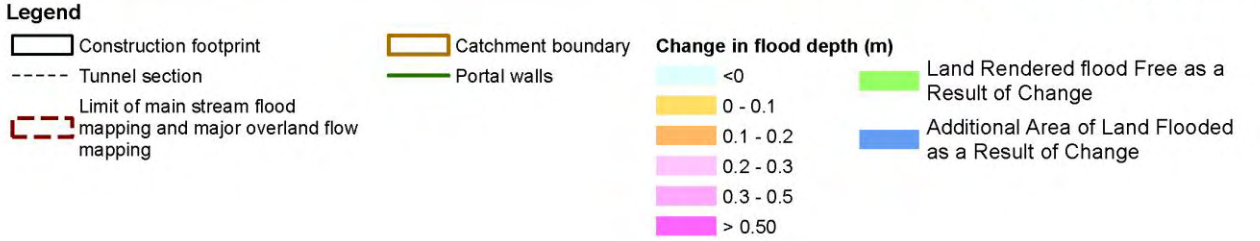


Figure 18-20 Change in flood depth under operational conditions – 1% AEP event (map 6)

Internal to the road corridor

Internal to the road corridor, the project would exacerbate flooding conditions during storms up to 1% AEP in intensity at the following locations:

- Flat Rock Creek Catchment:
 - At the location of a newly formed sag which would be located beneath the Reserve Road overpass on the Gore Hill Freeway westbound off ramp to Epping Road and the Pacific Highway. During a 1% AEP storm event, floodwater would pond across the two lane carriageway to a maximum depth of about 1.6 metres
 - At the location of a newly formed sag which would be located beneath the Reserve Road overpass on the Gore Hill Freeway eastbound on ramp to the Beaches Link tunnel. During a 1% AEP storm event, floodwater would pond across the two lane carriageway to a maximum depth of about 0.6 metres
 - Along the eastbound lanes of the Lane Cove Tunnel and Gore Hill Freeway carriageways extending from the Reserve Road interchange to a location east of the T1 North Shore and Western Line and T9 Northern Line overpass. Depths of flow along the two carriageways would be a maximum of about 300 millimetres in a 1% AEP storm event
- Burnt Bridge Creek Catchment:
 - While the flood modelling carried out as part of this study indicates that the depth of flow in the road corridor would be increased as part of the project, improvements to the existing pavement drainage system, the features of which were not incorporated in the flood models, would be aimed at controlling runoff under post-upgrade conditions.

Internal to the road corridor flow velocities and durations of inundation would generally be increased in the areas where increases in the depth and extent of inundation would be increased.

18.6.3 Potential impacts of the project on scour potential

The project has the potential to cause scouring in Burnt Bridge Creek, as well as the receiving drainage lines that are located along the Wakehurst Parkway due to the following:

- Increases in the rate of flow (and hence the depth and velocity of flow) associated with:
 - The enlargement of transverse drainage structures
 - The discharge of runoff from the widened carriageway
 - Changes in the distribution of flow along the project corridor
- Increases in the velocity of flow where it discharges from pipe outlets or newly lined sections of channel
- The concentration of flow resulting from the formalisation of the drainage system within the project corridor.

Increases in the rate of flow in the receiving drainage lines could result in a lowering of the stream bed through a process of headwater erosion, as well as a possible widening of the watercourse through a process of bank erosion. The lining of channels and the concentration of flow could also result in localised scour in the receiving drainage lines at the downstream limit of the drainage works.

Scour of Burnt Bridge Creek and the receiving drainage lines that are located along the Wakehurst Parkway has the potential to increase the turbidity of flow discharging to Bantry Bay and Manly Dam and to a lesser extent, Manly Lagoon.

18.6.4 Consistency with state government and local council flood plans and policies

The Warringah Local Environmental Plan 2011, the Manly Local Environmental Plan 2013 and the Willoughby Local Environmental Plan 2012 each contain flood planning clauses that apply to land at or below the Flood Planning Level, which is defined in all documents as equal to the peak 1% AEP flood level plus 0.5 metres. It is noted that both the North Sydney Local Environmental Plan 2013 and the Mosman Local Environmental Plan 2012 do not include a definition of the Flood Planning Level.

In accordance with the Secretary's environmental assessment requirements, a flood planning area has been defined by the current assessment through mapping the extent of land which lies below the peak 1% AEP flood level plus 0.5 metres under present day conditions. The flood planning area shown on Figure 4.7 of Appendix R (Technical working paper: Flooding) is based on mainstream flooding along the major creeks and tributaries that are crossed by the project, as well as the main paths associated with major overland flow. It should be noted that the flood modelling carried out for the assessment was developed for the specific purpose of assessing the flood risks and impacts associated with the project and therefore should be taken as preliminary only in terms of defining the flood planning area across the broader extent of flood prone land within the catchments that are crossed by the project.

The findings of the assessment presented in Section 18.6.2, show that the project would have only a minor impact on peak 1% AEP flood levels. As a result, the project would have no significant impact on the extent of the flood planning area and therefore the area of land to which clause 6.3 of Manly Local Environmental Plan 2013, Warringah Local Environmental Plan 2011 and Willoughby Local Environmental Plan 2012 would apply. While North Sydney Local Environmental Plan 2013 and Mosman Local Environmental Plan 2012 do not contain a definition of the flood planning level, the project would have no significant impact on the extent of the flood planning area were the two councils to adopt the same definition as set out in clause 6.3 of Manly Local Environmental Plan 2013, Warringah Local Environmental Plan 2013 and Willoughby Local Environmental Plan 2012.

While a floodplain risk management study and plan has only been prepared for the Manly Creek catchment, the findings of the assessment (Section 18.6.2) show that the project would have only a minor impact on peak flood levels external to the road corridor.

NSW State Emergency Service maintains two local units located on Station Street, Naremburn and Quirk Road, Balgowlah, both of which are located outside the project footprint and would not be affected by the project related flood impacts. Provided the flood mitigation measures set out in Section 18.8 are incorporated into the design of the project, the project would not increase the flood hazard in existing development for all events up to the 1% AEP event. The project would not have an adverse impact on NSW State Emergency Service's emergency response arrangements.

18.6.5 Impact of future climate change on flood behaviour

Impact of future climate change on flooding to the project

Annexure B of Appendix R (Technical working paper: Flooding) contains a series of figures which show flood behaviour under present day and project operation conditions for design storms with AEPs of 0.5% and 0.2%. Also included are a series of figures which show the impact that an increase in the intensity of a 1% AEP storm event would have on flooding patterns under project operation conditions. The 0.5% AEP and 0.2% AEP storms have been used as proxies to assess the impact that a 10 per cent and 30 per cent increase in 1% AEP rainfall intensities would have on flood behaviour in the vicinity of the project.

Impacts on flood behaviour associated with a potential increase in the rainfall intensities are summarised below.

Willoughby Creek Catchment

- While depth of ponding would be increased in ANZAC Park, it would not be deep enough to overtop the continuous concrete noise wall which runs along its northern side
- As a series of measures have been incorporated into the design of the project to prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at the Warringah Freeway would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Flat Rock Creek Catchment

- The rate at which flow approaches the Gore Hill Freeway from the urbanised catchments which lie to its north and south would increase, resulting in an increase in the depth of flow along several of its lanes
- As the operational facilities and ancillary infrastructure at the Gore Hill Freeway would be designed to prevent the ingress of floodwater to the building during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Burnt Bridge Creek Catchment

- Floodwater would surcharge the existing transverse drainage structure on Burnt Bridge Creek during storms that are more intense than about 0.2% AEP
- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at the Burnt Bridge Creek Deviation would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Bantry Bay Catchment

- As a series of measures have been incorporated into the design of the project that would prevent the ingress of floodwater to the tunnel portals for events up to the PMF, increases in peak flood levels associated with future climate change would not increase the flood risk to the project
- As the motorway facilities and ventilation outlet at the Wakehurst Parkway would be designed to prevent the ingress of floodwater to the tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Manly Creek Catchment

- Surcharge of the new pavement and transverse drainage could occur as a result of an increase in rainfall intensities. As the project generally runs along the catchment divide, surcharge of the proposed drainage is unlikely to result in an increase in the flood risk to road users
- As the operational facilities and ancillary infrastructure at Frenchs Forest and Killarney Heights at the Wakehurst Parkway would be designed to prevent the ingress of floodwater to the

tunnels during a PMF event, increases in peak flood levels associated with future climate change would not increase the flood risk to the project.

Trefoil Creek Catchment

- Surcharge of the new pavement drainage could occur as a result of an increase in rainfall intensities. As the project is located on the catchment divide, surcharge of the proposed drainage is unlikely to result in an increase in the flood risk to road users.

Impact of the project on flood behaviour under future climate change conditions

While the project would generally have a similar impact on flood behaviour to that described in Section 18.6.2 for a 1% AEP storm event under present day conditions for the assessed climate change scenarios, it would increase peak post-climate change 1% AEP flood levels, as described below.

Increases in sea level were not included in the assessment of climate change impacts on the basis that the surface works associated with the project operation are located above Reduced Level (RL) 10 metres Australian Height Datum (AHD) and are therefore well above areas that would be impacted by an increase in sea level due to climate change.

Burnt Bridge Creek Catchment

- Immediately upstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek, peak post-climate change 1% AEP flood levels could be increased by up to 250 millimetres, with the impacts extending into eleven residential properties located on either side of the watercourse
- Immediately downstream of the Burnt Bridge Creek Deviation crossing of Burnt Bridge Creek, peak post-climate change 1% AEP flood levels could be increased by up to 200 millimetres, noting that no existing or future development would be impacted as a result of these changes.

18.6.6 Impact of a partial blockage of the local stormwater drainage system on flood behaviour

The mechanism and geometrical characteristics of blockages in the piped system are difficult to quantify and would be different for each storm event. Realistic scenarios would be limited to one or two pipes becoming partially blocked during a storm event. However, for the purposes of the flooding impact assessment, analyses were carried out with the cross sectional areas of all pipes and conduits reduced by 50 per cent for the 1% AEP storm event. This represents a case which is well beyond a blockage scenario which could reasonably be expected to occur and is presented for illustrative purposes.

Annexure C (Figure C.1) of Appendix R (Technical working paper: Flooding) shows the impact a partial blockage of the local stormwater drainage system and the extended culverts under the Burnt Bridge Creek Deviation would have on peak 1% AEP flood levels in the vicinity of the proposed tunnel portals, bridges and surface road works. The key findings of the assessment are outlined below.

While the tunnel system would not be impacted by flooding should the existing stormwater drainage system experience a partial blockage during storms up to 1% AEP in intensity, there is the potential for floodwater to enter the tunnels should a partial blockage occur during more extreme storm events. For example, a partial blockage of the stormwater drainage system during a PMF event would result in flow discharging to the tunnel system at the location of the Gore Hill Freeway connection, while floodwater would commence to enter the tunnels via the Burnt Bridge Creek Deviation tunnel portals. During further design development, a risk assessment would be carried out to assess the flood risk in the tunnel system should the stormwater drainage system experience a partial blockage during storms that are more intense than 1% AEP.

Willoughby Creek Catchment

- While peak 1% AEP flood levels would be increased by about 1.5 metres in ANZAC Park, they would not be high enough to overtop the proposed flood walls which would border the proposed tunnel portals.

Flat Rock Creek Catchment

- While peak 1% AEP flood levels would be increased in the road corridor, they would not be high enough to cause floodwater to enter the proposed tunnel portals.

Burnt Bridge Creek Catchment

- Flow would surcharge the existing Burnt Bridge Creek transverse drainage structure on Burnt Bridge Creek Deviation, where it would discharge across both the northbound and southbound lanes before re-entering the creek on the eastern (downstream) side of the road corridor
- There would be a minor increase in the depth of overland flow discharging north along the access road.

Bantry Bay Catchment

- A partial blockage of the new pavement drainage system would result in the minor inundation of the Wakehurst Parkway at the major sag in the road which is located a short distance to the north of the tunnel portals. For example, flow would pond across the road until it reached the height of the adjacent footpath before discharging into the adjacent bushland.

Manly Creek Catchment

- A partial blockage of the new pavement drainage system would result in the minor inundation of the Wakehurst Parkway at the location of the two major sags in the road. For example, flow would pond across the road at these two locations until it reached the height of the adjacent footpath before discharging into the adjacent bushland
- A partial blockage of the transverse drainage may result in floodwater discharging onto the surface of the Wakehurst Parkway where it would pond at the location of the two major sags in the road. In this instance, flow would pond across the road until it reached the height of the adjacent footpath before discharging into the adjacent bushland.

Refer to Table 6.1 and 6.2 of Appendix R (Technical working paper: Flooding) for further details on the assessment findings outlined above.

18.6.7 Application of Australian Rainfall and Runoff 2019 to design flood estimation

The ARR 2019 was released during the preparation of the environmental impact statement. As a result, the procedures set out in ARR 1987 have been used as the basis of carrying out the flooding investigation for the project, noting the approach is consistent with the flood studies that have been carried out to date in the catchments through which it runs.

As the procedures set out in ARR 2019 would be used by councils to carry out new flood studies and to also update previous studies, a sensitivity study was carried out as part of the present investigation to assess the likely changes that would occur in predicted flood behaviour in the vicinity of the project where it runs through the Willoughby Creek catchment.

The procedures set out in ARR 2019 were applied to the hydrologic model that relate to the Willoughby Creek, Bantry Bay and Manly Creek (upper reaches only) catchments, and both them and the hydraulic model in the case of the Willoughby Creek catchment run for the 1% AEP storm event. The investigation found that there would be a reduction in the rate of runoff which would be generated by the catchment which in turn would result in a reduction in peak flood levels. This finding would apply to the adjacent catchments through which the project runs given the similar level of development in the area.

Based on the above finding, it was concluded that the adoption of the procedures set out in ARR 1987 represents a worse-case scenario in terms of assessing flood behaviour in the vicinity of the project.

18.7 Assessment of cumulative impacts

This section presents the findings of an assessment of the potential impacts the project would have on flood behaviour in combination with other nearby projects. The assessment was based on impacts during the operation of the project only, given the short term nature of exposure to potential flood impacts during the construction of the project together with the general requirement to manage adverse impacts on existing development.

18.7.1 Other motorway projects

Western Harbour Tunnel and Warringah Freeway Upgrade

The flood impact assessment set out in this technical working paper assumes that the Western Harbour Tunnel and Warringah Freeway Upgrade project forms part of baseline (ie pre-project) flooding conditions (ie it assumes that construction of the Western Harbour Tunnel and Warringah Freeway Upgrade project precedes that of the project).

While the present investigation found that the project would not exacerbate flooding conditions in existing development located in the Willoughby Creek catchment, a similar investigation found that the Western Harbour Tunnel and Warringah Freeway Upgrade project would increase peak 1% AEP flood levels by up to 16 millimetres in nine residential properties located along Cammeray Road, Park Avenue, Fall Street and Grafton Street in Cammeray.

18.7.2 Other projects

There are no other proposed non-motorway projects that are of a scale that would influence flood behaviour in the vicinity of the project.

18.8 Environmental management measures

The project has aimed to limit its impact in respect to flooding, both in terms of impacts on the project itself and the areas surrounding it. Project elements have been designed with consideration of the surrounding areas and management measures are proposed in order to reduce the impacts of flooding brought on by the project. Environmental management measures relating to flooding impacts are outlined in Table 18-3.

Table 18-3 Environmental management measures - flooding

Reference	Phase	Impact	Environmental management measure	Location
F1	Design	Impact of the project on flood behaviour	Where flood levels in the 1% AEP event are predicted to increase at any residential, commercial and/or industrial buildings as a result of operation of the project, a floor level survey will be carried out. If the survey indicates existing buildings would experience above floor inundation during a 1% AEP event as a result of the project, further refinements will be made (as required) to the design of permanent project components to minimise the potential for impacts.	BL/GHF
F2	Design	Operational flooding impacts	Impact of the project on flood behaviour during operation will be confirmed during further project development. This will include the consideration of future climate change and a partial blockage of the local stormwater drainage system.	BL/GHF
F3	Design	Impact of flooding on the project	Flood emergency management measures for construction and operation of the project will be prepared in consultation with State Emergency Services and relevant councils and incorporated into relevant environmental and/or safety management documentation.	BL/GHF
F4	Design	Impact of the project on scour potential	Measures will be assessed during further design development which are aimed at reducing as far as is practical the risk of increased scour in the receiving drainage lines that are located along the Wakehurst Parkway. Scour countermeasures will also be provided at the outlet of new or upgraded transverse and longitudinal drainage lines.	BL/GHF

Reference	Phase	Impact	Environmental management measure	Location
F5	Design and construction	Impacts of construction sites on flood behaviour	<p>Detailed construction planning will consider flood risk at construction sites and construction support sites. This will include:</p> <ul style="list-style-type: none"> • A review of site layout and staging of construction activities to avoid or minimise obstruction of overland flow paths and limit the extent of flow diversion required • Identification of measures to not worsen flood impacts on the community and on other property and infrastructure during construction up to and including the 1% AEP flood event where reasonable and feasible • Measures to mitigate alterations to local runoff conditions due to construction activities. 	BL/GHF
F6	Construction	Flooding impacts to tunnel excavation	Entries to tunnel excavations, including cut and cover sections of tunnel, will be protected against frequent flooding by locating openings outside flood prone areas, and/or the provision of local bunding and flood protection barriers.	BL/GHF
F7	Construction	Flooding impacts to tunnel excavation	The flood standard adopted at each tunnel entry during construction will be developed taking into consideration the duration of construction, the magnitude of inflows and the potential risks to personal safety and the project works.	BL/GHF
F8	Construction	Flood impacts to construction sites	Spoil stockpiles will be located in areas which are not subject to frequent inundation by floodwater, ideally outside the 10% AEP flood extent. The exact level of flood risk accepted at stockpile sites will depend on the duration of stockpiling operations, the type of material stored, the nature of the receiving drainage lines and also the extent to which it would impact flooding conditions in adjacent development.	BL/GHF
F9	Operation	Flood impacts to construction sites	Site facilities will be located outside high flood hazard areas based on a 1% AEP flood.	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 19

Biodiversity

19 Biodiversity

This chapter provides an assessment of the potential impacts of the project on terrestrial, aquatic and marine biodiversity and identifies measures to address these impacts.

A detailed assessment of terrestrial and aquatic biodiversity has been carried out for the project and is included in Appendix S (Technical working paper: Biodiversity development assessment report). A detailed assessment of marine biodiversity has been carried out for the project and is included in Appendix T (Technical working paper: Marine ecology).

The Secretary's environmental assessment requirements as they relate to biodiversity, and where in the environmental impact statement these have been addressed, are detailed in Table 19-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to biodiversity are included in Section 19.6.

Table 19-1 Secretary's environmental assessment requirements – biodiversity

Secretary's requirement	Where addressed in EIS
Biodiversity	
1. Biodiversity impacts related to the proposal are to be assessed in accordance with the Biodiversity Assessment Method and documented in a Biodiversity Development Assessment Report (BDAR).	Biodiversity impacts related to the project are provided in Section 19.5 and documented in Appendix S (Technical working paper: Biodiversity development assessment report).
2. The BDAR must include information in the form detailed in the <i>Biodiversity Conservation Act 2016</i> (s. 6.12), Biodiversity Conservation Regulation 2017 (s. 6.8) and Biodiversity Assessment Method (BAM) including details of the measures proposed to address the offset obligation as follows: <ol style="list-style-type: none"> a. the total number and classes of biodiversity credits required to be retired for the developments/project; b. the number of classes of like-for-like biodiversity credits proposed to be retired; c. the number and classes of biodiversity credits proposed to be retired in accordance with the variation rules; d. any proposal to fund a biodiversity conservation action; and 	The biodiversity development assessment report is provided in Appendix S (Technical working paper: Biodiversity development assessment report).

Secretary's requirement	Where addressed in EIS
e. any proposal to make a payment to the Biodiversity Conservation Fund.	
3. The BDAR must document the application of the avoid, minimise and offset framework including assessing all direct, indirect and prescribed impacts in accordance with the BAM.	<p>Section 19.4 describes how the development of the project has avoided and minimised direct and indirect biodiversity impacts with further discussion provided in Appendix S (Technical working paper: Biodiversity development assessment report). Further details about route option development are provided in Chapter 4 (Project development and alternatives).</p> <p>Section 19.5 provides an assessment of all direct, indirect and prescribed impacts in accordance with the <i>Biodiversity Assessment Method</i>. Section 19.6 provides environmental management measures to further avoid and/or minimise biodiversity impacts and Section 19.6.1 details the proposed offsets for the project. Further detail is included in Appendix S (Technical working paper: Biodiversity development assessment report).</p>
4. If requesting the application of the variation rules, the BDAR must contain details of what reasonable steps have been taken to attempt to obtain the required like-for-like biodiversity credits.	Not applicable.
5. The BDAR must include all spatial data associated with the survey and assessment as per Appendix 11 of the BAM.	Spatial data is provided as part of the Appendix S (Technical working paper: Biodiversity development assessment report) submission and <i>Biodiversity Assessment Method</i> credit calculator finalisation.
6. The BDAR must be prepared by a person accredited in accordance with the Accreditation scheme for the Application of the Biodiversity Assessment Method Order 2017 under s. 6.10 of the <i>Biodiversity Conservation Act 2016</i> .	Details on accreditation in accordance with the Accreditation scheme for the Application of the Biodiversity Assessment Method Order 2017 is provided in Appendix S (Technical working paper: Biodiversity development assessment report).
7. In accordance with section 9.1 and 9.2 of the BAM the BDAR must assess all direct and indirect impacts of the proposal on native vegetation, threatened ecological communities and threatened species habitat.	Section 19.5 provides an assessment of biodiversity impacts related to the project with further details provided in Appendix S (Technical working paper: Biodiversity development assessment report).

Secretary's requirement	Where addressed in EIS
<p>8. Impacts on biodiversity values that cannot be assessed using the BAM must also be otherwise assessed. The values include:</p> <ul style="list-style-type: none"> a. marine mammals; b. wandering seabirds; and c. matters of national significance listed under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999. 	<p>Section 19.5 includes an assessment of impacts on biodiversity values that cannot be assessed using the <i>Biodiversity Assessment Method</i>. Further details are provided in Appendix S (Technical working paper: Biodiversity development assessment report) and Appendix T (Technical working paper: Marine ecology).</p>
<p>9. Species declared as threatened under the <i>Biodiversity Conservation Act 2016</i> and recorded recently (since 1990) within approximately 1.5 kilometres of the project's development corridor should be considered as likely to be affected by the proposal.</p>	<p>Section 19.5 provides an assessment of the impacts to threatened species. Consideration of species recently recorded within 1.5 kilometres of the construction footprint are documented in Appendix S (Technical working paper: Biodiversity development assessment report).</p>
<p>10. Identify and assess the impacts of tidal flushing on the crossing of Middle Harbour. This assessment should also include details of any potential sediment accumulation and the impacts this may have on marine populations that dwell on the harbour floor.</p>	<p>Section 19.5.5 provides an assessment of the impacts of tidal flushing, including low dissolved oxygen and sedimentation on marine populations. This is further discussed in Appendix T (Technical working paper: Marine ecology).</p>

19.1 Legislative and policy framework

Chapter 2 (Assessment process) describes the environmental impact assessment and approval process for the project, including relevant NSW and Commonwealth legislation applicable to the project. The key legislative requirements and assessment guidelines specific to biodiversity are outlined below.

19.1.1 Biodiversity Conservation Act 2016

The *Biodiversity Conservation Act 2016* replaced the *Threatened Species Conservation Act 1995* on 25 August 2017. The *Biodiversity Conservation Act 2016* aims to maintain a healthy, productive and resilient environment for the greatest well-being of the community, now and into the future, consistent with the principles of ecologically sustainable development. It establishes a framework for assessment and offsetting of biodiversity impacts as well as investment in biodiversity conservation.

The *Biodiversity Assessment Method* (Office of Environment and Heritage (OEH), 2017) is established under section 6.7 of the *Biodiversity Conservation Act 2016*. The purpose of the *Biodiversity Assessment Method* is to assess impacts on threatened species and threatened ecological communities, and their habitats, and the impact on biodiversity values, where required under the *Biodiversity Conservation Act 2016*. The Biodiversity development assessment report provided in Appendix S (Technical working paper: Biodiversity development assessment report) was prepared on the basis of the *Biodiversity Assessment Method* in force before 22 October 2020.

19.1.2 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) includes provisions to protect and manage matters of national environmental significance, including nationally and internationally important flora, fauna, ecological communities and migratory species, defined in the *Environment Protection and Biodiversity Conservation Act 1999* as matters of national environmental significance.

In accordance with sections 67 and 67A of the *Environment Protection and Biodiversity Conservation Act 1999*, any action that has potential to result in an impact on any matters of national environmental significance or on Commonwealth land are considered 'controlled actions' and require a referral to the Australian Government Minister for the Environment for approval. The significance of impacts on matters of national environmental significance is determined in accordance with the *Significant Impact Guidelines 1.1 – Matters of National Environmental Significance* (Department of the Environment, 2013).

19.1.3 Fisheries Management Act 1994

The *Fisheries Management Act 1994* contains provisions for the conservation of fish stocks, key fish habitat, biodiversity, threatened species, populations and ecological communities. The *Fisheries Management Act 1994* regulates the conservation of fish, marine vegetation and some aquatic macroinvertebrates and the development and sharing of fishery resources of NSW for present and future generations. Part 7 of the *Fisheries Management Act 1994* identifies requirements for the protection of aquatic habitats, while Part 7A of the *Fisheries Management Act 1994* lists threatened species, populations and ecological communities and key threatening processes for species, populations and ecological communities in NSW waters. Section 220ZZ of the *Fisheries Management Act 1994* outlines significant impact considerations to threatened species, populations and ecological communities listed under the *Fisheries Management Act 1994*.

19.1.4 Assessment policy and guidelines

A number of assessment guidelines were used to inform the biodiversity assessment, the most relevant of which were:

- *Biodiversity Assessment Method* (OEH, 2017) – for the assessment of impacts on threatened species, threatened ecological communities, and their habitats, and the impact on biodiversity values, where required under the *Biodiversity Conservation Act 2016*
- *Significant Impact Guidelines 1.1 – Matters of National Environmental Significance* (Department of the Environment, 2013) – for the assessment of significance of impacts on matters of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999*
- *Policy and guidelines for fish habitat conservation and management* (NSW Department of Primary Industries (NSW DPI), 2013) – for the assessment of freshwater and marine biodiversity matters.

Lists of all of the assessment guidelines that were used to inform the biodiversity assessment are provided in Appendix S (Technical working paper: Biodiversity development assessment report) and Appendix T (Technical working paper: Marine ecology).

19.2 Assessment methodology

The biodiversity assessment includes consideration of potential impacts on:

- Terrestrial biodiversity, consistent with the *Biodiversity Assessment Method* (Section 19.2.1)
- Aquatic (freshwater) biodiversity (Section 19.2.2)
- Marine biodiversity (Section 19.2.3).

The key terminology used for the terrestrial, aquatic and marine biodiversity assessments with regard to extent of assessments and identification of impacts is summarised in Table 19-2.

Table 19-2 Biodiversity assessment extent terminology

Term	Definition
Terrestrial biodiversity	
Assessment area	An area within 500 metres of the construction footprint
Construction footprint	The aboveground area to be directly impacted by the project
Terrestrial biodiversity locality	An area within 10 kilometres of the construction footprint
Aquatic biodiversity	
Assessment area	An area within 500 metres of the construction footprint
Construction footprint	The aboveground area to be directly impacted by the project
Aquatic biodiversity study area	An area encompassing the construction footprint and areas immediately adjacent (about 500 metres around the construction footprint)
Marine biodiversity	
Project area	The marine area to be directly impacted by the project
Marine biodiversity study area	Estuarine areas from the highest astronomical tide encompassing the project area and areas nearby from Yeoland Point to Grotto Point
Marine biodiversity study locality	An area within 10 kilometres of the project area (for the purpose of the desktop review)

19.2.1 Terrestrial biodiversity

The assessment of potential impacts on terrestrial biodiversity has been carried out in accordance with the *Biodiversity Assessment Method* (OEH, 2017). The assessment methodology is summarised below, with further detail provided in Appendix S (Technical working paper: Biodiversity development assessment report).

Desktop assessment

A desktop assessment was carried out for the project, including review of information from relevant databases, vegetation maps, topographic maps, aerial photography, reports and published literature.

The following databases were searched on several occasions between June 2016 and April 2020:

- BioNet Atlas of NSW Wildlife
- Environment Protection and Biodiversity Conservation Act 1999 Protected Matters Search Tool
- Threatened species profile search.

The database searches were carried out for the terrestrial biodiversity locality.

The desktop assessment was used to identify threatened species, populations, communities and their habitats with a likelihood of occurrence in areas that may be impacted by the project.

Field surveys

Multiple field surveys were carried out between May 2016 and April 2020, and included:

- Random meander surveys to verify vegetation communities and the condition of vegetation across accessible land within the construction footprint
- Targeted flora and fauna surveys for species identified as having a high or moderate likelihood of occurrence in areas that may be impacted by the project, as identified through the desktop assessment
- Vegetation integrity plots involving quantitative (quadrat/transect) site surveys in accordance with the *Biodiversity Assessment Method*
- Floristic analysis of vegetation plot data to determine vegetation community and plant community types. Native vegetation was classified according to the plant community types in the Vegetation Information System Classification (DPIE (EES), 2020b). Areas of non-PCT vegetation were also identified and mapped.

Further detail on the field surveys between May 2016 and April 2020 is provided in Appendix S (Technical working paper: Biodiversity development assessment report).

Assessment of potential impacts

The potential impacts of the project were assessed against the relevant matters in the *Biodiversity Assessment Method* (OEH, 2017), including:

- Removal of native vegetation and habitat, including direct and indirect impacts on native vegetation and threatened flora
- The potential for serious and irreversible impacts on identified threatened species and ecological communities
- The prescribed biodiversity impacts under the *Biodiversity Assessment Method* (OEH, 2017)
- The potential for impacts on relevant matters of national environmental significance under the *Environment Protection and Biodiversity Conservation Act 1999*.

For the purposes of the assessment, it is assumed that all vegetation within the construction footprint would be removed, except for the Burnt Bridge Creek riparian corridor exclusion zone shown in Figure 19-3.

19.2.2 Aquatic biodiversity

The freshwater aquatic habitat assessment was informed by the results of inspections carried out across five waterways, and associated tributaries, and two waterbodies within the aquatic biodiversity study area:

- Willoughby Creek
- Flat Rock Creek
- Burnt Bridge Creek
- Manly Creek
- Manly Dam
- Trefoil Creek
- Wakehurst Golf Course dam – a dam downstream of the Wakehurst Parkway east construction support site (BL13).

The extent and condition of freshwater habitats within the aquatic biodiversity study area was recorded during the site inspections.

No fish or macroinvertebrate sampling was carried out during the inspections. The likelihood of occurrence of aquatic species has been assessed based on the availability of suitable habitat. Further details of the inspection locations are provided in Annexure D (Freshwater ecology impact assessment) of Appendix S (Technical working paper: Biodiversity development assessment report).

In summary, the aquatic assessment involved the following:

- Identification of the location, extent and condition of waterways potentially impacted by the project
- Assessment of potential impacts to freshwater ecology, including threatened species and ecological communities, and geomorphology due to construction and operation of the project
- Identification of environmental management measures and offsets required to manage potential impacts to aquatic biodiversity.

19.2.3 Marine biodiversity

The assessment methodology for marine biodiversity is summarised below, with further details provided in Appendix T (Technical working paper: Marine ecology).

Desktop assessment

A desktop assessment was carried out for the project, including review of information from relevant databases, aerial photography, reports and published literature.

The following databases were searched:

- BioNet Atlas of NSW Wildlife
- Environment Protection and Biodiversity Conservation Act 1999 Protected Matters Search Tool
- Threatened species profile search
- NSW Department of Planning, Industry and Environment's Fish Communities and Threatened Species Distribution of NSW
- NSW Department of Planning, Industry and Environment's Listed Protected Fish Species website
- NSW Department of Planning, Industry and Environment's Listed Threatened Species, Populations and Ecological Communities website
- National System for the Prevention and Management of Marine Pest Incursions website
- Atlas of Living Australia.

The database searches were carried out for the marine biodiversity study locality.

The desktop assessment was used to identify threatened species, populations, communities and their habitats with a likelihood of occurrence in areas to be impacted by the project.

Field surveys

Preliminary sampling and predictive habitat mapping from aerial photography captured in May 2017 was used to identify areas for field surveys. Sites for field surveys also took into account the outcomes of the desktop assessment, including consideration of relevant species, communities, populations and habitats, and their likelihood of occurrence in areas that may be impacted by the project.

Field surveys were carried out within Middle Harbour in November and December 2017, between Yeoland Point at Castle Cove and Grotto Point at the entrance to Middle Harbour. The field surveys included mapping and confirmation of seagrass, subtidal rocky reef, intertidal rocky reef and deep water soft sediment habitats. Surveys of macroalgae, sessile invertebrate and epibiota coverage and fish numbers, and macroinvertebrate sampling were also carried out in relevant habitats.

Assessment of potential impacts

A risk based approach was applied to the assessment of potential direct and indirect impacts of the project on marine biodiversity, including impacts associated with:

- Removal of habitat
- Turbidity
- Sedimentation
- Mobilisation of contaminants
- Introduction/spread of marine pests
- Altered hydrodynamics
- Underwater noise
- Boat strike to marine mammals and reptiles
- Spill of contaminants.

The assessment considered the sensitivity of key fish habitat types, including Type 1 (highly sensitive), Type 2 (moderately sensitive) and Type 3 (minimally sensitive) habitats.

The likelihood and consequence of direct and indirect impacts on each key fish habitat were evaluated to determine an anticipated level of risk. The levels of risk applied to the assessment are summarised in Table 19-3.

Table 19-3 Risk levels applied to the assessment of potential marine biodiversity impacts

Level of risk	Description
Extreme	The risk is unmanageable and unjustified. Measures to reduce the risk to a lower level are required.
High	The risk is significant and requires substantial measures for risk reduction and/or management.
Medium	The risk may be acceptable and requires routine management measures.
Low	The risk is acceptable and requires either routine management measures or no further measures.

19.3 Existing environment

This section summarises the existing key biodiversity values along and around the project alignment, including:

- Terrestrial flora (Section 19.3.1)
- Terrestrial fauna (Section 19.3.2)
- Aquatic biodiversity (Section 19.3.3)
- Marine biodiversity (Section 19.3.6).

19.3.1 Terrestrial flora

Vegetation communities

Vegetation communities within the construction footprint are summarised in Table 19-4 and shown in Figure 19-1 to Figure 19-5.

The construction footprint of the project overlaps with the construction footprint of the Western Harbour Tunnel and Warringah Upgrade project at Warringah Freeway/Cammeray Golf Course construction support site (BL1). This overlap area was previously assessed as part of the environmental impact statement prepared for the Western Harbour Tunnel and Warringah Upgrade project in 2020. As such, consideration of vegetation within the overlap is not included in the assessment of the Beaches Link and Gore Freeway Connection project.

In addition, the recently completed Northern Beaches Hospital road upgrade project overlaps with the northern extent of the construction footprint. The area of overlap has been heavily modified/cleared due to the construction of the Northern Beaches Hospital road upgrade project. As such, for the purposes of this assessment, all calculations of biodiversity impacts have excluded the area of overlap (see Figure 19-5).

Field surveys carried out for the project identified seven native vegetation communities within the construction footprint, consistent with the following plant community types (PCT):

- PCT 1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion
- PCT 1292: Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion
- PCT 1783: Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast
- PCT 1786: Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region
- PCT 1824: Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin
- PCT 1841: Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region
- PCT 1845: Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney.

These vegetation communities cover around 15.05 hectares within the construction footprint.

Other vegetation within the construction footprint is also described in Table 19-4 and shown in Figure 19-1 to Figure 19-5 and includes:

- Native revegetation
- Native plantings
- Urban exotic/native
- Weeds and exotics.

This vegetation covers around 6.77 hectares within the construction footprint.

A vegetation exclusion zone is shown on Figure 19-3. This zone was included to reduce the direct impact on the Burnt Bridge Creek riparian corridor and is further discussed in Section 19.4.

Threatened ecological communities

Several patches of the Duffys Forest endangered ecological community (aligned with PCT 1786) have been identified within the construction footprint, as shown in Figure 19-4 and Figure 19-5. This community is listed as endangered under the *Biodiversity Conservation Act 2016*.

The Wakehurst Parkway north construction support site (BL14) would be the same site that was used as the main construction support site for the Northern Beaches Hospital road upgrade project (refer to Figure 19-5). Revegetation works were carried out at this site, including planting with species consistent with the Duffys Forest endangered ecological community within the eastern section of the decommissioned construction support site. During site establishment of the Wakehurst Parkway north construction support site (BL14), this revegetated area would remain fenced off and protected from disturbance. Due to the timing of these recent revegetation works, the current site layout of the Wakehurst Parkway north construction support site (BL14) does not show the revegetation area. During further design development and construction planning, the temporary construction support site layout would be refined to show the revegetation area, and ensure it is avoided and protected during construction.

Table 19-4 Vegetation communities within the construction footprint

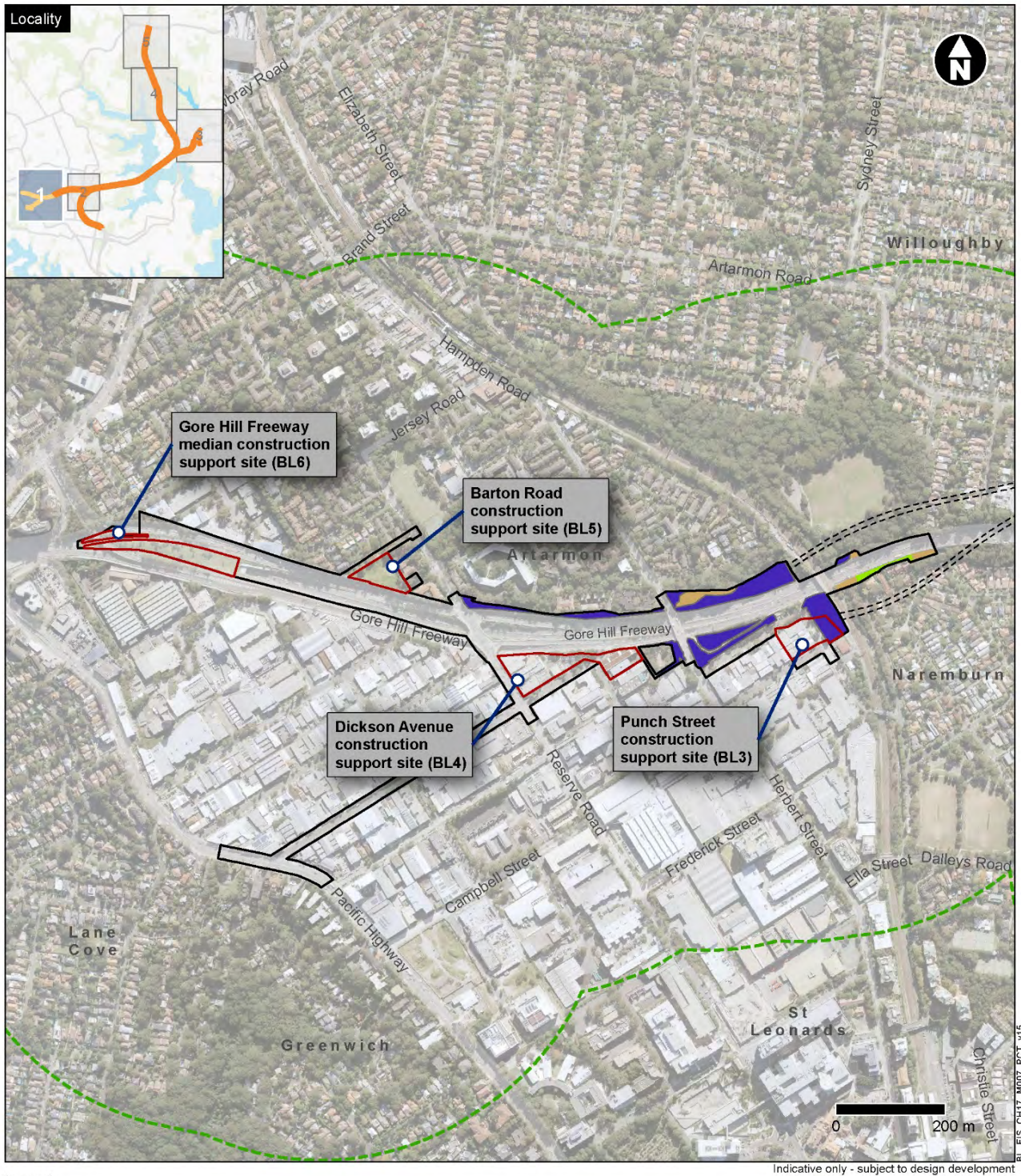
Mapped vegetation ¹	Corresponding plant community type (PCT)	Location within the construction footprint	Area within the construction footprint (ha)
Native vegetation community	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion (PCT 1250)	This community occurs on sandy soils influenced by Hawkesbury Sandstone and alluvium geologies. Within the construction footprint, the community was found adjoining the Wakehurst Parkway, within a steep gully forming the head of a tributary of Manly Creek.	0.20
Native vegetation community	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion (PCT 1292)	This community occurs on sandy soils derived from sandstone and alluvium geologies. Within the construction footprint, this community occurs along the Burnt Bridge Creek riparian corridor within Balgowlah Golf Course, and the Kitchener Street construction support site (BL11). Within the construction footprint, this community experiences moderate to high levels of disturbance intersected by walking paths and roads as well being exposed to rubbish, stormwater debris and erosion of substrates and creek banks. It is likely that these factors have contributed to the diversity of exotic plant species recorded within the construction footprint. Weed coverage however is generally restricted to the mid-storey and groundcover with only three exotic canopy trees recorded.	0.88
Native vegetation community	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast (PCT 1783)	This community occurs along the Wakehurst Parkway on dry sandy soils derived from Hawkesbury sandstone. Along the Wakehurst Parkway the community is subjected to disturbance such as walking paths, edge effects associated with the road and minor weed incursions. This community also occurs within the proposed Wakehurst Parkway east construction support site (BL13).	4.23

Mapped vegetation ¹	Corresponding plant community type (PCT)	Location within the construction footprint	Area within the construction footprint (ha)
Native vegetation community	<p>Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (PCT 1786)</p> <p>(consistent with the Duffys Forest endangered ecological community)</p>	<p>This community occurs on sandy soils derived from sandstone geology and was generally found on the upper slopes supporting a diverse range of small trees, shrubs and ground covers. This community was recorded along the Wakehurst Parkway within the construction footprint and subsequently experiences moderate levels of disturbances in the form of walking paths, edge effects associated with the road and minor weed incursions. This community also occurs within the proposed Wakehurst Parkway south construction support site (BL12).</p>	1.38
Native vegetation community	<p>Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin (PCT 1824)</p>	<p>This community is associated with wetter areas on sandy soils derived from sandstone geology. This community was mapped along the Wakehurst Parkway within the construction footprint, and subsequently experiences moderate levels of disturbance in the form of walking paths, edge effects associated with the road and minor weed incursions. This community also occurs within the proposed Wakehurst Parkway east construction support site (BL13).</p>	6.18
Native vegetation community	<p>Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region (PCT 1841)</p>	<p>This community occurs on sandy soils with slight loam components derived from Hawkesbury sandstone geology. These areas vary in gradient from gentle to steep and were typically situated within proximity to a watercourse. Within the construction footprint, this community was recorded along Burnt Bridge Creek within the Balgowlah Golf Course, within Flat Rock Drive construction support site (BL2) associated with an existing aboveground watercourse and at the Gore Hill Freeway.</p>	1.79

Mapped vegetation ¹	Corresponding plant community type (PCT)	Location within the construction footprint	Area within the construction footprint (ha)
Native vegetation community	Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney (PCT 1845)	This community occurs on sandy soils derived from sandstone geology and was generally found on the upper slopes supporting a diverse range of small trees, shrubs and ground covers. This community was recorded along the northern section of the Wakehurst Parkway within the construction footprint and subsequently experiences moderate levels of disturbance in the form of walking paths, edge effects associated with the road and minor weed incursions.	0.39
Total area of mapped native vegetation communities (PCTs)			15.05
Native revegetation	Assigned to the adjoining Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region (PCT 1841) for the purpose of assessment using the <i>Biodiversity Assessment Method</i> credit calculator	This vegetation type is located within Flat Rock Drive construction support site (BL2). The Flat Rock Drive construction support site (BL2) is located within Flat Rock Reserve, a council reserve containing native revegetation. Flat Rock Reserve supported a municipal waste landfill site until 1985. The site was capped with clay in 1998 and has since been progressively revegetated.	1.29
Native plantings	Not consistent with the definition of any plant community type Miscellaneous ecosystems - highly disturbed with no or limited native vegetation	This vegetation association occurs within highly disturbed areas which have been subject to landscaping following development of infrastructure (eg roads, rail, and electricity easements), recreational facilities (eg sports fields, walking tracks), parking areas as well as residential and commercial areas. These landscaped areas have commonly been planted out with native species using horticultural specimens with unknown genetic origins. This vegetation type occurs at Gore Hill Freeway, within the proposed Flat Rock Drive construction support site (BL2), Balgowlah Golf Course construction support site (BL10) and Wakehurst Parkway east construction support site (BL13).	0.36

Mapped vegetation ¹	Corresponding plant community type (PCT)	Location within the construction footprint	Area within the construction footprint (ha)
Urban exotic/native	<p>Not consistent with the definition of any plant community type</p> <p>Miscellaneous ecosystems - highly disturbed with no or limited native vegetation</p>	<p>This vegetation type occurs as garden, park and road verge plantings within existing disturbed areas of the construction footprint. These areas generally contain planted native and exotic horticultural specimens or isolated remnant trees within otherwise planted areas.</p> <p>This vegetation type occurs at Gore Hill Freeway, within the proposed Punch Street construction support site (BL3), Balgowlah Golf Course construction support site (BL10) and Wakehurst Parkway south construction support site (BL12).</p>	4.89
Weeds and exotics	<p>Not consistent with the definition of any plant community type</p> <p>Miscellaneous ecosystems - highly disturbed with no or limited native vegetation</p>	<p>This vegetation type occurs throughout the construction footprint as cleared lands dominated by weeds and/or exotic species. These areas generally occur as exotic grasslands or dense thickets of woody weeds within parks and road verges.</p>	0.23
Total vegetation within construction footprint (including native vegetation communities)			21.82

Note 1: Vegetation mapped by project ecologists as part of field surveys for the biodiversity development assessment report



Indicative only - subject to design development

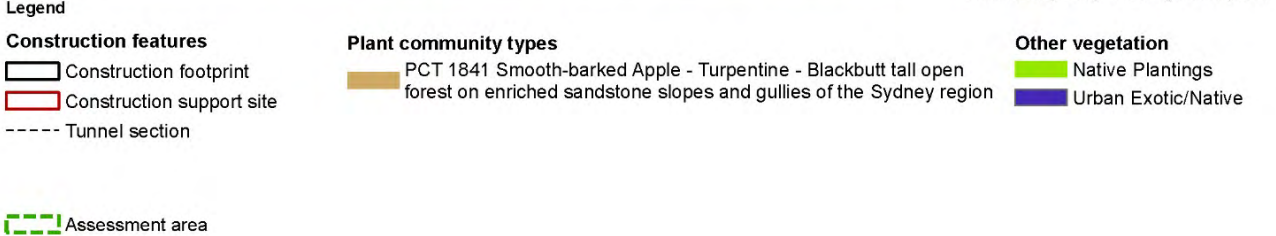


Figure 19-1 Distribution of plant community types and other vegetation (map 1)

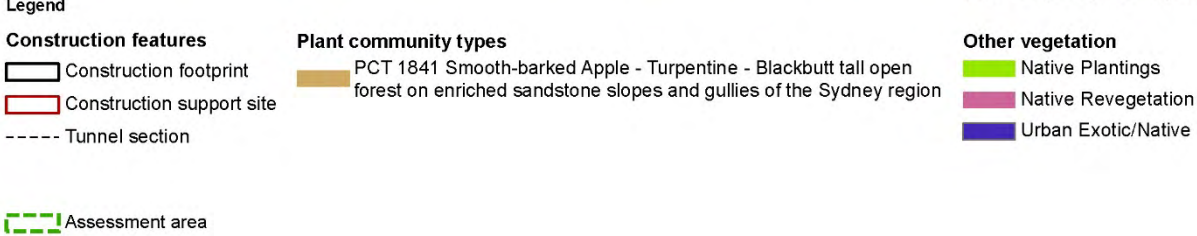
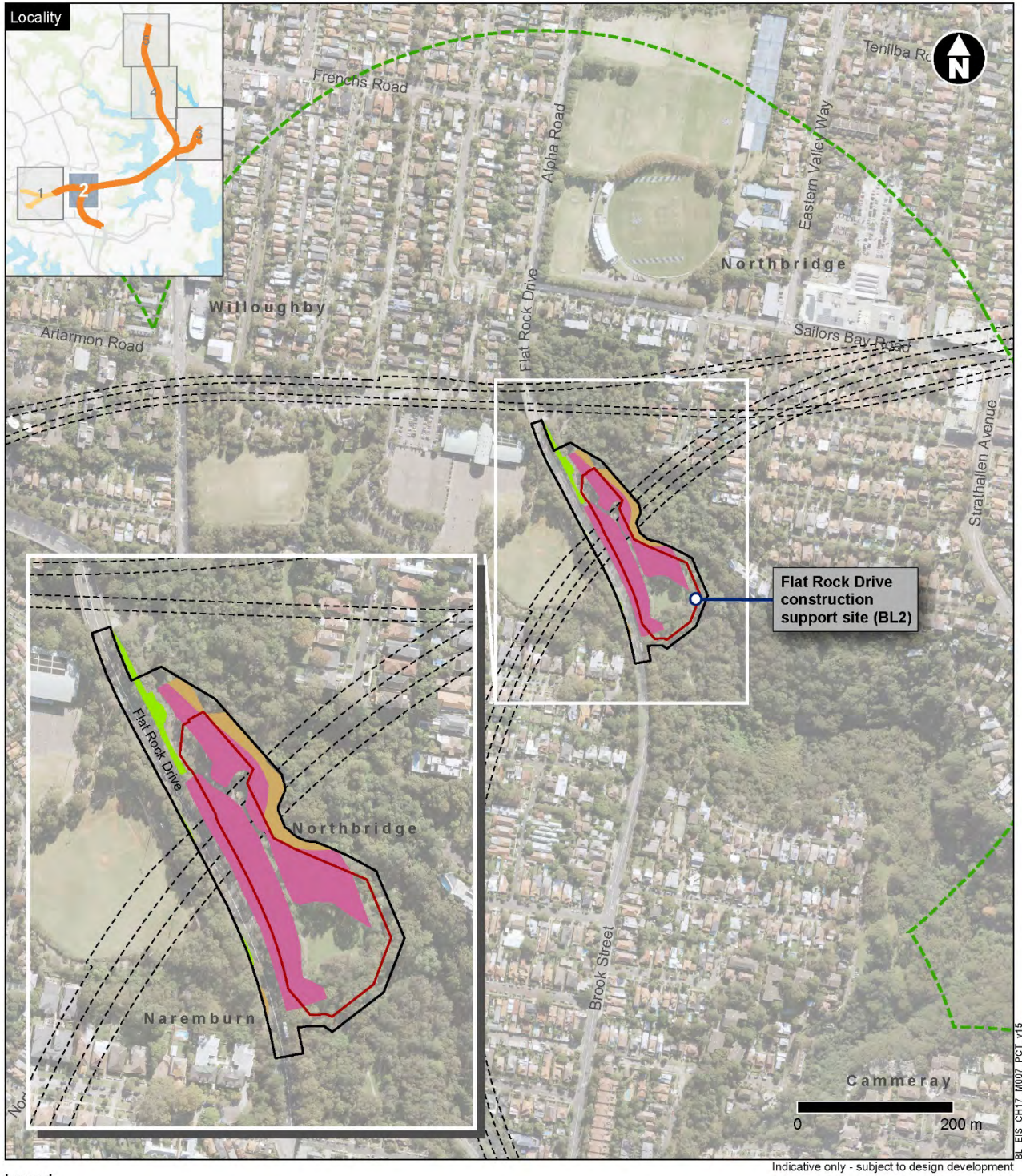


Figure 19-2 Distribution of plant community types and other vegetation (map 2)

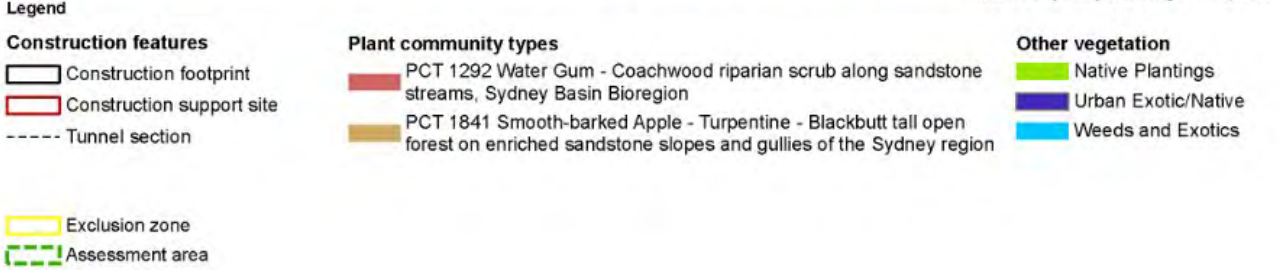
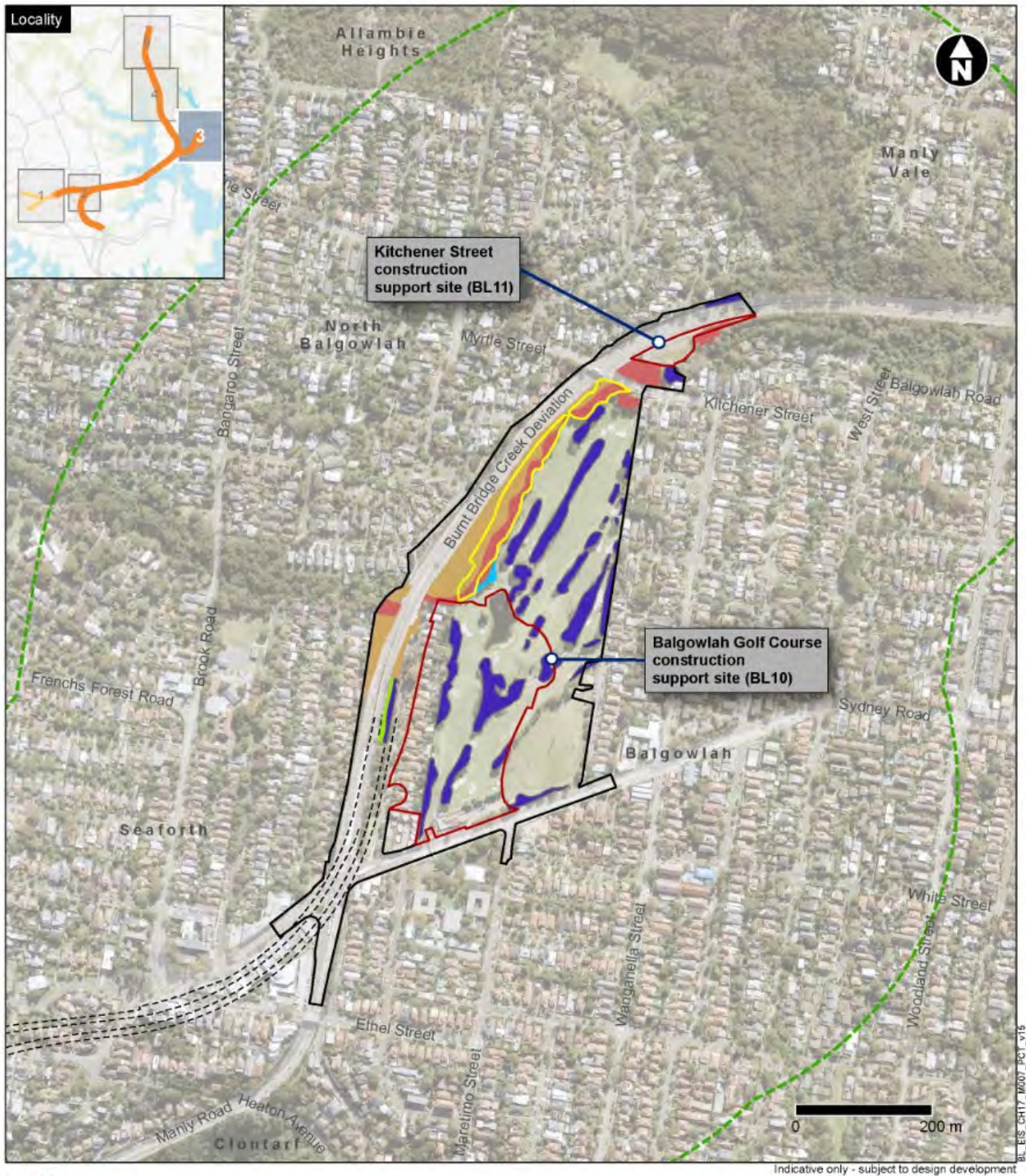
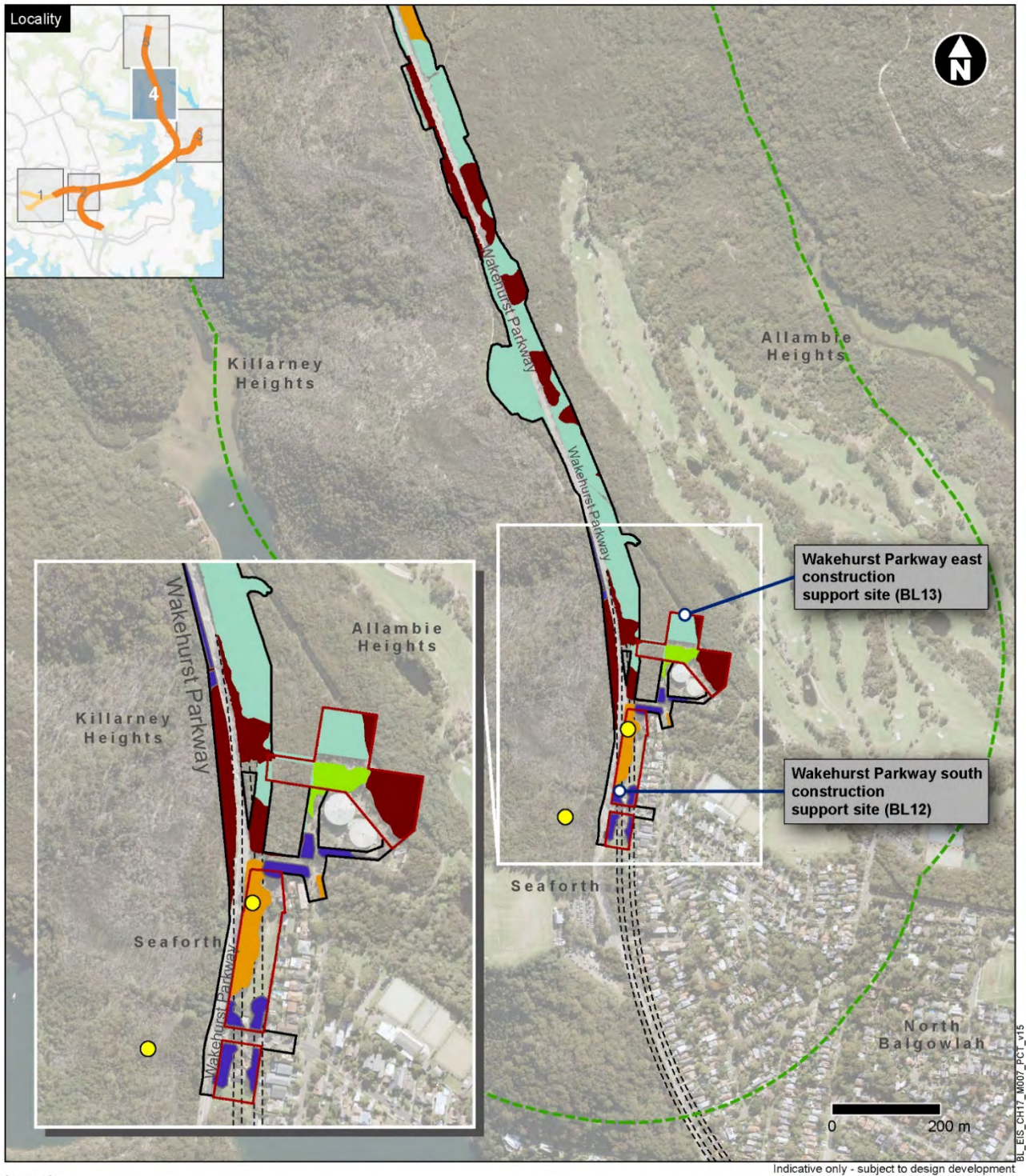


Figure 19-3 Distribution of plant community types and other vegetation (map 3)



Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Plant community types

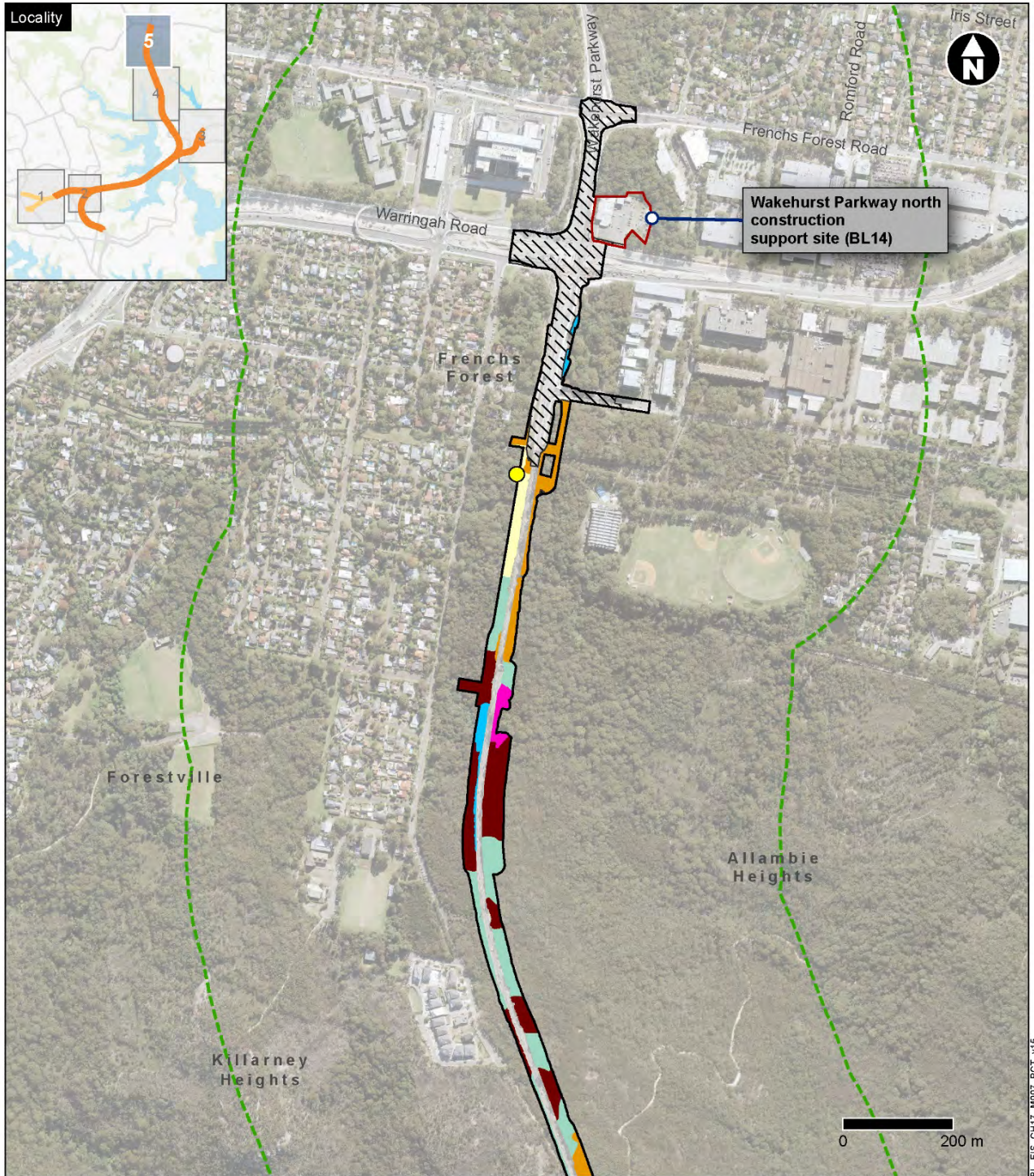
- PCT 1783 Red Bloodwood - Scribbly Gum / Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast
- PCT 1786 Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (EEC)
- PCT 1824 Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin

Other vegetation

- Native Plantings
 - Urban Exotic/Native
- Threatened fauna habitat**
- Hollow-bearing tree

Assessment area

Figure 19-4 Distribution of plant community types and other vegetation (map 4)



BL_EIS_CH17_MOD7_PCT_v15

Indicative only - subject to design development

Legend

Construction features

- Construction footprint
- Construction support site

Assessment area

- Area not assessed by the BDAR

Plant community types

- PCT 1250 Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion
- PCT 1783 Red Bloodwood - Scribbly Gum / Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast
- PCT 1786 Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (EEC)
- PCT 1824 Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin
- PCT 1845 Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney

Other vegetation

- Weeds and Exotics
- Threatened fauna habitat**
- Hollow-bearing tree

Figure 19-5 Distribution of plant community types and other vegetation (map 5)

Threatened flora

Field surveys carried out for the project identified two listed threatened flora species within the construction footprint:

- Magenta Lilly Pilly (*Syzygium paniculatum*)
- Netted Bottle Brush (*Callistemon linearifolius*).

Three other threatened flora species, Sunshine Wattle (*Acacia terminalis* subsp. *terminalis*), Glandular Pink-bell (*Tetratheca glandulosa*) and *Epacris purpurascens* var. *purpurascens*, were recorded during the field surveys in proximity to the construction footprint.

In addition, 14 listed threatened species were identified as having moderate likelihood of occurrence within the construction footprint, despite not being identified during field surveys.

Details of these 19 species are provided in Table 19-5, with the locations of species recorded during field surveys for the project shown in Figure 19-6 to Figure 19-11.

Table 19-5 Threatened flora species known or likely to occur in the construction footprint

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Magenta Lilly Pilly (<i>Syzygium paniculatum</i>)	Endangered (BC Act) Vulnerable (EPBC Act)	<p>Known to occur in the construction footprint.</p> <p>One in situ remnant individual was recorded next to the construction footprint at the Wakehurst Parkway, located within PCT 1250. The individual is mapped at the edge of the construction footprint, and therefore has been conservatively assessed to be within the construction footprint for the purpose of this assessment. The species is not usually known to be associated with this vegetation type, is considered unlikely to occur at this location and is a widely available and commonly planted horticultural species. However, there is no evidence that this specimen has been planted, and it may be of wild provenance.</p> <p>Eleven planted individuals were recorded at the Burnt Bridge Creek Deviation, only four of which are located within the construction footprint. These planted individuals are not of conservation significance.</p> <p>Two planted individuals were also recorded about 18 metres to the east of the construction footprint at Flat Rock Reserve. Although the reserve has been extensively re-planted, it is possible that these specimens could be of wild provenance.</p>
Netted Bottle Brush (<i>Callistemon linearifolius</i>)	Vulnerable (BC Act)	<p>Known to occur in the construction footprint.</p> <p>Four planted individuals were recorded within the construction footprint at the Burnt Bridge Creek Deviation. As they are planted, these individuals are not of conservation significance and are not assessed further under the <i>Biodiversity Assessment Method</i>.</p>

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Sunshine Wattle (<i>Acacia terminalis</i> subsp. <i>terminalis</i>)	Endangered (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. Remnant individuals were recorded in a small fenced area of bushland between the Wakehurst Parkway and the Seaforth Oval car park, associated with PCT 1786, about 145 metres south of the construction footprint. Another five individuals of <i>Acacia terminalis</i> subsp. <i>terminalis</i> were recorded around 170 metres west of the construction footprint, in vegetation along Burnt Bridge Creek.
Glandular Pink-bell (<i>Tetratheca glandulosa</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. Recorded in proximity to the construction footprint during field surveys for the project. This species was recorded in bushland next to the Wakehurst Parkway, about 50 metres east of the construction footprint.
<i>Epacris purpurascens</i> var. <i>purpurascens</i>	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. Recorded in proximity to the construction footprint during field surveys for the project. This species was recorded to the north of the construction footprint at Artarmon Park, where it occurs in several patches. The closest patch is about 60 metres north of the construction footprint.
Angus's Onion Orchid (<i>Microtis angusii</i>)	Endangered (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species has been previously recorded within proximity to the construction footprint, including recently near Seaforth Oval. Potential habitat for the species is also known to occur within the construction footprint.
Bauer's Midge Orchid (<i>Genoplesium baueri</i>)	Endangered (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.
Bynoe's Wattle (<i>Acacia bynoeana</i>)	Endangered (BC Act) Vulnerable (EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Caley's Grevillea (<i>Grevillea caleyi</i>)	Critically endangered (BC Act) Endangered (EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.
Camfield's Stringybark (<i>Eucalyptus camfieldii</i>)	Vulnerable (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the broader terrestrial biodiversity locality.
Hairy Geebung (<i>Persoonia hirsuta</i>)	Endangered (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.
<i>Haloragodendron lucasii</i>	Endangered (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.
<i>Hibbertia puberula</i>	Endangered (BC Act)	Moderate likelihood of occurrence in the construction footprint. Although the species has not been recorded recently within the terrestrial biodiversity locality, potential habitat for the species has been recorded in the terrestrial biodiversity locality.
<i>Lasiopetalum joyceae</i>	Vulnerable (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.
<i>Leptospermum deanei</i>	Vulnerable (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.
<i>Pimelea curviflora</i> var. <i>curviflora</i>	Vulnerable (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Seaforth Mintbush (<i>Prostanthera marifolia</i>)	Critically endangered (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species and potential habitat for the species has been previously recorded within the terrestrial biodiversity locality.
Somersby Mintbush (<i>Prostanthera junonis</i>)	Endangered (BC Act and EPBC Act)	Moderate likelihood of occurrence in the construction footprint. The species has been previously recorded in proximity to the construction footprint including along the Wakehurst Parkway, near Seaforth Oval and near the Wakehurst Golf Club. Habitat for the species has also been previously recorded within the terrestrial biodiversity locality.
Scrub Turpentine (<i>Rhodamnia rubescens</i>)	Critically endangered (BC Act)	Moderate likelihood of occurrence in the construction footprint. The species has been recorded within the terrestrial biodiversity locality in urban reserves. Marginal habitat occurs in the construction footprint.

Note 1: BC Act refers to *Biodiversity Conservation Act 2016*
EPBC Act refers to *Environment Protection and Biodiversity Conservation Act 1999*

19.3.2 Terrestrial fauna

Terrestrial fauna habitat

Table 19-6 provides a summary of the terrestrial fauna habitat types within and next to the construction footprint, and the known or potential fauna species occurring within those habitats.

The key terrestrial fauna habitat types identified for the project include:

- Vegetated habitats
- Human-made structures and built environments (including existing buildings, culverts and bridges)
- Marine and intertidal habitats. The assessment of marine and intertidal habitats in relation to marine species is discussed in Section 19.3.6.

Table 19-6 Terrestrial fauna habitats

Habitat type	Location	Known or potential fauna species
Vegetated habitats	Large tracts of native vegetation (consisting of plant community types and revegetation areas) occur at Flat Rock Reserve, within and near Flat Rock Drive construction support site (BL2), and in the northern extent of the construction footprint, on either side of the Wakehurst Parkway at the Wakehurst Parkway south construction support site (BL12) and the Wakehurst Parkway east construction support site (BL13).	<p>Vegetated areas within and near Flat Rock Drive construction support site (BL2) and next to the Wakehurst Parkway provide fauna habitat resources for a range of mammals, birds, reptiles and bats, including the following:</p> <p>Flowering plants that offer potential foraging resources to arboreal mammals and birds such as: Noisy Miner (<i>Manorina melanocephala</i>); Rainbow Lorikeet (<i>Trichoglossus moluccanus</i>); Red Wattlebird (<i>Anthochaera carunculata</i>); Ringtail Possum (<i>Pseudocheirus peregrinus</i>); Sugar Glider (<i>Petaurus breviceps</i>); Grey-headed Flying-fox (<i>Pteropus poliocephalus</i>); Powerful Owl (<i>Ninox strenua</i>); Eastern Pygmy-possum (<i>Cercartetus nanus</i>); and Square-tailed Kite (<i>Lophoictinia isura</i>)</p> <p>Intact native vegetation offers foraging habitat to a diversity of microbat species, that may forage above or below the tree canopy for invertebrates</p> <p>Ground layer plants that offer potential sheltering and foraging habitat to reptiles, small mammals, birds and some amphibians such as: Brown Antechinus (<i>Antechinus stuartii</i>); Bush Rat (<i>Rattus fuscipes</i>); Australian Brush Turkey (<i>Alectura lathami</i>); Rosenberg's Goanna (<i>Varanus rosenbergi</i>); and Bibron's Toadlet (<i>Pseudophryne bibronii</i>)</p> <p>Three hollow-bearing trees located near the Wakehurst Parkway (two within the construction footprint and one outside) offer potential nesting, roosting and sheltering habitat to hollow-dependent birds (such as Rainbow Lorikeet), arboreal mammals (such as Common Brushtail Possum (<i>Trichosurus vulpecula</i>)); and hollow-roosting microbats.</p>

Habitat type	Location	Known or potential fauna species
	<p>Urban and landscaped areas throughout the construction footprint including native and exotic vegetation at the following locations within the construction footprint:</p> <ul style="list-style-type: none"> • Within and next to the Gore Hill Freeway • Balgowlah Golf Course construction support site (BL10) • Kitchener Street construction support site (BL11). 	<p>Landscaped areas provide habitat for highly mobile species which are capable of using small, isolated patches of habitat within disturbed urban environments including:</p> <p>Flowering and fruiting plants that offer potential foraging resources to bats, birds and arboreal mammals, such as: Grey-headed Flying-fox, Australian Magpie (<i>Cracticus tibicen</i>), Noisy Miner, Rainbow Lorikeet, Grey Butcherbird (<i>Cracticus torquatus</i>), Common Brushtail Possum and Ringtail Possum.</p>
	<p>Riparian vegetation associated with Burnt Bridge Creek.</p>	<p>A Grey-headed Flying-fox camp has been identified at a location in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the construction footprint.</p>
	<p>Riparian vegetation associated with unnamed ephemeral watercourses within open forest areas next to the Wakehurst Parkway.</p>	<p>Potential sheltering, foraging and breeding habitat for the Red-crowned Toadlet (<i>Pseudophryne australis</i>).</p>
	<p>Rocky habitat associated with Hawkesbury sandstone bedrock, boulders, crevices and ledges located within the construction footprint at Flat Rock Reserve, Burnt Bridge Creek and along the Wakehurst Parkway.</p>	<p>Potential sheltering and foraging habitat for: Large-eared Pied Bat (<i>Chalinolobus dwyeri</i>), Brown Antechinus; Bush Rat; Red-crowned Toadlet; Rosenberg's Goanna; and Gully Skink (<i>Saproscincus spectabilis</i>).</p>
<p>Human-made structures and built environments</p>	<p>Existing culverts, bridges and buildings within the construction footprint.</p>	<p>Potential artificial microbat roosting habitat for: Little Bent-winged Bat (<i>Miniopterus australis</i>), Large Bent-winged Bat (<i>Miniopterus orianae oceanensis</i>), Eastern Coastal Free-tailed bat (<i>Micronomus norfolkensis</i>), Yellow-bellied Sheath-tail-bat (<i>Saccolaimus flaviventris</i>) and Greater Broad-nosed Bat (<i>Scoteanax rueppellii</i>).</p>

Habitat type	Location	Known or potential fauna species
Marine and intertidal habitats	Intertidal sand and mudflats within the construction footprint along the foreshore of Clive Park at Northbridge, Beauty Point at The Spit and Peach Tree Bay at Seaforth.	<ul style="list-style-type: none"> • Small areas of sand and mudflats provide marginal foraging habitat to threatened shorebird species, where worms, bivalves, crustaceans and other invertebrates occur within soft substrate tidal areas that are exposed during low tide. However, no threatened shorebird species were recorded during targeted surveys, nor were determined as having a high likelihood of occurrence within the construction footprint • No nesting or roosting habitat provided, as these areas are inundated at high tide.
	Intertidal rocky shores along bays and headlands within the construction footprint, including: Peach Tree Bay; Seaforth Bluff; Beauty Point; Quakers Hat; Fig Tree Point; Fig Tree Cove; Clive Park; and Sailors Bay.	<ul style="list-style-type: none"> • Supports a high abundance of Sydney Rock Oysters (<i>Saccostrea glomerata</i>), which offer limited foraging resources for threatened shorebirds. However, no threatened shorebird species were identified during database searches as having a high likelihood of occurrence within the construction footprint • No nesting or roosting opportunities are provided, as these areas are inundated at high tide.
	Open water habitat within Middle Harbour.	<ul style="list-style-type: none"> • Foraging habitat for a number of threatened bird and bat species that forage for fish or other marine prey species, including: • Little Penguins (<i>Eudyptula minor</i>) which have been recorded at several locations within the construction footprint, including at The Spit, Long Bay, Sailors Bay, and in the main channel of Middle Harbour • White-bellied Sea Eagle (<i>Haliaeetus leucogaster</i>) due to the presence of preferred prey species (ie fish, turtles and sea snakes) within the construction footprint, as well as potential perching habitat in trees along the foreshore at The Spit, Seaforth and Clontarf • Southern Myotis (<i>Myotis macropus</i>) due to the presence of preferred prey species (ie fish) within and near the construction footprint • Not a preferred habitat for wandering seabirds with no wandering seabird species identified as having a high likelihood of occurrence within the construction footprint.

Threatened fauna species and endangered populations

Field surveys carried out for the project identified six listed threatened fauna species, within or next to the construction footprint:

- Grey-headed Flying-fox recorded in a number of locations flying over the construction footprint. In addition, a Grey-headed Flying-fox camp has been identified at a location in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the construction footprint
- Rosenberg's Goanna recorded within vegetated areas alongside the Wakehurst Parkway in the construction footprint
- Powerful Owl recorded in bushland off Flat Rock Drive near the Flat Rock Drive construction support site (BL2)
- Large Bent-winged Bat recorded in bushland near the Flat Rock Drive construction support site (BL2)
- Little Bent-winged Bat recorded in bushland near the Flat Rock Drive construction support site (BL2)
- Large-eared Pied Bat recorded about 125 metres from the construction footprint.

Another six listed threatened species were identified as having a high likelihood of occurrence within the construction footprint or assumed to be present, despite not being identified during field surveys. Some species have been identified as a result of recent database searches and surveys carried out for the recently completed Northern Beaches Hospital road upgrade project. These species with a high likelihood of occurrence include:

- Red-crowned Toadlet
- Eastern Pygmy-possum
- Eastern Coastal Free-tailed Bat
- Glossy Black-Cockatoo (*Calyptorhynchus lathami*)
- Varied Sittella (*Daphoenositta chrysoptera*)
- White-bellied Sea Eagle.

Two threatened fauna species, Southern Brown Bandicoot (*Isoodon obesulus obesulus*) and Southern Myotis, are considered likely to occur in areas next to the construction footprint.

In addition, nine species were identified as having a moderate likelihood of occurrence within the construction footprint, despite not being identified during field surveys. These species were:

- Barking Owl (*Ninox connivens*)
- Eastern Osprey (*Pandion cristatus*)
- Little Lorikeet (*Glossopsitta pusilla*)
- Masked Owl (*Tyto novaehollandiae*)
- Spotted-tailed Quoll (*Dasyurus maculatus*)
- Square-tailed Kite
- Swift Parrot (*Lathamus discolor*)
- Dusky Woodswallow (*Artamus cyanopterus cyanopterus*)
- Brown Treecreeper (*Climacteris picumnus victoriae*).

One endangered population is known to occasionally occur in the construction footprint, being the population of Little Penguins in the Manly Point area, about 5.5 kilometres north-east of the project.

Details of these 23 threatened fauna species and one endangered population are provided in Table 19-7, with the locations of species recorded during field surveys for the project shown in Figure 19-6 to Figure 19-11.

Migratory bird species

As identified above, one migratory bird species listed under the *Environment Protection and Biodiversity Conservation Act 1999*, the White-bellied Sea Eagle, has a high likelihood of occurrence due to potential habitat in Middle Harbour.

Migratory freshwater and marine species, such as whales, turtles and fish, are discussed in Section 19.3.3 and Section 19.3.6 respectively.

Table 19-7 Threatened fauna species known or likely to occur in the construction footprint

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Threatened species		
Grey-headed Flying-fox (<i>Pteropus poliocephalus</i>)	Vulnerable (BC Act and EPBC Act)	<p>Known to occur in the construction footprint.</p> <p>This species was recorded in a number of locations flying over the construction footprint. A Grey-headed Flying-fox camp has been identified at a location in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres east of the construction footprint. It is highly likely that the Grey-headed Flying-fox would also use land within the construction footprint and surrounds for foraging.</p>
Rosenberg's Goanna (<i>Varanus rosenbergi</i>)	Vulnerable (BC Act)	<p>Known to occur in the construction footprint.</p> <p>This species was recorded during field surveys for the project within vegetated areas next to the Wakehurst Parkway. Vegetation in this area offers potential foraging and nesting habitat for the species due to the presence of preferred prey species including birds, reptiles and small mammals, while the presence of sandstone boulders, slabs and rock crevices offer sheltering habitat to the species. Termite mounds recorded in proximity to the Wakehurst Parkway also offer preferred nesting habitat to the species. Rosenberg's Goanna may also forage for roadkill along the margins of the Wakehurst Parkway, where fauna mortality due to vehicle strike is high.</p>
Powerful Owl (<i>Ninox strenua</i>)	Vulnerable (BC Act)	<p>High likelihood of occurrence in the construction footprint.</p> <p>The Powerful Owl was recorded during field surveys for the project in bushland off Flat Rock Drive, in proximity to the construction footprint. It has also been previously recorded within vegetated areas next to the Wakehurst Parkway. A hollow-bearing tree, which included one large tree hollow (greater than 0.2 metres diameter), was identified in the northern extent of the construction footprint near the Wakehurst Parkway as offering potential nesting habitat; however, no activity was identified during field surveys. These areas within and next to the construction footprint also offer potential foraging habitat for the Powerful Owl due to the presence of preferred prey species that are known and are likely to inhabit the construction footprint.</p>

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
<p>Large Bent-winged Bat <i>(Miniopterus orianae oceanensis)</i></p>	<p>Vulnerable (BC Act)</p>	<p>High likelihood of occurrence in the construction footprint.</p> <p>This species was recorded during field surveys for the project in bushland near the Flat Rock Drive construction support site (BL2). Native vegetation throughout the construction footprint, particularly larger tracts of native vegetation within and next to the northern extent of the construction footprint along the Wakehurst Parkway, offers potential foraging habitat to the species. Potential artificial roosting habitat (ie culverts and bridges) is also present throughout the construction footprint; however, targeted surveys within concrete culverts at Artarmon and Balgowlah, and a concrete underground walkway at Willoughby did not detect the presence of any roosting Large Bent-winged Bats. Areas surveyed for the project were not identified to support a maternity cave.</p>
<p>Little Bent-winged Bat <i>(Miniopterus australis)</i></p>	<p>Vulnerable (BC Act)</p>	<p>High likelihood of occurrence in the construction footprint.</p> <p>This species was recorded during field surveys for the project in bushland near the Flat Rock Drive construction support site (BL2) and has been previously recorded in the northern extent of the construction footprint, along the Wakehurst Parkway.</p> <p>Native vegetation throughout the construction footprint, particularly larger tracts of native vegetation within and next to the northern extent of the construction footprint along the Wakehurst Parkway offers potential foraging habitat to the species. Potential artificial roosting habitat (ie culverts and bridges) are also present throughout the construction footprint; however, targeted surveys for the project at concrete culverts at Artarmon and Balgowlah, and a concrete underground walkway at Willoughby did not detect the presence of any roosting Little Bent-winged Bats.</p>
<p>Large-eared Pied Bat <i>(Chalinolobus dwyeri)</i></p>	<p>Vulnerable (BC Act and EPBC Act)</p>	<p>High likelihood of occurrence in the construction footprint.</p> <p>This species' echolocation call was recorded at a dam approximately 125 metres from the construction footprint. The species has also been recently recorded in the Wakehurst Parkway east construction support site (BL13). All plant community types in the construction footprint are associated with the Large-eared Pied Bat. It is likely that the species uses native vegetation in the construction footprint for foraging and may be roosting in rocky habitat in proximity to the construction footprint along the Wakehurst Parkway.</p>

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Eastern Coastal Free-tailed Bat <i>(Micronomus norfolkensis)</i>	Vulnerable (BC Act)	<p>High likelihood of occurrence in the construction footprint.</p> <p>This species was not recorded in the construction footprint during field surveys. Native vegetation throughout the construction footprint, particularly larger tracts of native vegetation within and next to the northern extent of the construction footprint along the Wakehurst Parkway offers potential foraging habitat to the species. Two hollow-bearing trees were identified within the construction footprint in proximity to the Wakehurst Parkway during field surveys for the project, which may provide roosting habitat. Culverts and bridges within the construction footprint also offer potential roosting habitat for the species. However, targeted surveys carried out for the project did not detect the presence of any roosting Eastern Coastal Free-tailed Bats.</p>
Eastern Pygmy-possum <i>(Cercartetus nanus)</i>	Vulnerable (BC Act)	<p>High likelihood of occurrence in the construction footprint.</p> <p>This species was not recorded in the construction footprint during field surveys. However, database searches show that the species has been recently recorded in the Wakehurst Parkway east construction support site (BL13). Potential foraging and sheltering habitat for this species is present in native vegetation within and adjoining the northern extent of the construction footprint next to Wakehurst Parkway. These vegetated habitats support preferred foraging resources, due to the presence of a variety of banksia, eucalypt and bottlebrush species.</p>
Glossy Black-Cockatoo <i>(Calyptorhynchus lathami)</i>	Vulnerable (BC Act)	<p>High likelihood of occurrence in the construction footprint.</p> <p>This species was not recorded in the construction footprint during field surveys. Preferred foraging trees species (<i>Allocasuarina</i> and <i>Casuarina</i> species) occur within areas of native vegetation within and next to the construction footprint. The species was not observed to use a large tree hollow identified in the northern extent of the construction footprint next to the Wakehurst Parkway during field surveys. This tree hollow is located within an area unlikely to support preferred nesting habitat for the species.</p>
Red-crowned Toadlet <i>(Pseudophryne australis)</i>	Vulnerable (BC Act)	<p>High likelihood of occurrence in the construction footprint.</p> <p>This species was not recorded in the construction footprint during field surveys. However, this species was recorded along the Wakehurst Parkway during investigations for the Northern Beaches Hospital road upgrade project. Riparian vegetation associated with unnamed ephemeral watercourses within open forest areas next to the Wakehurst Parkway offer potential sheltering, foraging and breeding habitat for the species.</p>

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Southern Brown Bandicoot <i>(Isoodon obesulus obesulus)</i>	Endangered (BC Act and EPBC Act)	High likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. However, it has previously been recorded in proximity to the construction footprint next to the Wakehurst Parkway. The construction footprint supports potential habitat for the species in native vegetation next to the Wakehurst Parkway.
Southern Myotis <i>(Myotis macropus)</i>	Vulnerable (BC Act)	High likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. However, potential foraging habitat for this species is present within and next to the construction footprint within Middle Harbour, particularly along sheltered bays such as Sandy Bay and Shell Cove. There is some potential roosting habitat for this species within the construction footprint, due to the presence of human-made structures such as jetties, wharves along the Middle Harbour foreshore, existing culverts, bridges and buildings.
Varied Sittella <i>(Daphoenositta chrysoptera)</i>	Vulnerable (BC Act)	High likelihood of occurrence in the construction footprint. The species was not recorded in the construction footprint during field surveys. However, it has previously been recorded in the construction footprint by the Gore Hill Freeway.
White-bellied Sea Eagle <i>(Haliaeetus leucogaster)</i>	Vulnerable (BC Act) Migratory (EPBC Act)	High likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. However, this species has been previously recorded throughout Middle Harbour. Potential foraging habitat for the species is present in Middle Harbour within the construction footprint. Potential perching habitat is also present around Middle Harbour in trees along the foreshore at The Spit, Seaforth and Clontarf.
Barking Owl <i>(Ninox connivens)</i>	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. Potential foraging habitat for this species is present within large tracts of native vegetation within and adjoining the northern extent of the construction footprint next to the Wakehurst Parkway. The species was not observed to utilise a large tree hollow identified at this location during field surveys, and the area is unlikely to support preferred nesting habitat for the species.

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Eastern Osprey (<i>Pandion cristatus</i>)	Vulnerable (BC Act) Migratory (EPBC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. Potential foraging habitat for this species is present within Middle Harbour. The areas within and next to the construction footprint are not known to support nesting habitat for the species.
Little Lorikeet (<i>Glossopsitta pusilla</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. Potential foraging habitat for this species is present within landscaped areas throughout the construction footprint. Two hollow-bearing trees were identified within the construction footprint in proximity to the Wakehurst Parkway during field surveys for the project, which may provide roosting habitat.
Masked Owl (<i>Tyto novaehollandiae</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. However, potential foraging habitat for this species is present within areas of native vegetation within and next to the construction footprint along the Wakehurst Parkway, due to the presence of prey species. The species was not observed to utilise a large tree hollow identified within this area during field surveys for the project, with the areas within or next to the construction footprint unlikely to support preferred nesting habitat for the species.
Spotted-tailed Quoll (<i>Dasyurus maculatus</i>)	Vulnerable (BC Act) Endangered (EPBC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. However, large tracts of native vegetation within and adjoining the northern extent of the construction footprint next to the Wakehurst Parkway offer potential habitat for the species.
Square-tailed Kite (<i>Lophoictinia isura</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. However, potential foraging habitat for this species is present within the areas of native vegetation within and next to the construction footprint along the Wakehurst Parkway.

Species	Conservation significance ¹	Likelihood of occurrence in the construction footprint
Swift Parrot (<i>Lathamus discolor</i>)	Endangered (BC Act) Critically Endangered (EPBC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. Nectivorous trees within the construction footprint offer marginal foraging habitat to the species; however, the construction footprint does not support preferred habitat for the species.
Dusky Woodswallow (<i>Artamus cyanopterus cyanopterus</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. Marginal habitat exists along the edge of the Wakehurst Parkway.
Brown Treecreeper (<i>Climacteris picumnus victoriae</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. Marginal habitat exists along the edge of the Wakehurst Parkway.
Endangered population		
Little Penguin (<i>Eudyptula minor</i>)	Endangered population (BC Act) Marine (EPBC Act)	High likelihood of occurrence in the construction footprint. This species was not recorded in the construction footprint during field surveys. However, this species has been previously recorded at several locations within Middle Harbour including at The Spit and Sailors Bay, and in the main channel of Middle Harbour. Potential foraging habitat for the species is present within and next to the construction footprint in Middle Harbour. No nesting habitat is present within the construction footprint, with nesting limited to the Manly area.

Note 1: BC Act refers to *Biodiversity Conservation Act 2016*
EPBC Act refers to *Environment Protection and Biodiversity Conservation Act 1999*

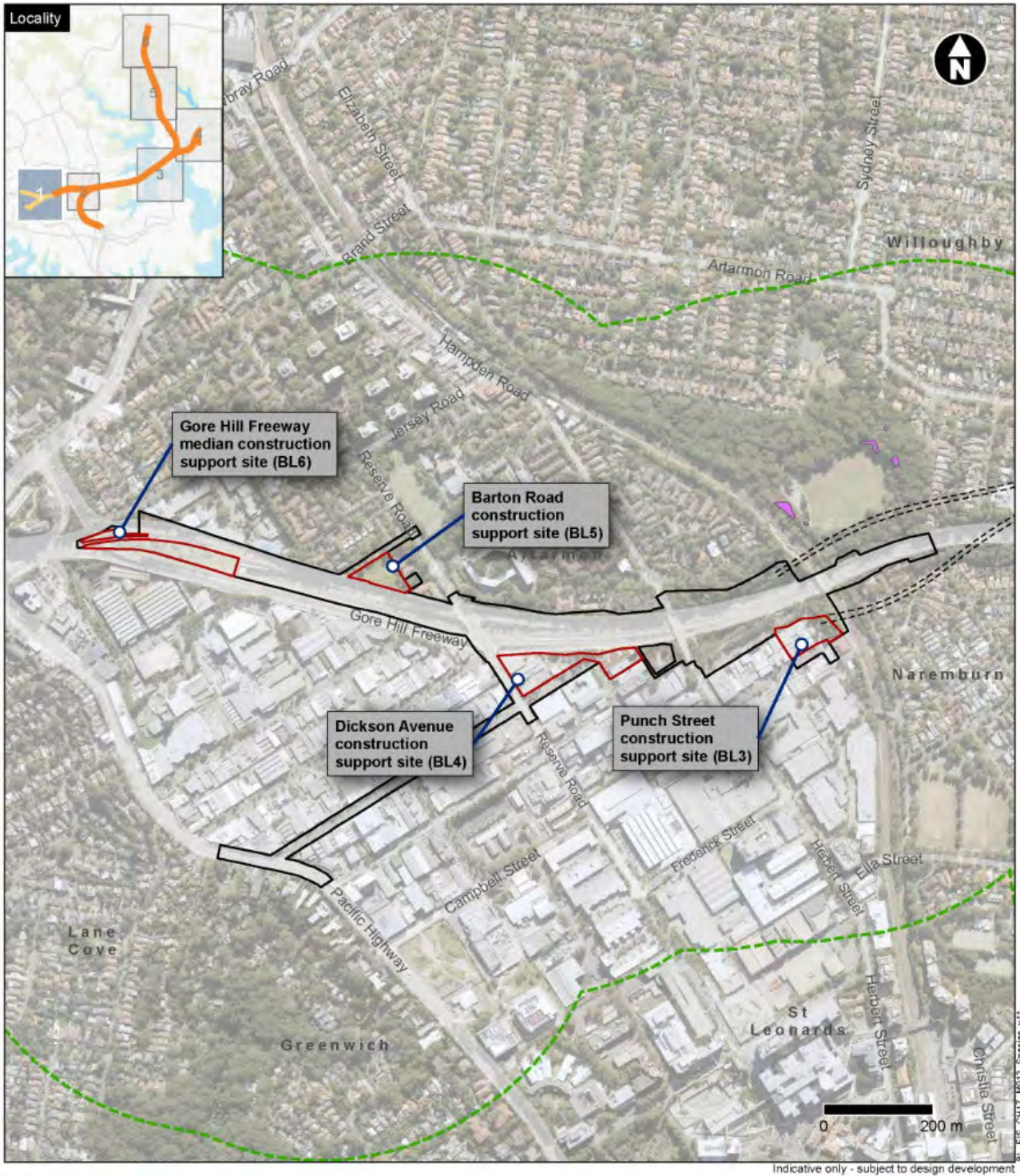


Figure 19-6 Recorded threatened species (map 1)

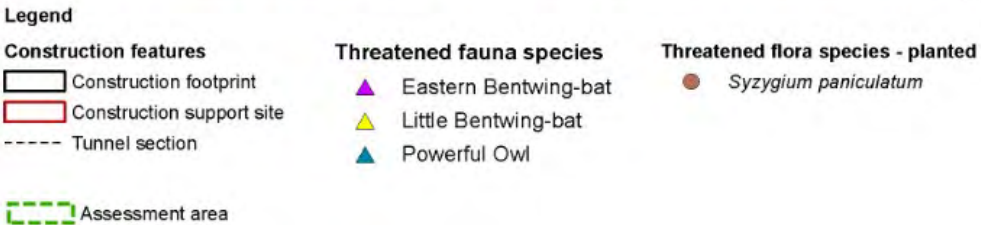
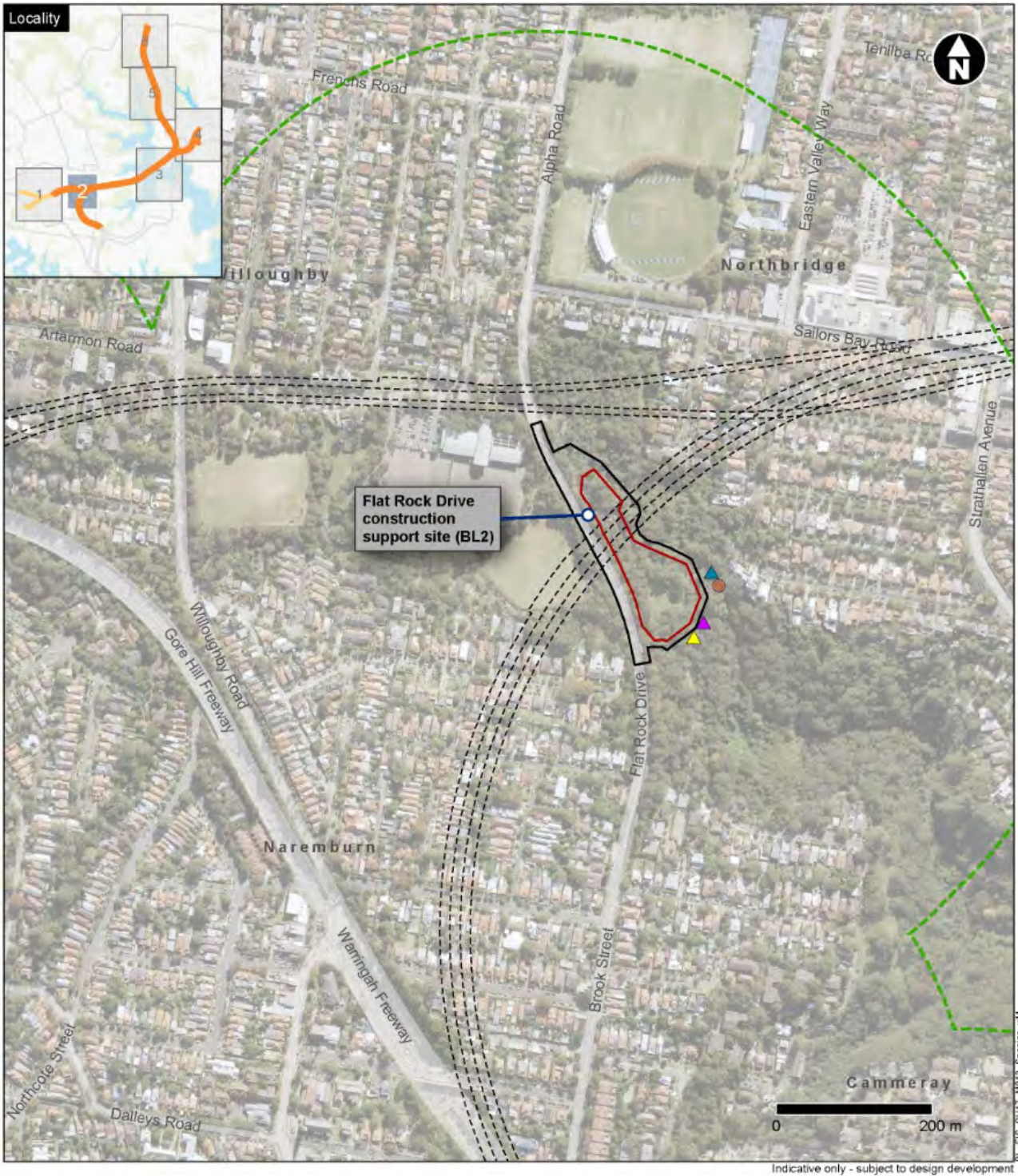
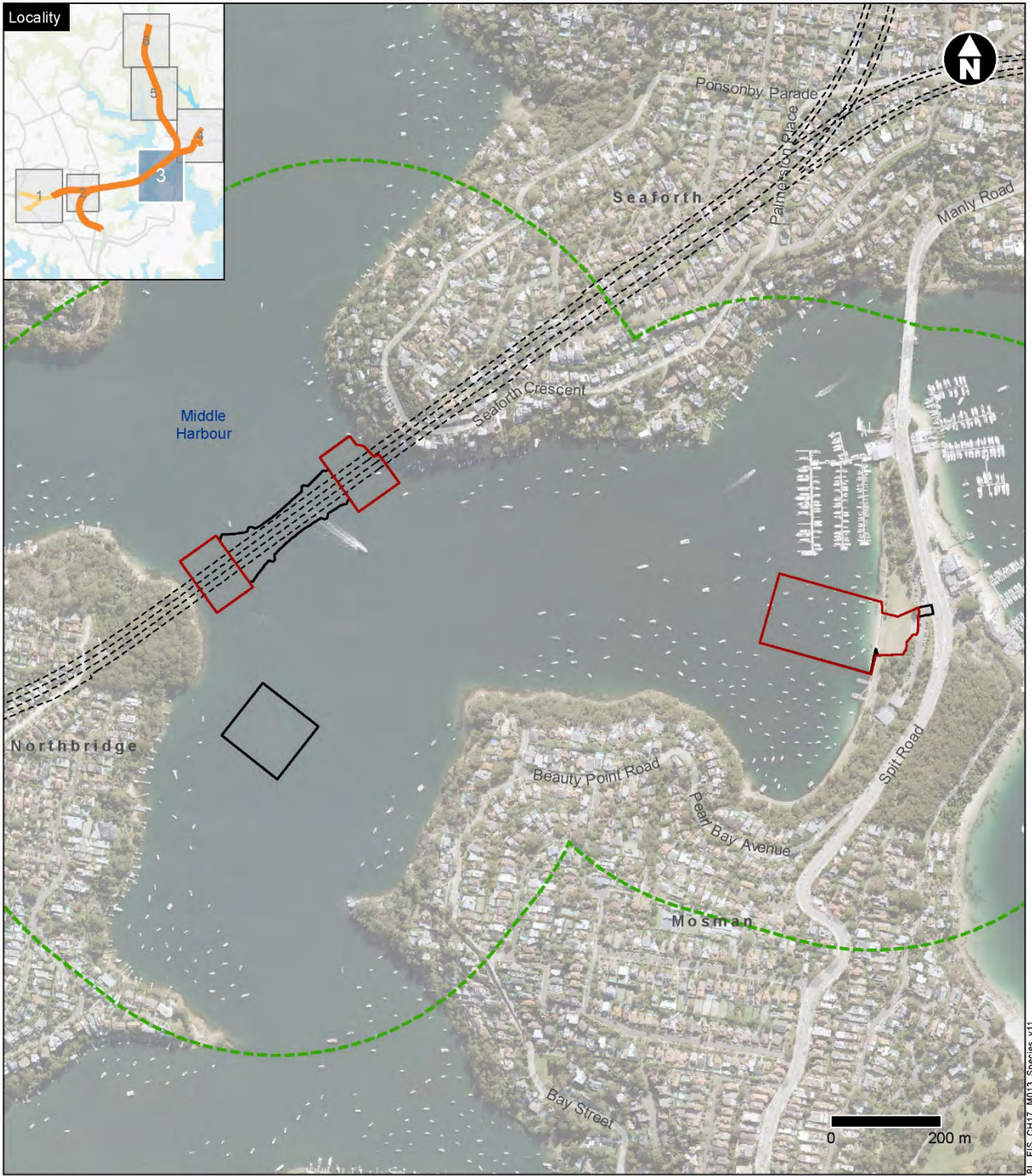


Figure 19-7 Recorded threatened species (map 2)



Indicative only - subject to design development

- Legend**
- Construction features**
- Construction footprint
 - Construction support site
 - Tunnel section
- Assessment area

Figure 19-8 Recorded threatened species (map 3)



Legend

- Construction features**
- Construction footprint
 - Construction support site
 - Tunnel section
 - Exclusion zone
 - Assessment area

- Threatened fauna species**
- Grey-headed Flying-fox camp (Balgowlah Camp)
- Threatened flora species - remnant**
- Acacia terminalis* subsp. *terminalis*

- Threatened flora species - planted**
- Callistemon linearifolius*
 - Syzygium paniculatum*

Figure 19-9 Recorded threatened species (map 4)

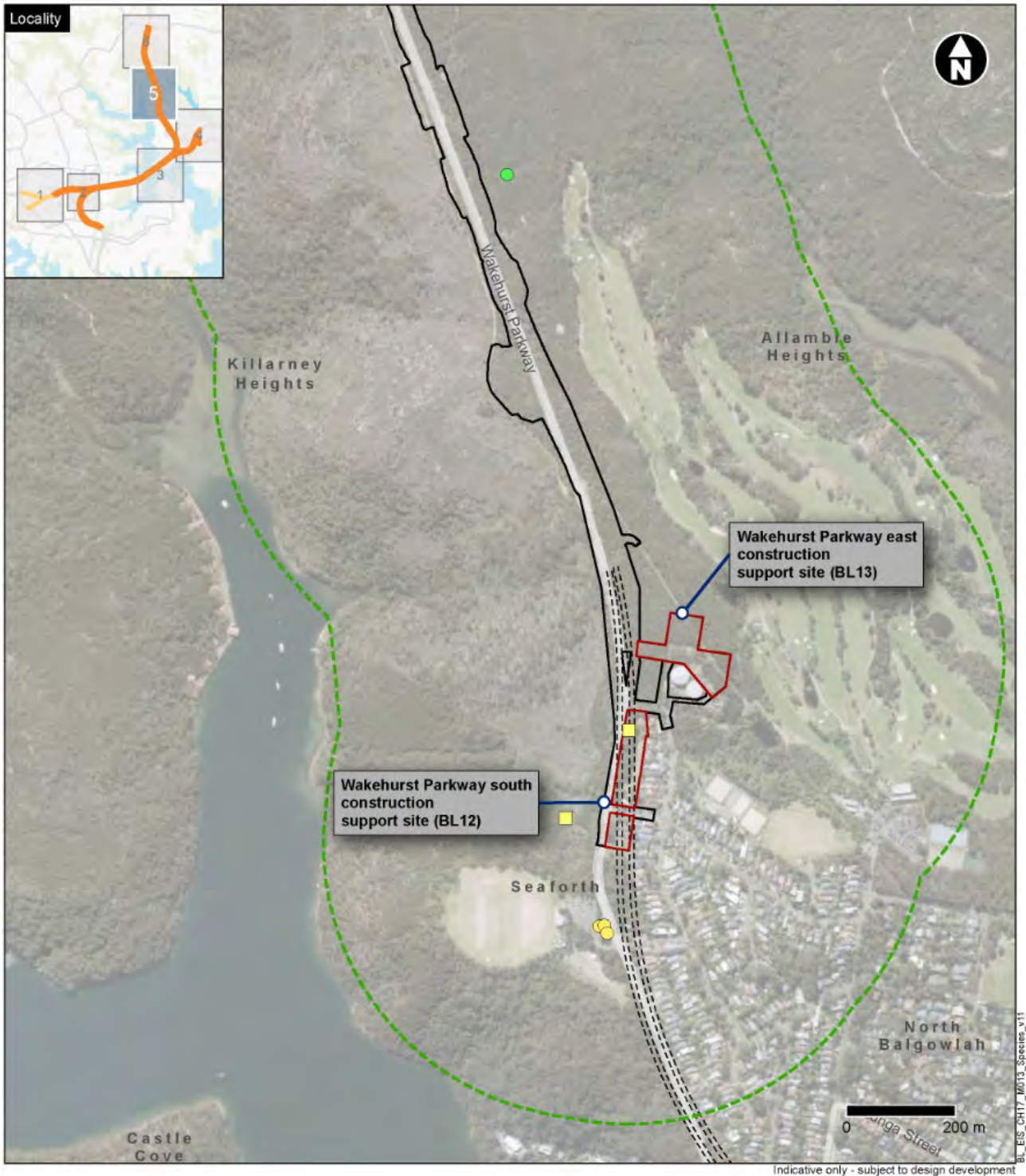


Figure 19-10 Recorded threatened species (map 5)



Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Threatened fauna habitat

- Hollow-bearing tree

Threatened flora species - remnant

- Syzygium paniculatum*

Area not assessed by the BDAR

Assessment area

Figure 19-11 Recorded threatened species (map 6)

19.3.3 Aquatic biodiversity

Aquatic habitat

Table 19-8 provides a summary of the aquatic freshwater habitats associated with the waterways within and downstream of the construction footprint. Key fish habitat classification and whether the waterway is considered a sensitive receiving environment is discussed in Annexure D (Freshwater ecology impact assessment) of Appendix S (Technical working paper: Biodiversity development assessment report).

Manly Dam, Manly Creek and the natural reaches of Flat Rock Creek have been identified as Type 1 highly sensitive key fish habitat and sensitive receiving environments. The classification of waterways regarding their status as sensitive receiving environments is discussed in Chapter 17 (Hydrodynamics and water quality) and summarised in Table 19-8.

The quality of these waterways was also assessed as part of the surface water assessment in Appendix O (Technical working paper: Surface water quality and hydrology), the results of which are provided in Chapter 17 (Hydrodynamics and water quality). In general, the waterways potentially impacted by the project are largely influenced by surrounding urban development with occurrences of contaminants such as suspended sediments, heavy metals and persistent organic pollutants including from stormwater, wastewater overflows and leachate from contaminated lands. Some of these waterways have also been substantially modified from natural channels to artificial, concrete-lined channels to accommodate higher volume and velocity flows from an increase in urban, impervious surfaces.

Although no fish or macroinvertebrate sampling was carried out as part of the aquatic assessment, the waterways in the aquatic biodiversity study area are considered suitable for the majority of common and exotic fish species typically found in waterways in the Sydney region. The most suitable habitat are the natural reaches of these waterways (Manly Dam, Manly Creek and some reaches of Flat Rock Creek).

Common native fish species typically found in waterways in the Sydney region include Short-finned and Long-finned Eels (*Anguilla australis* and *A. reinhardtii*), Common Galaxias (*Galaxias maculatus*), Australian Bass (*Macquaria novemaculeata*) and a number of gudgeon species. Exotic fish species are also widespread across the Sydney region.

Sydney's waterways typically support an array of macroinvertebrates including the Sydney Crayfish (*Euastacus australasiensis*) and the Freshwater Shrimp (*Paratya australiensis*) as well as small insects and freshwater mussels. These species depend on healthy waterways and access to diverse habitats including swamps, floodplains, wetlands, streams and rivers, of which only streams occur within the aquatic biodiversity study area.

The Manly Creek catchment, including the middle and lower reaches of Manly Creek, is home to the only confirmed population of Climbing Galaxias (*Galaxias brevipinnis*) in the Sydney area. Although not a threatened or protected species, the community prepared an action plan for its protection in the Manly Creek catchment (Salkavich et al., 2002). The action plan considers water pollution to be among the threats to this population.

Within the eastern side of the Burnt Bridge Creek catchment is the Balgowlah Golf Course stormwater harvesting dam which was completed in 2013. The dam is a four megalitre pond/dam with a maximum nominal water depth of 2.5 metres which is used irrigate the Balgowlah Golf Course. However, given its recent construction and disconnection with natural watercourses, the Balgowlah Golf Course stormwater harvesting dam is unlikely to provide potential habitat for native fish.

Threatened ecological communities, species and endangered populations

No threatened freshwater fauna, flora species or ecological communities or endangered populations listed under the *Fisheries Management Act 1994* and/or the *Environment Protection and Biodiversity Conservation Act 1999* have been identified as likely to occur within the aquatic biodiversity study area.

Freshwater migratory species

No freshwater migratory species listed under the *Environment Protection and Biodiversity Conservation Act 1999* are considered likely to occur within the aquatic biodiversity study area.

Table 19-8 Aquatic freshwater habitats

Location	Habitat features	Key fish habitat classification	Sensitive receiving environment
<p>Willoughby Creek at Cammeray, located about 60 metres east of the Cammeray Golf Course construction support site (BL1)</p>	<ul style="list-style-type: none"> • The area of the creek next to Primrose Park tennis courts was identified as a semi-natural waterway, partially modified to accept stormwater discharge. Around 10 metres downstream of the survey location, the creek contains entrenched bedrock and a concrete-lined channel. A natural bedrock/boulder waterfall and a shallow plunge pool is located around 50 metres upstream of the survey location • Banks in the upstream section of the creek are vegetated by dense tree cover and shrubs with a groundcover consisting primarily of ferns. Walking tracks and tennis courts are present on the south east bank, and on the opposite bank the riparian vegetation corridor is around 70 metres wide and continuous. Further downstream, the riparian corridor includes Primrose Park sporting fields • Moderate condition riparian vegetation including commonly occurring native tree species are present within remnant riparian vegetation, such as Black Wattle (<i>Callicoma serratifolia</i>), Coachwood (<i>Ceratopetalum apetalum</i>), Blueberry Ash (<i>Elaeocarpus reticulatus</i>) and Cheese Tree (<i>Glochidion ferdinandi</i>) • Localised infestations of Large Leaf Privet (<i>Ligustrum lucidum</i>) and Lantana (<i>Lantana camara</i>) are also known to occur • This riparian vegetation provides shade and potentially other ecological functions (eg a source of food and habitat, in the form of wood debris, for aquatic biota). No instream vegetation or woody debris were identified within the section of the creek inspected. Some rocky features are present. 	<p>Type 3 minimally sensitive key fish habitat Class 3 minimal key fish habitat for fish passage.</p>	<p>No</p>

Location	Habitat features	Key fish habitat classification	Sensitive receiving environment
<p>Flat Rock Creek at Nareburn, located directly east of, and within Flat Rock Drive construction support site (BL2) and above the ramp tunnel alignment at Artarmon (from Gore Hill Freeway Connection). Further detail on Flat Rock Creek illustrating the various linings is provided in Figure 17-2 of Chapter 17 (Hydrodynamics and water quality).</p>	<ul style="list-style-type: none"> The upper reaches of Flat Rock Creek in Artarmon consist of a covered concrete lined drain and vegetated floodway associated with the Artarmon Reserve detention basin. The creek is a concrete lined channel as it crosses the Gore Hill Freeway for the first time and continues in an open lined channel as it meanders east and crosses back under the Gore Hill Freeway. The creek is installed within an underground box culvert between Willoughby Road, Willoughby and 150 metres east of Flat Rock Drive, Northbridge. 	Not key fish habitat.	No
	<ul style="list-style-type: none"> Flat Rock Creek was identified as freshwater upstream of its confluence with Quarry Creek 150 metres east of Flat Rock Drive and upstream of Quarry Creek, the channel consists of a steep gorge with natural bedrock and large boulders. Dense riparian vegetation encroached on the channel is likely due to frequent low flow conditions in the main channel. Riparian vegetation consists of native, tall, woody trees, dense shrubs and groundcover. In the upper reaches, instream woody debris (less than three metres long) provides aquatic habitat. 	<p>Type 1 highly sensitive key fish habitat</p> <p>Class 2 moderate key fish habitat for fish passage.</p>	Yes
	<ul style="list-style-type: none"> Flat Rock Creek was identified as estuarine downstream of the confluence with Quarry Creek Downstream of Quarry Creek, the channel is subjected to stormwater discharge with evidence of channel and bank erosion a likely result of high flow events. The south bank consists of dense native and exotic, overhanging riparian vegetation. Fish habitat includes some undercut banks with potential to provide refuge as well as large woody debris (greater than three metres long) and dense instream patches of Common Reed (<i>Phragmites australis</i>) present in some sections. 	<p>Type 1 highly sensitive key fish habitat</p> <p>Class 1 major key fish habitat for fish passage.</p>	Yes

Location	Habitat features	Key fish habitat classification	Sensitive receiving environment
Existing aboveground watercourse within the northern extent of Flat Rock Reserve in the Flat Rock Drive construction support site (BL2)	<ul style="list-style-type: none"> • This watercourse drains through a 0.40 metre underground pipe at the Small Street roundabout, but also receives catchment runoff from the escarpment which forms the north eastern bank. This escarpment bank is steep, ranging between three and 10 metres along the watercourse and is generally comprised of sandstone • The natural channel bed is generally bedrock with a layer of sediment and detritus and colonised by exotic grasses and forbs where there is no flow. Concrete or rock is laid on the channel bed in sections exposed to higher flow velocities. Channel banks are steep, and the watercourse width ranges between two and 10 metres. Riffles and pools were also observed • Dense native and exotic riparian vegetation occurs along both banks. The escarpment is well vegetated with a mix of native and exotic woody trees, ferns with a dense midstorey and groundcover. 	Not key fish habitat.	No
<p>Burnt Bridge Creek at North Balgowlah, located next to the following temporary construction support sites: Balgowlah Golf Course construction support site (BL10) Kitchener Street construction support site (BL11).</p> <p>Further detail on Burnt Bridge Creek illustrating the various linings is provided in Figure 17-3 of Chapter 17 (Hydrodynamics and water quality).</p>	<ul style="list-style-type: none"> • The upstream reach of Burnt Bridge Creek, located upstream of the existing Burnt Bridge Creek Deviation culverts, is mostly a natural channel with rocky outcrops and low levels of sedimentation over bedrock. Culvert crossings act as potential barriers to fish passage during low flows. Exotic Parrots Feather plants (<i>Myriophyllum aquaticum</i>) and native eels (<i>Anguilla</i> spp.) were observed in the deeper pools. Emergent woody debris along the banks have potential to provide habitat for freshwater fish and invertebrates during high flows. The channel receives substantial shading from the native riparian overstorey of She-oaks (<i>Casuarina</i> spp.). However, the width of the riparian corridor is limited by residences and landscaped gardens, and exotic vegetation was prevalent in the understorey. There is also a large trunk sewer line installed along the creek alignment which would indicate substantial disturbance during its installation 	Type 2 moderately sensitive key fish habitat Class 2 moderate key fish habitat for fish passage.	No

Location	Habitat features	Key fish habitat classification	Sensitive receiving environment
	<ul style="list-style-type: none"> To the east of the existing Burnt Bridge Creek Deviation culverts, the downstream reach of Burnt Bridge Creek is a wider channel with modified bedrock and sections of concrete and boulder retaining walls through the golf course with the trunk sewer line noted above installed along the length of the creek in the golf course area. This section of the watercourse is known to experience hazardous flooding velocities (up to five to eight metres per second). A weir has created a deeper pool where organic debris has accumulated and exotic macrophytes have established. A thin corridor of native riparian vegetation is located next to the channel, some of which overhangs instream and provides shading along sections of the reach Further downstream, the Kitchener Street bridge spans the width of the channel along this reach with two large box culverts perched over bedrock. Flows are restricted to partially connected pools. Erosion and bank undercutting were observed along this reach. The width of riparian corridor along this reach is limited by nearby residences and Burnt Bridge Creek Deviation. The riparian corridor provides moderate shading over the channel, with small woody debris instream. 		
<p>Manly Creek (also known as Curl Curl Creek), located about 300 metres east of the northern extent of the construction footprint</p>	<ul style="list-style-type: none"> The substratum of Manly Creek comprises mostly sandstone bedrock, boulders and cobbles and is inundated by a series of connected pools, runs and riffles with some unconsolidated materials accumulated in the pools The banks are low and large snags and boulders provide potential fish habitat at this location The riparian corridor consists of woody vegetation. 	<p>Type 1 highly sensitive key fish habitat</p> <p>Class 1 major key fish habitat for fish passage.</p>	<p>Yes</p>

Location	Habitat features	Key fish habitat classification	Sensitive receiving environment
Manly Dam located to the east of the construction footprint	<ul style="list-style-type: none"> • Manly Dam contains large areas of emergent, native/exotic aquatic macrophytes including native sedges (<i>Eleocharis</i> spp.) and the exotic Yellow Waterlily (<i>Nymphaea mexicana</i>) • The dam supports an extensive wetland community, and is located within 100 metres of areas of Coastal Sandstone Gully Forest groundwater dependent ecosystem and Coastal Upland Damp Heath Swamp endangered ecological community • Shallow wetland areas scattered around the dam foreshore support native and exotic emergent macrophytes that offer potential habitat for Common Eastern Froglet (<i>Crinia signifera</i>), Eastern Dwarf Tree Frog (<i>Litoria fallax</i>) and Eastern Banjo Frog (<i>Limnodynastes dumerilii</i>) • Deeper parts of the dam support Eastern Long-necked Turtles (<i>Chelodina longicollis</i>), Australian Bass (<i>Macquaria novemaculeata</i>) and Silver Perch (<i>Bidyanus bidyanus</i>). 	<p>Type 1 highly sensitive key fish habitat</p> <p>Class 1 sensitive key fish habitat for fish passage.</p>	Yes
Trefoil Creek, located about 300 metres north of the northern extent of the construction footprint	<ul style="list-style-type: none"> • Trefoil Creek is a narrow (less than one metre wide), natural, ephemeral channel located within a steep gully characterised by small, disconnected pools with a sandy silt substratum overlaying bedrock. Accumulated debris and log jams are common along the reach and likely to be mobilised during high flows • Riparian vegetation comprises dense, overhanging native and exotic vegetation providing substantial riparian shading over ephemeral and disconnected pools. 	<p>Type 2 moderately sensitive key fish habitat</p> <p>Class 3 minimal key fish habitat for fish passage.</p>	Yes

Location	Habitat features	Key fish habitat classification	Sensitive receiving environment
<p>Unnamed small, ephemeral watercourses located within the construction footprint next to the Wakehurst Parkway</p>	<ul style="list-style-type: none"> Riparian vegetation includes Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, offering habitat to locally occurring amphibian, reptile and mammal species, due to the diversity of fauna habitat features available (ie rocks and logs, well-developed leaf litter and intact native vegetation) Standing pools and riffles with an ephemeral flow varying in width and depth are likely to provide sheltering, foraging and breeding habitat for numerous species of amphibian, reptile, mammal, invertebrate and bird including threatened species such as Red-crowned Toadlet given the presence of substantial fauna habitat (ie logs, leaf litter, rock). 	<p>Type 3 minimally sensitive key fish habitat Class 3 minimal key fish habitat for fish passage.</p>	<p>No</p>
<p>Wakehurst Golf Course dam, located about 100 metres north-east of the Wakehurst Parkway east construction support site (BL13)</p>	<ul style="list-style-type: none"> This dam is a freshwater lagoon, bound by sandstone escarpment to the west and levee banks to its north, east and south and nested within the bushland reserve between the Wakehurst Parkway and Wakehurst Golf Course Riparian vegetation includes mostly dense, native vegetation with some exotic understorey Some fringing areas of native emergent macrophytes (<i>Eleocharis</i> spp.) and filamentous green algae were recorded A vegetated drainage line discharges into the dam. Upstream sections were vegetated with shrubs, ferns, grasses and forbs or layered with detritus. No instream macrophytes were observed although moss was observed in some sections. 	<p>Not key fish habitat.</p>	<p>No</p>

19.3.4 Groundwater dependent ecosystems

A search of the *National Atlas of Groundwater Dependent Ecosystems* (BOM, 2018) did not identify any groundwater dependent ecosystems within the construction footprint. However, three areas of groundwater dependent ecosystems may rely on subsurface groundwater associated with local waterways within, or close to the construction footprint. These groundwater dependent ecosystems are outlined in Table 19-9 and shown on Figure 19-12.

No high priority groundwater dependent ecosystems (as defined by the Department of Planning, Industry and Environment (Water)) would be located within or next to the construction footprint.

Table 19-9 Groundwater dependent ecosystems mapped by BOM (2018) in proximity to the project

Location of mapped groundwater dependent ecosystem	Distance from the project	Mapped ecosystems
Upper reaches of Flat Rock Creek at Munro Park – moderate to high potential for terrestrial groundwater dependent ecosystem	About 280 metres south-east of the tunnel alignment and the Flat Rock Drive construction support site (BL2)	Coastal Sandstone Gully Forest Sandstone Riparian Scrub Coastal Sand Forest
Bates Creek – moderate to high potential for terrestrial groundwater dependent ecosystem	About 550 metres west of the Wakehurst Parkway surface road works	Estuarine Mangrove Forest Seagrass Meadow Coastal Sandstone Gully Forest
Manly Dam Reserve – moderate potential for terrestrial groundwater dependent ecosystem	About 650 metres east of the Wakehurst Parkway surface road works	Coastal Sandstone Gully Forest Coastal Sandstone Plateau Heath

Coastal Upland Swamp in the Sydney Basin Bioregion, listed as Endangered under the *Biodiversity Conservation Act 2016* and *Environment Protection and Biodiversity Conservation Act 1999*, is mapped near the construction footprint. While it is not mapped as a groundwater dependent ecosystem within the *National Atlas of Groundwater Dependent Ecosystems* (BOM, 2018), this threatened ecological community may also be sensitive to changes to groundwater flows. A review of the regional vegetation mapping by OEH (2016), as well as ground truthing, identified that the closest areas of Coastal Upland Swamp to the construction footprint are two patches 95 metres west of the Wakehurst Parkway in Garigal National Park and one small patch north of Bantry Bay Oval, about 135 metres to the south-east of the construction footprint. The extent of groundwater dependence of both of these areas of Coastal Upland Swamp, or their connectivity to other areas of groundwater, is not known.

19.3.5 Wetlands and conservation areas

No wetlands listed under the State Environmental Planning Policy (Coastal Management) 2018 are located within the aquatic biodiversity study area. There are no wetlands of international importance within the construction footprint. Therefore, impacts to wetlands and conservation areas are not assessed further.

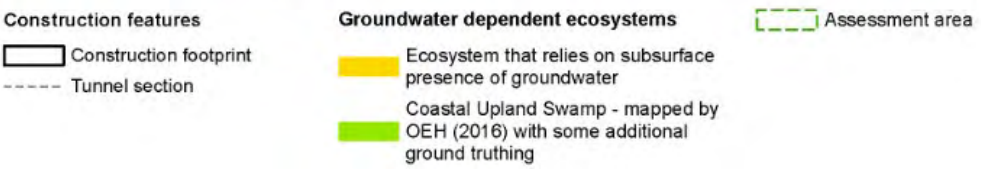
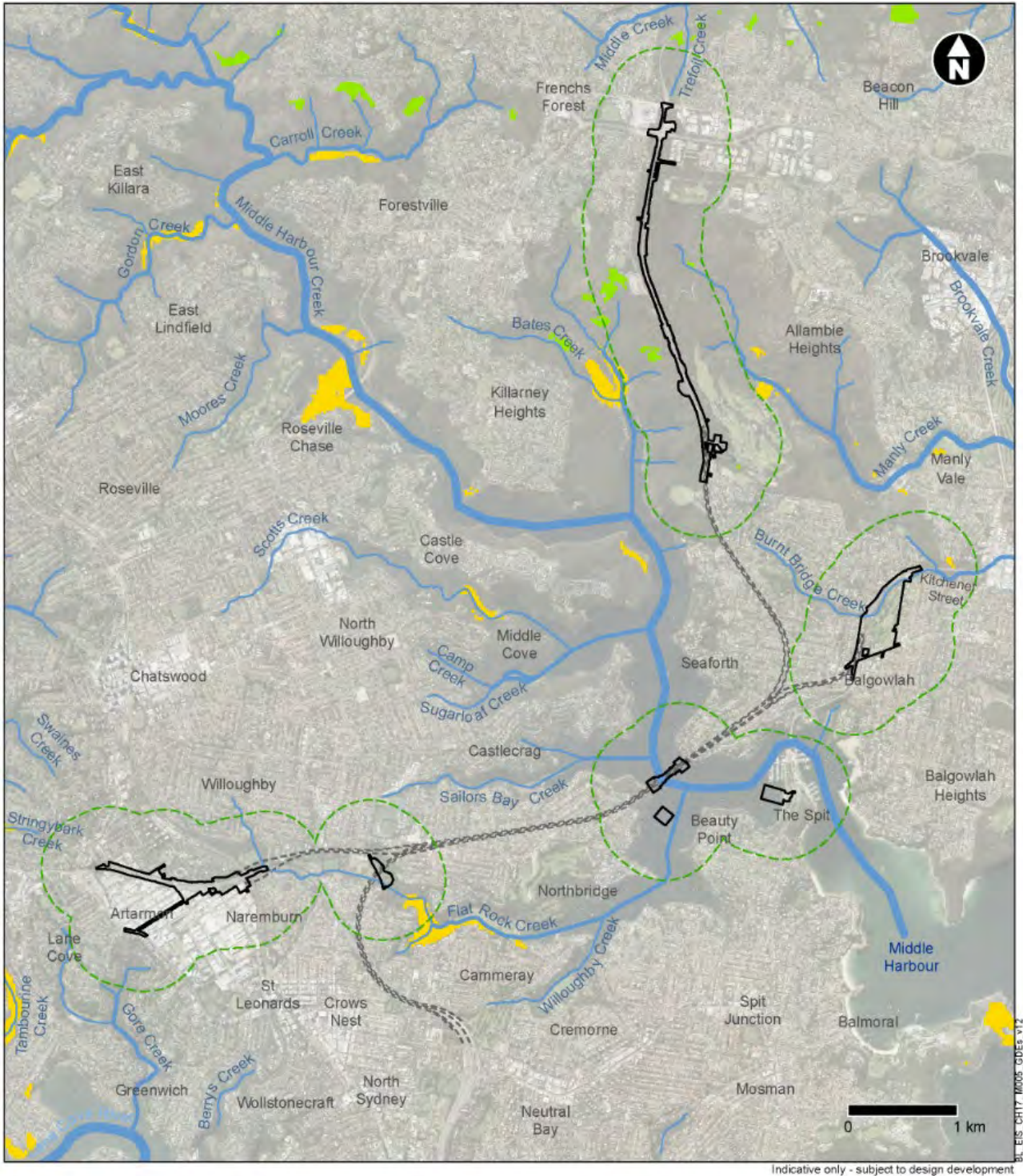


Figure 19-12 Distribution of groundwater dependent ecosystems

19.3.6 Marine biodiversity

Marine habitats

Eight marine habitat types were identified within the marine biodiversity study area and are shown in Figure 19-13. The habitats and relevant key fish habitat classifications as defined in the *Policy and guidelines for fish habitat conservation and management* (NSW DPI, 2013) are summarised in Table 19-10.

No critical habitats listed on State or Commonwealth registers of critical habitat occur within the marine biodiversity study locality.

Table 19-10 Marine habitats within the marine biodiversity study area

Key fish habitat classification	Marine habitat
Highly sensitive key fish habitat (Type 1)	Seagrass
	Saltmarsh
	Subtidal rocky reef
Moderately sensitive key fish habitat (Type 2)	Intertidal rocky shore
	Mangrove
	Intertidal sand and mudflat
Minimally sensitive key fish habitat (Type 3)	Deepwater soft sediment
	Open water

Two natural sills occur within the harbour at The Spit and Grotto Point. These natural sills in some circumstances could interact with hydrology, resulting in natural situations arising where dissolved oxygen levels in the bottom layers at the sills is reduced. Based on average annual rainfall patterns, the conditions leading to dissolved oxygen depletion near the bed of the harbour are likely to occur naturally a few times per year, particularly during the warmer late summer and autumn period.

The occurrence of these events may result in mortality to some benthic (bottom dwelling) infauna (animals which live in the sediments on the floor of a waterbody) and epifauna (animals living on the surface of the bed of a harbour or riverbed) within the deepest parts of Middle Harbour. However, fish and sharks would be able to avoid these environments and any impacts that would otherwise result from these naturally occurring events. Although there would be some naturally occurring mortality of benthic fauna associated with these events, recolonisation would typically occur through natural processes, with these communities likely to be resilient to these types of disturbances.

Threatened marine ecological communities, species and endangered populations

Saltmarsh and seagrass (*Posidonia australis*) meadow communities occur within the marine biodiversity study area. These two marine threatened ecological communities are listed under the *Fisheries Management Act 1994* and the *Environment Protection and Biodiversity Conservation Act 1999* (refer to Table 19-11).

Although the Subtropical and temperate coastal saltmarsh community occurs within and around Middle Harbour, it has not been identified in the project area.

The fragmented patches of seagrass within the marine biodiversity study area at Explosives Reserve, Castlecrag, Clive Park, Beauty Point, Seaforth and Brady Point do not meet the condition thresholds to be considered part of the *Posidonia australis* meadows of the Manning-Hawkesbury ecoregion listed as an endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999*. The seagrass patches are, however, consistent with the *Posidonia australis* endangered population listed under the *Fisheries Management Act 1994*.

Table 19-11 Threatened marine ecological communities in the marine biodiversity study area

Marine ecological community	Conservation significance ¹
Seagrass (<i>Posidonia australis</i>)	Endangered population (FM Act) Endangered (EPBC Act)
Subtropical and temperate coastal saltmarsh	Protected (FM Act) Vulnerable (EPBC Act)

1. FM Act = *Fisheries Management Act 1994*
EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*

Two listed marine fish species were identified as having a high likelihood of occurrence within the project area, Black Rockcod (*Epinephelus daemeli*) and White’s Seahorse (*Hippocampus whitei*). These species have a high likelihood of occurrence due to the presence of suitable habitat within the project area. In addition, nine listed marine species were identified as having a moderate likelihood of occurrence within the project area.

White’s Seahorse is listed as endangered under the *Fisheries Management Act 1994* and has been nominated for threat-listing under the *Environment Protection and Biodiversity Conservation Act 1999*. A preliminary assessment of significance under the *Environment Protection and Biodiversity Conservation Act 1999* has been carried out for White’s Seahorse for completeness.

Details of the 11 listed marine species likely to occur within the project area are provided in Table 19-12.

Fauna passage is not currently affected by the natural sills within the harbour, with fish, sharks, marine mammals and marine turtles able to transit through these shallow waters to deeper waters upstream, including areas within and surrounding the project area.

Migratory marine species

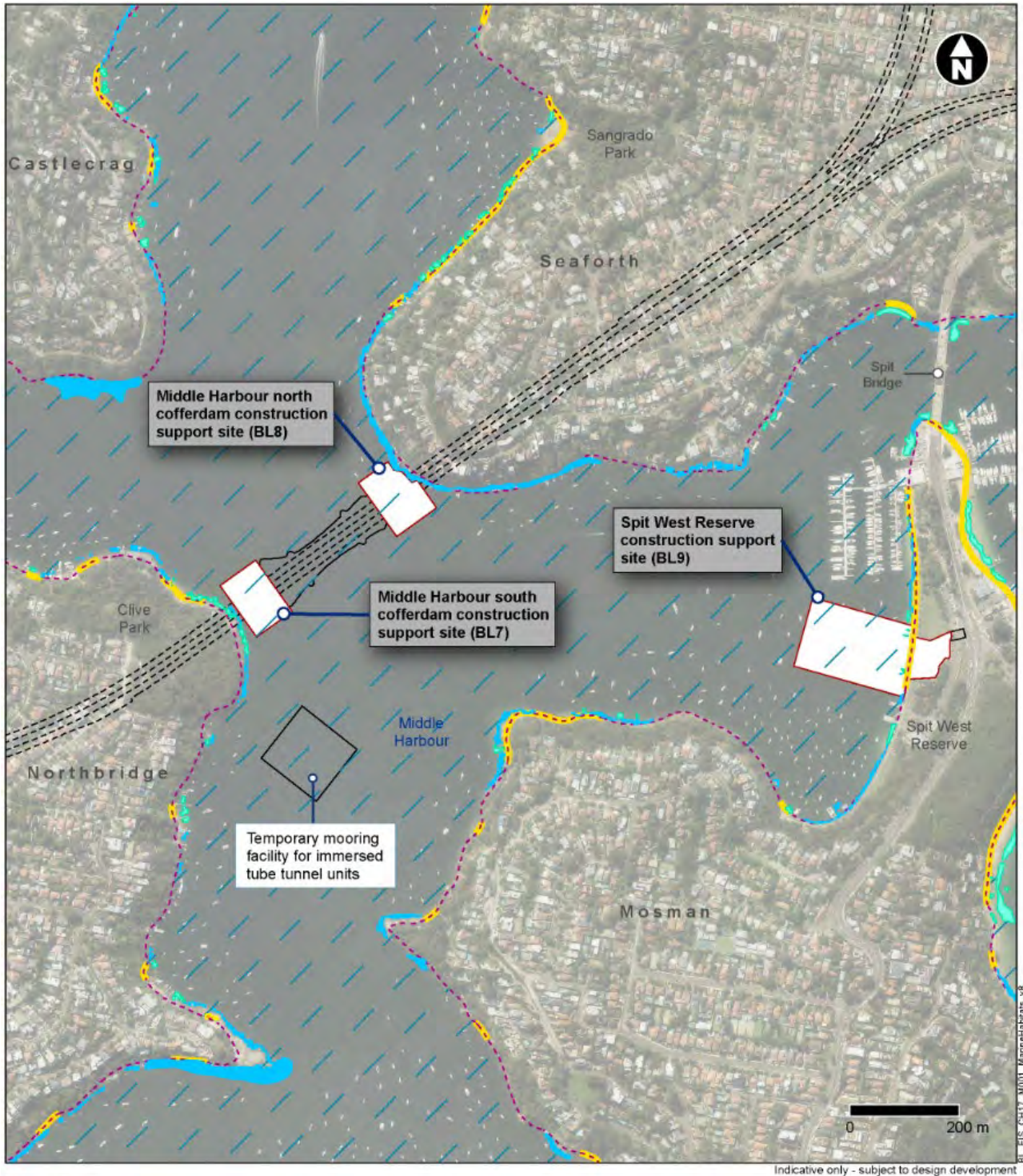
No migratory marine species listed under the *Environment Protection and Biodiversity Conservation Act 1999* have high or moderate likelihood of occurrence in the marine biodiversity study area.

Table 19-12 Threatened marine species known or likely to occur in the project area

Species	Conservation significance ¹	Likelihood of occurrence in the project area
Black Rockcod (<i>Epinephelus daemeli</i>)	Vulnerable (FM Act) Vulnerable (EPBC Act)	High likelihood of occurrence in the project area. Suitable habitat for this species is present within the project area. Suitable habitat for this species within the project area includes medium to high relief subtidal rocky reef areas, which are present along the shorelines of Middle Harbour.
White's Seahorse (<i>Hippocampus whitei</i>)	Endangered (FM Act) Nominated for threat-listing, marine (EPBC Act)	High likelihood of occurrence in the project area. Suitable habitat for this species is present within the project area, including low, medium and high relief subtidal rocky reef areas and <i>Halophila</i> , <i>Zostera</i> and <i>Posidonia</i> seagrass meadows.
New Zealand Fur-seal (<i>Arctocephalus forsteri</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the project area. Foraging habitat and suitable rest areas are present within the project area.
Australian Fur-seal (<i>Arctocephalus pusillus doriferus</i>)	Vulnerable (BC Act)	Moderate likelihood of occurrence in the project area. Foraging habitat and suitable rest areas are present within the project area.
Loggerhead Turtle (<i>Caretta caretta</i>)	Endangered (BC Act) Endangered, migratory, marine (EPBC Act)	Moderate likelihood of occurrence in the project area. This species has been anecdotally recorded within the marine biodiversity study area; however high-quality preferred habitat for this species is not present within the project area.
Green Turtle (<i>Chelonia mydas</i>)	Vulnerable (BC Act) Vulnerable, migratory, marine (EPBC Act)	Moderate likelihood of occurrence in the project area. This species has been anecdotally recorded within the marine biodiversity study area, however high-quality preferred habitat for this species is not present within the project area.
Leatherback Turtle (<i>Dermochelys coriacea</i>)	Endangered (BC Act) Endangered, migratory, marine (EPBC Act)	Moderate likelihood of occurrence in the project area. This species has been anecdotally recorded within the marine biodiversity study area; however high-quality preferred habitat for this species is not present within the project area.

Species	Conservation significance ¹	Likelihood of occurrence in the project area
Hawksbill Turtle (<i>Eretmochelys imbricata</i>)	Vulnerable, migratory, marine (EPBC Act)	Moderate likelihood of occurrence in the project area. This species has been anecdotally recorded within the marine biodiversity study area; however high-quality preferred habitat for this species is not present within the project area.
Flatback Turtle (<i>Natator depressus</i>)	Vulnerable, migratory, marine (EPBC Act)	Moderate likelihood of occurrence in the project area. This species has been anecdotally recorded within the marine biodiversity study area; however high-quality preferred habitat for this species is not present within the project area.
Grey Nurse Shark (<i>Carcharias Taurus</i>)	Critically endangered (FM Act) Critically endangered (EPBC Act)	Moderate likelihood of occurrence in the project area. Foraging habitat for this species is present within the project area.
White Shark (<i>Carcharodon carcharias</i>)	Vulnerable (FM Act) Vulnerable, migratory (EPBC Act)	Moderate likelihood of occurrence in the project area. Foraging habitat for this species is present within the project area.

Note 1: FM Act refers to *Fisheries Management Act 1994*
BC Act refers to *Biodiversity Conservation Act 2016*
EPBC Act refers to *Environment Protection and Biodiversity Conservation Act 1999*



Legend

- | | | |
|---------------------------|---|--|
| Construction footprint | Highly sensitive key fish habitat (Type 1) | Minimally sensitive key fish habitat (Type 3) |
| Construction support site | Seagrass | Shallow and deep soft sediment habitat |
| Tunnel section | Subtidal rocky reef | |
| | Moderately sensitive key fish habitat (Type 2) | |
| | Intertidal rocky shore | |
| | Mangrove | |
| | Intertidal sand and mudflat | |

Figure 19-13 Marine habitats within the marine biodiversity study area

19.4 Avoidance and minimisation

Based on the outcomes of the desktop assessment and field surveys, opportunities to avoid or minimise biodiversity impacts were considered as part of the project design development process. Chapter 4 (Project development and alternatives) describes the alternatives that were considered as part of the project development process and explains the selection of the preferred corridor and design.

Five corridor alternatives were considered for the project; four of these included upgrading the Wakehurst Parkway, where there is the potential for greater biodiversity impacts compared to the remainder of the project. The five corridors 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 project largely avoids surface impacts to terrestrial biodiversity values by tunnelling, and the preferred corridor avoids impacts associated with other options to the areas around Parriwi Park and Fisher Bay Bushland Reserve, where threatened species have been recorded.

Throughout the refinement of the preferred corridor design, a number of elements have been included to avoid and minimise impacts on biodiversity during construction and in operation of the project, including:

- The Flat Rock Drive construction support site (BL2) was chosen to be located in an area of Flat Rock Reserve which was previously used as a landfill site until 1985. This area contains mostly native revegetation, avoiding impact to surrounding remnant vegetation. Refer to Section 3 of Appendix S (Technical working paper: Biodiversity development assessment report) for further details
- The preferred design for the connection to and from the Burnt Bridge Creek Deviation and surface road works at Balgowlah have reduced impacts to Burnt Bridge Creek to the east and west of Burnt Bridge Creek Deviation, including potentially reduced impact on mature trees in the golf course compared to other options. Furthermore, direct impact of the Burnt Bridge Creek riparian corridor has been reduced by establishing an exclusion zone around riparian native vegetation adjoining the creek
- The preferred design for the connection to Sydney Road from the Burnt Bridge Creek Deviation avoids the need to demolish and replace the Kitchener Street bridge which reduces potential noise impacts and duration of impacts to the Grey-headed Flying-fox camp at Balgowlah compared to other options
- Impacts to terrestrial fauna connectivity have been minimised by providing a number of dedicated fauna crossings spanning the Wakehurst Parkway that would provide fauna connectivity between Garigal National Park to the west and Manly Dam Reserve to the east. Fauna fencing would be provided for the length of the Wakehurst Parkway to reduce the risk of vehicle strike and fauna mortality, and guide fauna towards crossing structures
- Impacts to the Duffys Forest endangered ecological community have been avoided as far as possible by optimising the location of the tunnel portals and permanent tunnel support facilities
- Tunnelling has largely avoided impacts to areas supporting groundwater dependent ecosystems, apart from some vegetation at Flat Rock Creek/Quarry Creek that would be subject to potential water table drawdown impacts
- The project design and construction works have been developed to largely avoid direct impacts to seagrass and other sensitive marine habitat areas in Middle Harbour
- The construction methodology for the crossing of Middle Harbour and immersed tube tunnel alignment have been designed to reduce the construction footprint and avoid dredging of the sandbar at the entrance to Middle Harbour or dredging in the vicinity of the Spit West Reserve construction support site (BL9). The sandbar is considered one of the more sensitive marine habitat areas within Middle Harbour.

Further discussion on the avoidance and minimisation of biodiversity impacts is included in Section 4 of Appendix S (Technical working paper: Biodiversity development assessment report).

19.5 Assessment of potential impacts

This section assesses the potential impacts during construction and operation of the project on:

- Terrestrial flora, including removal of vegetation and loss of threatened flora species, edge effects, spread of weeds and pathogens (Section 19.5.1)
- Terrestrial fauna, including potential removal or degradation of fauna habitat, fauna injury and mortality, noise, vibration, dust and light spill impacts (Section 19.5.2)
- Aquatic biodiversity, including potential loss of aquatic habitat and water quality impacts (Section 19.5.3)
- Groundwater dependent ecosystems, including groundwater drawdown impacts (Section 19.5.4)
- Marine biodiversity, including potential loss of marine habitat, marine water quality impacts, and underwater noise impacts (Section 19.5.5).

Vegetation removal including the clearing of fauna habitat would be further minimised during further design development and detailed construction planning, where feasible and reasonable. Appendix W (Technical working paper: Arboricultural impact assessment) provides a preliminary assessment of trees that could be retained subject to further design development and construction planning.

In addition, the final layout of the new and improved open space and recreation facilities at Balgowlah, including the retention and/or removal of trees, would be subject to the outcome of the dedicated community consultation process. This consultation would be jointly led by Transport for NSW and Northern Beaches Council and would be separate to the consultation for the Beaches Link environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. Further information on the new and improved open space and recreation facilities at Balgowlah is included in Section 5.2.1.3 of Chapter 5 (Project description).

19.5.1 Assessment of potential impacts to terrestrial flora

Removal of native vegetation

Construction of the project would require removal of about 15.44 hectares of native vegetation and native revegetation (refer to Table 19-13). This includes around 1.38 hectares of Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (PCT 1786), located along the Wakehurst Parkway at Frenchs Forest (refer to Figure 19-4 and Figure 19-5), which is consistent with the Duffys Forest endangered ecological community listed under the *Biodiversity Conservation Act 2016*.

As described in Section 19.4, to reduce impacts on native vegetation, an exclusion zone is proposed to be established around riparian vegetation adjoining Burnt Bridge Creek adjacent to the surface road works at Balgowlah where reasonable and feasible. The exclusion zone would be about 0.90 hectares in area and would contain 0.48 hectares of PCT 1292: Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion and 0.42 hectares of PCT 1841: Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region.

Biodiversity offsets would be provided for these impacts, as outlined in Section 19.6.1.

During further design development and construction planning, vegetation removal would be further minimised where feasible and reasonable. Refer to environmental management measures in Table 19-18.

Table 19-13 Vegetation to be removed as part of the project

Plant community type (PCT)	Condition	Area removed (ha)
PCT 1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	Moderate/ good	0.20
PCT 1292: Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	Moderate/ good	0.40
PCT 1783: Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	Moderate/ good	4.23
PCT 1786: Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (consistent with the Duffys Forest endangered ecological community)	Moderate/ good – Good	1.01
PCT 1786: Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (consistent with the Duffys Forest endangered ecological community)	Moderate/ good – Moderate	0.37
PCT 1824: Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	Moderate/ good	6.18
PCT 1841: Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	Moderate/ good	1.37
PCT 1845: Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	Moderate/ good	0.39
Native revegetation	Highly disturbed	1.29
Total		15.44

Removal of threatened flora species

Potential impacts to threatened flora species as a result of the project are summarised in Table 19-14, including impacts to both native remnant and planted individuals of Magenta Lilly Pilly (*Syzygium paniculatum*) and planted individuals of Netted Bottle Brush (*Callistemon linearifolius*). These impacts are indicative based on the current level of design development and would be confirmed during further design development.

Table 19-14 Summary of threatened flora species impacts

Species	Conservation significance	Habitat or individuals to be impacted
Magenta Lilly Pilly (<i>Syzygium paniculatum</i>)	Endangered (BC Act) Vulnerable (EPBC Act)	One remnant individual and up to four planted individuals
Netted Bottle Brush (<i>Callistemon linearifolius</i>)	Vulnerable (BC Act)	Up to four planted individuals

The project would not have a significant impact on any of these threatened flora species based on the very low numbers of remnant individuals to be removed, and the fact that other individuals are planted. Biodiversity offsets would be provided for the impacted remnant individual, as outlined in Section 19.6.1. Offsets are not required for planted individuals impacted by the project, as these are not considered to be of conservation significance.

Edge effects on native vegetation

The project would result in indirect impacts to some areas of native vegetation adjoining the construction footprint, mainly due to fragmentation of vegetation and creation of new edges, which may result in edge effects. However, most of the construction footprint adjoins small, fragmented areas of vegetation within urban areas. This vegetation is often already situated adjacent to an existing cleared edge, such as a road, and is subject to ongoing disturbance and edge effects.

The assessment of potential edge effects found:

- A total of 0.23 hectares of native vegetation would be subject to increased edge effects to the extent they would become unviable due to the small size and isolation of the remaining patches
- A total of 8.20 hectares of native vegetation would be subject to increased edge effects as a result of the project due to the creation of one or more new edges within previously unfragmented vegetation. These new edges could be subject to degradation by the establishment and spread of weeds, enriched runoff from road pavement and dumping of rubbish. However, the project would include the provision of drainage infrastructure that would appropriately manage surface water flows. Fauna fencing to be installed along the Wakehurst Parkway would likely prevent the dumping of rubbish along the roadside.

Of the 8.43 hectares of native vegetation subject to edge effects, about 1.36 hectares meets the criteria for Duffys Forest endangered ecological community. There are no areas of indirect impact that meet the criteria for any *Environment Protection and Biodiversity Conservation Act 1999* listed threatened ecological community.

Invasion and spread of weeds, pathogens and disease

An increase in the movement of people, vehicles, machinery, vegetation waste and soil during and following construction activities may facilitate the introduction or spread of exotic grasses and other weed species. Areas along the Wakehurst Parkway would be particularly susceptible to weed establishment due to earthworks being carried out to widen the road. Areas around the Flat Rock Drive construction support site (BL2) would also be potentially highly susceptible to weed establishment from construction works.

In addition, the soil-borne pathogen *Phytophthora cinnamomi* (Phytophthora) is known to occur within the construction footprint. This pathogen is associated with damage and death to native plants. Construction of the project has the potential to increase the spread of this pathogen which could be dispersed by vehicles, animals, walkers and the movement of soil, or over large distances in flowing water, such as storm runoff.

Management measures would be implemented where feasible and reasonable to minimise the risk of introduction and spread of weeds and pathogens during construction of the project (refer to Section 19.6).

19.5.2 Assessment of potential impacts to terrestrial fauna

Removal of fauna habitat

Table 19-15 provides a summary of the potential impacts to terrestrial fauna habitats and associated threatened species for the following habitat types:

- Vegetated habitats
- Human-made structures and built environments (including existing culverts, bridges and buildings)
- Marine and intertidal habitats. The assessment of potential impacts to marine species is discussed in Section 19.5.5.

Vegetated habitats that would be removed are primarily located next to the Wakehurst Parkway, within the Flat Rock Drive construction support site (BL2), Balgowlah Golf Course construction support site (BL10), Wakehurst Parkway south construction support site (BL12) and Wakehurst Parkway east construction support site (BL13).

The removal of flowering and fruiting trees, shrubs and ground layer vegetation, and rocky habitat would result in the loss of potential foraging and sheltering habitat to a number of threatened fauna species known or considered likely to occur in the construction footprint. However, these impacts would be negligible since the habitat to be removed does not comprise a significant proportion of habitat available to species in the surrounding terrestrial biodiversity locality or wider bioregion.

Two hollow-bearing trees would also be removed as part of construction works along the Wakehurst Parkway. One has a hollow diameter of 0.10 to 0.15 metres, and the other has a hollow diameter more than 0.20 metres.

The realignment and upgrade of the Wakehurst Parkway would increase existing fragmentation of the nearby vegetation, which would potentially adversely affect the movement patterns of a number of threatened terrestrial fauna species known or likely to occur in the area such as Rosenberg's Goanna, Eastern Pygmy-possum, Red-crowned Toadlet and Southern Brown Bandicoot. Fauna exclusion fencing, fauna underpasses and rope crossings would be upgraded/replaced or constructed as part of the realignment and upgrade of the Wakehurst Parkway to facilitate the safe crossing of fauna beneath or over the road. The proposed fauna exclusion fencing along both the eastern and western edge of the realigned and upgraded Wakehurst Parkway, would prevent fauna from accessing the road and being subjected to vehicle strike. Therefore, impacts due to increased habitat fragmentation as a result of the project would be minimised. Locations of the upgraded/replaced or new fauna underpasses and rope crossings is provided in Chapter 5 (Project description).

Direct impacts to human-made structures and the built environment would be limited to the alteration of existing bridges and culverts at the surface connections at Artarmon, surface road works at Balgowlah and the realignment and upgrade of the Wakehurst Parkway, which offer limited and marginal potential roosting habitat for some bat species. These species include the Large Bent-winged Bat, Little Bent-winged Bat, and Southern Myotis. These works would be temporary and are unlikely to adversely impact such species.

No marine or intertidal habitats that provide potential habitat for terrestrial fauna would be directly impacted by the project.

Table 19-15 Potential impacts to threatened fauna habitats and associated threatened species

Habitat type	Known or potential threatened fauna species	Potential impacts
Vegetated habitats	<ul style="list-style-type: none"> • Grey-headed Flying-fox • Powerful Owl • Rosenberg's Goanna • Large Bent-winged Bat • Eastern Coastal Free-tailed Bat • Large-eared Pied Bat • Eastern Pygmy-possum • Spotted-tailed Quoll • Southern Brown Bandicoot • Glossy Black-Cockatoo • Little Bent-winged Bat • Red-crowned Toadlet • Barking Owl • Little Lorikeet • Masked Owl • Square-tailed Kite • Swift Parrot • Varied Sittella • Dusky Woodswallow • Brown Treecreeper. 	<ul style="list-style-type: none"> • Impacts to fauna due to the loss of potential foraging and sheltering habitat associated with vegetation or rocky habitat features to be removed, including Rosenberg's Goanna, Eastern Pygmy-possum, Large-eared Pied Bat and Red-crowned Toadlet. However, the habitat does not comprise a substantial portion of foraging habitat available in the surrounding terrestrial biodiversity locality or wider bioregion. Habitat removal would also be further minimised where feasible and reasonable. Further environmental management measures to minimise this impact are provided in Section 19.6 • The realignment and upgrade of the Wakehurst Parkway would increase existing fragmentation of the nearby vegetation. However, mitigation measures such as fauna exclusion fencing, fauna underpasses and rope crossings would be implemented to minimise impacts • Potential edge effects to vegetated habitats next to the Wakehurst Parkway are not expected to result in any associated habitat impacts, including downstream riparian areas which provide potential sheltering, foraging and breeding habitat for the Red-crowned Toadlet.
Human-made structures and built environments	<ul style="list-style-type: none"> • Large Bent-winged Bat • Little Bent-winged Bat • Eastern Coastal Free-tailed Bat • Yellow-bellied Sheath-tail-bat • Greater Broad-nosed Bat • Southern Myotis 	<ul style="list-style-type: none"> • Direct impacts would be limited to the alteration of existing bridges and culverts at Artarmon, Balgowlah and the Wakehurst Parkway which offer limited and marginal potential roosting habitat and is unlikely to adversely impact threatened bat species.

Habitat type	Known or potential threatened fauna species	Potential impacts
Marine and intertidal habitats	<ul style="list-style-type: none"> • Southern Myotis • White-bellied Sea Eagle • Eastern Osprey • Little Penguin 	<ul style="list-style-type: none"> • Construction activities within Middle Harbour have the potential to decrease the surrounding water quality and impact the occurrence and behaviour of fish and other prey for threatened fauna species. However, these impacts would be temporary and localised and species would be able to forage in other parts of the harbour.

Fauna injury and mortality

Terrestrial fauna injury or mortality may occur during vegetation clearing activities (particularly during the felling of trees) or may result from collisions with work vehicles or plant, or accidental entrapment in plant, trenches or other works. Vehicle strike, particularly where construction vehicles would be in operation near tracts of fauna habitat along the Wakehurst Parkway, would not only directly impact the fauna species killed or injured, but would potentially impact predatory species likely to feed on the roadkill. For example, Rosenberg's Goanna has been known to feed on roadkill, and was recorded along the Wakehurst Parkway during field surveys carried out in 2017. Threatened fauna species with a high likelihood or known occurrence in the construction footprint could be subject to injury and mortality.

The majority of fauna species recorded within the construction footprint are highly mobile bird and mammal species that are likely to be able to move away from vegetation clearing and other construction activities quite readily. Fauna species susceptible to injury or mortality include less mobile species such as amphibians, reptiles, invertebrates and juvenile/nesting birds/mammals and small mammals. Threatened fauna species at highest risk of injury or mortality include:

- Red-crowned Toadlet
- Eastern Pygmy-possum
- Rosenberg's Goanna.

Marine fauna injury or mortality may occur during construction of the crossing of Middle Harbour or could result from collisions with watercraft or barges carrying out construction within Middle Harbour. This could include the threatened Little Penguin; however, this species typically forages in shallow waters at the shoreline, which the project largely avoids. Middle Harbour is subject to high levels of water traffic and the species may be adapted to avoiding water vessels.

Notwithstanding, an observer qualified to spot Little Penguins would be used during marine construction activities. A stop-work procedure would also be developed by a suitably qualified and experienced ecologist and implemented upon evidence of any Little Penguin in the proximity of the works area.

Noise, vibration, dust and light spill impacts

Construction activities would result in localised and temporary noise and vibration impacts; however, as most construction areas occur in highly urbanised areas that are subject to ambient noise, any increase in noise and vibration is not expected to have a significant impact on terrestrial fauna.

Realignment and upgrade of the Wakehurst Parkway may indirectly affect threatened fauna species that have been previously recorded in nearby native vegetation, including:

- Red-crowned Toadlet
- Eastern Pygmy-possum
- Large Bent-winged Bat
- Little Bent-winged Bat
- Large-eared Pied Bat
- Grey-headed Flying-fox
- Powerful Owl
- Eastern Coastal Free-tailed Bat
- Southern Myotis
- Rosenberg's Goanna
- Glossy Black-Cockatoo.

Construction activities including the realignment and upgrade of the Wakehurst Parkway around the cut and cover and trough structures of the ramp tunnels and widening of the Wakehurst Parkway, and establishment and operation of temporary construction support sites, could result in noise, vibration, light spill and dust impacts on nearby habitat throughout the duration of construction. Excavation along the Wakehurst Parkway is required (eg at cuttings) and would require the use of rock hammers. Controlled blasting has also been identified as an opportunity in a few selected locations to minimise the duration of excavation. Areas likely to require controlled blasting would be confirmed during further design development and construction planning, and would be managed in accordance with requirements in Appendix G (Technical working paper: Noise and vibration).

Fauna can be sensitive to elevated noise, changing their behaviour and impacting their physiology. Rock hammering and blasting have potential to impact fauna inhabiting vegetation and rock habitat next to the Wakehurst Parkway. Fauna may initially desert the immediate area at the start of excavation activities due to increased noise and vibration levels. Native vegetation and rocky habitats in the adjacent Garigal National Park and Manly Dam Reserve would provide refuge for any displaced individuals with mobility. Fauna could then gradually reinhabit, potentially developing a tolerance to the high noise levels during construction. However, due to the extent of adjoining habitat, the initial displacement from the immediate area could become permanent. For less mobile species or breeding individuals, the effects of the high noise levels may be more acute.

There is potential for indirect impacts to Large-eared Pied Bat habitat areas more than 100 metres from the construction footprint due to noise and vibration, light and dust. The works in the vicinity of potential roost and foraging habitat would be minimised by implementing environmental management measures included in Section 19.6. While there is the potential for impacts from controlled blasting to Large-eared Pied Bat habitat areas, this method would minimise the duration of excavation, which would reduce the exposure to other indirect impacts such as light and dust.

Potential typical noise impacts to the Grey-headed Flying-fox camp are expected to be similar to or less than existing background noise levels at this location during most construction activities. The background noise levels are currently dominated by road traffic noise from the Burnt Bridge Creek Deviation. Some noise generating construction activities are predicted in worst case to exceed existing day time road traffic noise levels on the Burnt Bridge Creek Deviation. These activities include surface works on Burnt Bridge Creek Deviation and oversized deliveries associated with the Kitchener Street construction support site (BL11) and would likely be short term in duration.

Grey-headed Flying-foxes occupying the Balgowlah camp appear to be accustomed to background traffic noise and have persisted at the camp despite regular maintenance of the gross pollutant trap by Northern Beaches Council directly near core roosting habitat. Accordingly, typical noise levels of key noise-generating construction activities during the day are not anticipated to adversely impact the Grey-headed Flying-fox camp. Some noise-generating construction activities would result in worst case noise levels that would exceed existing day time road traffic noise levels on Burnt Bridge Creek Deviation. However, reasonable and feasible noise management measures would be implemented when construction activities are occurring near the Grey-headed Flying-fox camp, as outlined in Section 19.6.

Grey-headed Flying-foxes may not be sensitive to construction noise at night time (ie related to construction activities proposed to occur outside of standard construction hours), as most individuals would be engaging in nocturnal foraging activities throughout the surrounding locality.

Construction activities in Middle Harbour resulting in impulsive or continuous underwater noise may lead to changed behaviour of the Little Penguin. The species may avoid foraging in areas subjected to continuous or high levels of sound. Sudden or high levels of sound may have the potential to result in hearing loss or damage to auditory tissues in the Little Penguin. The potential for an impact to occur and the scale or nature of impact would depend on an individual penguin's proximity to construction activities, lessening as distance from construction activities increases. Given the level of construction activity proposed in the harbour, it is expected that individuals of the species would avoid the area reducing the risk of hearing loss and/or auditory damage occurring. Notwithstanding, an observer qualified to spot Little Penguins would be used during marine

construction activities. A stop-work procedure would also be developed by a suitably qualified and experienced ecologist and implemented upon evidence of any Little Penguin in the proximity of the works area.

Water quality impacts on terrestrial fauna

Runoff from the Wakehurst Parkway during construction and operation of the project has the potential to result in soil erosion and sedimentation impacts downstream if not appropriately managed. This may impact the potential sheltering, foraging and breeding habitat of the Red-crowned Toadlet. The project would include the provision of temporary and permanent water quality control measures along the Wakehurst Parkway, including new or modified drainage and water quality basins. As discussed further in Section 19.5.3, the results of water quality modelling indicates that during operation, the project would not decrease the water quality of nearby ephemeral and unnamed freshwater waterways at the Wakehurst Parkway (refer to Appendix O (Technical working paper: Surface water quality and hydrology) for further details).

Given that potential construction impacts on Red-crowned Toadlet habitat would be managed by the implementation of standard environmental management measures as outlined in Chapter 16 (Geology, soils and groundwater) and Chapter 17 (Hydrodynamics and water quality) and that water quality of the Red-crowned Toadlet habitat is unlikely to decrease during operation of the project, adverse impacts on potential Red-crowned Toadlet habitat are unlikely.

Construction works within Middle Harbour have the potential to result in water quality impacts (eg during piling and dredging activities) which could result in potential adverse impacts to foraging habitat for threatened fauna species such as the Little Penguin and White-bellied Sea Eagle. However, the selected methodology for the project has considered dredging methods and controls to limit the potential for turbidity impacts and mobilisation of sediment, to minimise the impact on the surrounding marine environment. This includes, but is not limited to, the installation of floating silt curtains and the use of a closed environmental clamshell bucket for dredging the upper layers of sediment to minimise the spread of excavated material into the water column. Accordingly, any potential increase in turbidity and sedimentation of marine waters near construction activities would be likely minimal, localised and temporary.

19.5.3 Assessment of potential impacts to aquatic biodiversity

Loss of aquatic habitat

Instream works would be required along an existing aboveground watercourse within Flat Rock Reserve and Burnt Bridge Creek.

The existing aboveground watercourse within Flat Rock Reserve would be diverted for around 100 metres through a newly constructed culvert at the north eastern perimeter of the Flat Rock Drive construction support site (BL2). Aquatic habitat impacts associated with these drainage works are anticipated to be minor.

Burnt Bridge Creek would undergo localised adjustment to facilitate an extension of the existing box culvert crossing of the Burnt Bridge Creek Deviation further into Balgowlah Golf Course. Scour protection would also be installed at the downstream limit of the culvert works. This may result in the loss of some small invertebrates as well as some instream habitat, including instream macrophytes and some unconsolidated sediments. However, the instream works are anticipated to have a minimal and localised impact to instream freshwater habitats.

A small area of riparian vegetation would be removed for the localised adjustment and drainage works at Burnt Bridge Creek. This has the potential to impact bank stability and surface water quality if not appropriately managed. Riparian vegetation directly affected during construction would be restored where practicable in accordance with the environmental management measures included in Section 19.6 and Chapter 22 (Urban design and visual amenity), to ensure that impacts to downstream aquatic habitats are minimised.

Due to the instream works within Burnt Bridge Creek there would be a net loss of about 60 square metres of Type 2 moderately sensitive key fish habitat. Offsets for aquatic habitat are discussed in Section 19.6.1.

The instream works would be carried out during low flows with fish passage to be maintained throughout the works. Where practical, native freshwater fauna, including fish and crayfish, would be relocated to a similar habitat along the same waterway prior to the start of the instream works. The adjusted Burnt Bridge Creek would be designed to be a low flow channel which maintains connectivity during low flows, and to promote fish passage. Therefore, significant or long-term impacts to freshwater ecology are not expected as a result of the project.

The project would also impact the Balgowlah Golf Course stormwater harvesting dam as part of constructing the new access road between Sydney Road and Burnt Bridge Creek Deviation. The Balgowlah Golf Course stormwater harvesting dam would initially be retained and maintained for construction water and for irrigation of Balgowlah Oval by Northern Beaches Council. As construction progresses, the stormwater harvesting dam would be dewatered and filled in. As discussed in Section 19.3.3, the stormwater harvesting dam is unlikely to provide habitat for native fish. Notwithstanding, dewatering procedures would be implemented in the event that native aquatic fauna are encountered to ensure any potential impacts are minimised.

Hydrological impacts

During construction and operation, there would be potential that baseflow reductions to Flat Rock Creek, Quarry Creek and Burnt Bridge Creek could affect surface environmental water availability and flows to these waterways. Estimates for maximum baseflow reduction include:

- A 20 per cent reduction in baseflow at the end of construction and 39 per cent after 100 years of operation at Flat Rock Creek
- A 23 per cent reduction in baseflow at the end of construction and 69 per cent after 100 years of operation at Quarry Creek
- A 79 per cent reduction in baseflow at the end of construction and 96 per cent after 100 years of operation at Burnt Bridge Creek.

During construction, baseflows would not be reduced completely and given the changes to baseflows during the construction period would be expected to be within natural ranges, there would be minor impacts only to aquatic biodiversity. Further, it is expected that the additional creek flows from treated water from the construction wastewater treatment plants could partially feed the surrounding groundwater system.

Reductions to baseflows during operation could be considered significant, in particular for Burnt Bridge Creek and Quarry Creek. However, they are unlikely to result in a complete loss of aquatic habitat. Pools would be retained in these waterways and there would still be high flows immediately after rainfall events. Between rainfall events there would still be some (low) flow along the waterways. Outside of the pool areas, substantially reduced flows between rainfall events would be expected to alter assemblages of freshwater biota in these creeks to generally include only those species that are most tolerant to low flows. Potential operational impacts to reductions in baseflows at Flat Rock Creek are likely to be offset by discharges to the creek from the Gore Hill Freeway operational wastewater treatment plant.

While the potential impacts to baseflow reductions may be overestimated due to conservative modelling, additional monitoring of surface water flows and groundwater levels in the vicinity of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek would be carried out to support a refined assessment of impacts and develop suitable design mitigation measures during further design development. Refer to Chapter 16 (Geology, soils and groundwater) and Chapter 17 (Hydrodynamics and water quality) for further discussion on baseflow reductions and environmental management measures to manage potential impacts.

Water quality impacts on aquatic biodiversity

Construction activities and temporary construction support sites in the vicinity of waterways could result in potential soil erosion, siltation and off-site movement of eroded sediments by stormwater into downstream waterways, accidental fuel and chemical spills, as well as potential changes to water quality and flow in nearby waterways if not appropriately managed. Impacts from construction activities, including wastewater treatment and discharge, are discussed in Chapter 17 (Hydrodynamics and water quality).

Potential impacts of construction activities on water quality would be managed by the implementation of standard environmental management measures as outlined in Chapter 17 (Hydrodynamics and water quality), including erosion and sediment controls for all work sites and surface work areas. With the implementation of appropriate measures during construction, impacts to water quality would be temporary and manageable. Water treatment devices, such as construction sediment basins, would be provided to manage sediment-laden runoff from disturbed areas during construction.

During operation, there would be an increase in impervious surfaces as a result of the project, which would result in an increased volume of runoff with the potential for increased scouring, erosion and sedimentation in downstream waterways. Runoff may also transport increased sediment loads and nutrients such as nitrogen and phosphorus to these waterways. The project would include the provision of water quality control measures during operation, including new and modified drainage infrastructure along the Gore Hill Freeway, Burnt Bridge Creek Deviation, Wakehurst Parkway and on surrounding roads directly affected by the project. In addition, new or modified permanent water quality basins would be provided at:

- Gore Hill Freeway – extension of the existing water quality basin at Punch Street
- Burnt Bridge Creek Deviation – within the new and improved open space and recreation facilities (subject to further consultation)
- Wakehurst Parkway – a new water quality basin to the west of the widened Wakehurst Parkway, adjacent to Garigal National Park and three new water quality basins to the east of the widened Wakehurst Parkway about 800 metres to 900 metres south of the intersection with Warringah Road.

Groundwater captured in the tunnels would be treated to comply with (ANZECC/ARMCANZ, 2000) and ANZG (2018) guidelines and spill controls and water quality monitoring would be implemented to manage operational impacts on ambient water quality within the receiving waterways. For locations where stormwater would be discharged (ie Gore Hill Freeway, Balgowlah and the Wakehurst Parkway), water quality treatment to meet existing conditions would be provided, at a minimum, such that impacts on surface water quality would be minimal.

Due to the presence of sensitive receiving environments along the Wakehurst Parkway, there is potential for impacts on aquatic biodiversity due to reduced water quality during operation. In particular, the population of Climbing Galaxias has been noted as being susceptible to water pollution. However, MUSIC model results for the Wakehurst Parkway stormwater catchments presented in Appendix O (Technical working paper: Surface water quality and hydrology) show that during operation, the project would result in an overall beneficial water quality outcome with a reduction in annual suspended solid and phosphorous loads, but an increase in total annual nitrogen loading of 188 kilograms per year for the overall combined Wakehurst Parkway catchments.

Based on these results, it was concluded that the operation of the project at the Wakehurst Parkway would not decrease the water quality of nearby ephemeral and unnamed freshwater waterways, nor Garigal National Park drainage lines, Bantry Bay, Manly Dam or Manly Creek.

With the implementation of appropriate management measures (refer to Chapter 17 (Hydrodynamics and water quality)), the likelihood of impacts to aquatic biodiversity as a result of the project would be low.

19.5.4 Impacts to groundwater dependent ecosystems

No direct impacts on groundwater dependent ecosystems would occur as a result of the project. Some areas of Coastal Sandstone Gully Forest, Sandstone Riparian Scrub and Coastal Sand Forest adjoining Flat Rock Creek would be subject to impacts from groundwater drawdown, with groundwater drawdown impacts of up to four metres predicted by 2028 and 11 metres by 2128. The level of groundwater dependency of this vegetation is unknown; however, it is likely that it is able to draw on surface water in Flat Rock Creek and soil moisture to prevent drying out of the community, except in dry periods where there is no recharge from rainfall or surface runoff. Groundwater drawdown as a result of the project may contribute to trees dying or becoming stressed during periods of prolonged drought.

Appendix N (Technical working paper: Groundwater) details that the maximum predicted baseflow impact to Flat Rock Creek after 100 years of operation of the project is a reduction of 84.7 kilolitres per day, equating to a flow reduction of 39 per cent. The maximum predicted baseflow impacts to Quarry Creek after 100 years of operation would be a reduction of 11.4 kilolitres per day, equating to a flow reduction of 69 per cent. Operational wastewater treatment plant discharges to Flat Rock Creek could offset this impact.

It is noted that groundwater modelling provides a conservative assessment which excludes the designed tunnel linings. Additional modelling carried out for a scenario in which the section of tunnel beneath Flat Rock Creek is lined. With the linings assumed, the predicted water table drawdown after 100 years of operation was predicted to be up to eight metres less than the drawdown predicted without the lining, demonstrating that implementation of tunnel lining would help mitigate potential groundwater drawdown impacts and that potential baseflow impacts would be lower than predicted (refer to Chapter 16 (Geology, soils and groundwater) and Appendix N (Technical working paper: Groundwater)).

Coastal Upland Swamp may also be sensitive to changes to groundwater flows, and two areas mapped as Coastal Upland Swamp may be impacted by groundwater drawdown as a result of the project. The extent of groundwater dependence of both of these areas of Coastal Upland Swamp, or their connectivity to other areas of groundwater, is not known and therefore the impacts from groundwater drawdown are uncertain.

The closest mapped patch of Coastal Upland Swamp is located about 95 metres to the west of the Wakehurst Parkway in Garigal National Park. Groundwater drawdown is predicted to be less than one metre (by 2028 and 2128). It is unlikely that groundwater drawdown of less than one metre would result in impacts to most of the area of this Coastal Upland Swamp; it is possible that some areas at the upslope edges of the patches could be affected in the event of prolonged low rainfall periods.

Another small (0.07 hectare) area of Coastal Upland Swamp was identified north of Bantry Bay Oval, about 135 metres south-east of the construction footprint, with predicted groundwater drawdown of less than one metre by 2028 and 2128 (see Appendix N (Technical working paper: Groundwater)). Due to its small size, urbanised context and modified floristics, including numerous weedy exotic species, impacts to this area of Coastal Upland Swamps are not considered to be significant.

Appropriate environmental management measures would be implemented to manage potential drawdown impacts to groundwater dependent ecosystems and baseflow reduction impacts (refer to Chapter 16 (Geology, soils and groundwater)).

19.5.5 Assessment of potential impacts to marine biodiversity

Impacts to key fish habitat

A risk assessment relating to the potential hazards to Type 1, 2 and 3 key fish habitats within the marine biodiversity study area is summarised in Table 19-16, including the removal of habitat, altered hydrodynamics, elevated turbidity and sedimentation from dredging, mobilisation of contaminants, introduction of marine pests and underwater noise from dredging and piling.

Removal of medium/high relief rocky reef habitat would occur during the installation of the Middle Harbour north cofferdam (BL8). This has the potential to provide habitat for Black Rockcod and White's Seahorse. As the removal of this habitat would be limited to less than 0.01 hectares, impacts would be small relative to the extent of the habitats in Middle Harbour so as to not compromise the functionality, long-term connectivity or viability of habitats, or ecological processes beyond the affected areas. No offsets would be required as this area of rocky reef would be reinstated after construction and there would therefore be no net loss of habitat.

Dredging for the installation of the immersed tube tunnels would result in the removal of about 3.50 hectares of deep water soft sediment habitat. This would include an unavoidable loss of about 1.41 hectares of deep water soft sediment habitat where the immersed tube tunnel units at the crossing would be placed. However, the hard surfaces of the immersed tube tunnels would be colonised through natural processes of recruitment and immigration by sessile invertebrates and some algae and provide habitat for some fish. The immersed tube tunnels would provide more surface area than the deep water soft sediment habitat it would replace, such that there would be no net loss to key fish habitat.

There is also potential for scour from vessel movements and shading from construction infrastructure to result in the removal of seagrass habitat near the Middle Harbour south (BL7) and Middle Harbour north (BL8) cofferdams and Spit West Reserve construction support site (BL9). With appropriate management of construction activities, including vessel movements, direct impacts to seagrass habitats would be minimal.

Alteration of hydrodynamics associated with the construction and operation of the immersed tube tunnels, including cofferdams, silt curtains and temporary wharves would impact currents around Type 1 key fish habitats and the flushing of deep water environments. Modelling of temporary changes to current speeds carried out for the project construction phase indicated that while the temporary changes would be relatively large in some locations at some parts of the tidal cycle, substantial impacts are not expected for the key fish habitats within the marine biodiversity study area. These habitats, including Type 1 seagrass and rocky reef habitats, thrive in many other parts of the marine biodiversity study area where natural currents are within the expected modified range. The temporary changes in hydrodynamics are not expected to impact deep water habitats.

Permanent alteration of hydrodynamics would occur due to the installation of the immersed tube tunnel, which would create a sill-like feature of about 9.2 metres high above the bed of the harbour at the deepest part of the Middle Harbour crossing location. The presence of the additional sill has the potential to impact on water quality within the marine biodiversity study area by reducing natural flushing of upstream environments, which could result in increased residence times of the deeper waters upstream of the sill from 1.6 days to 2.4 days. Longer residence time of the deeper waters could promote conditions more favourable to the depletion of dissolved oxygen in the bottom boundary layer and may lead to longer periods of low dissolved oxygen concentrations in the near-bed waters upstream of the. When dissolved oxygen concentrations are reduced there may be mortality to some benthic infauna and epifauna in soft sediment habitat in the deepest parts of the harbour, but fish and sharks would generally be able to avoid these bottom layers. It would be expected that recolonisation of affected deep water soft sediment habitat would occur through natural processes of recruitment of planktonic larvae and from movement of fauna from shallower unaffected areas of soft sediment.

Based on average annual rainfall patterns, the conditions leading to dissolved oxygen depletion to about 50 per cent saturation concentrations are likely to naturally occur a few times per year, particularly during the warmer late summer and autumn period. Due to the presence of existing low dissolved oxygen events, deep water communities are expected to be resilient to similar disturbances and would be able to rapidly recolonise following episodes of altered hydrodynamics. While the project would potentially result in low dissolved oxygen events lasting slightly longer at a slightly lower dissolved oxygen concentration than the present system, as currently occurs, any depletion of dissolved oxygen in deeper waters would be rapidly mixed vertically resulting in the project having a negligible effect on dissolved oxygen in surface waters and nearshore environments in which Type 1 and Type 2 key fish habitats are located.

The sill created by the immersed tube tunnels would likely increase the rate of siltation in the deepest water upstream of the crossing by three to four millimetres per decade. This rate is within the range of sedimentation rates within Sydney Harbour and forms a negligible contribution to overall sedimentation. Investigations of the existing water quality variability carried out for the project indicated that while the operation of the project has the potential to impact on the hydrodynamics for deep water habitats, the conditions would be similar to the existing disturbances caused by the two other natural sills within Middle Harbour (refer to Section 19.3.6).

Turbidity and sedimentation caused by dredging during the construction of the project has the potential to impact on about 0.02 hectares of medium relief subtidal rocky reef habitat around the Middle Harbour north cofferdam (BL8). Turbidity and sedimentation from dredging operations also has the potential to impact on seagrass and rocky reef habitats in the vicinity of the Middle Harbour south cofferdam (BL7) and Spit West Reserve construction support site (BL9). The modelling of the predicted sedimentation load carried out for the project indicated that the project is unlikely to substantially impact these habitats. Temporary increases in turbidity during construction may result in temporary shifts in the composition of fish communities. However, changes in fish community compositions would be expected to be within the natural variability observed within the marine biodiversity study area. Impacts associated with turbidity and sedimentation would be temporary and limited to the construction phase of the project and would not adversely impact the broader ecological functioning of marine communities.

Underwater noise would be caused by dredging and piling during the construction of the project in Middle Harbour. Construction related underwater noise may be impulsive or continuous and has the potential to impact fish and shark species within the marine biodiversity study area, including in seagrass, rocky reef, deep water and open water habitats. Potential impacts may include physical or behavioural impacts to marine species, such as temporary impacts to hearing or organs, changes to foraging behaviour, and changes in the distribution of marine species to avoid underwater noise generated by the project. Modelling carried out for the project indicated that underwater noise impacts would be largely limited to the immediate location of piling and dredging activities, but may extend to about 300 metres from the noise source, with the potential to impact up to 0.09 hectares of seagrass habitat, 1.54 hectares of rocky reef habitat, and 128.73 hectares of deep water and open water habitat. As different species have different tolerance thresholds to underwater noise, there would be a range of potential responses to these impacts. It is expected that any impacts to marine species would not affect the broader ecological functioning or viability of local populations due to the temporary nature of underwater noise impacts, with any changes in species assemblages recovered through natural processes of recruitment and immigration.

Piling methods proposed are similar to methods used currently throughout Sydney Harbour for ongoing wharf upgrades and other marine infrastructure construction and maintenance work, and potential impacts would be managed through well-established marine industry methodologies.

Overall, the impacts on key fish habitats during construction and operation of the project are not considered to be significant and would be adequately managed by the measures identified in Section 19.6.

Table 19-16 Risk assessment for key fish habitats

Hazard	Highly sensitive key fish habitat (Type 1)			Moderately sensitive key fish habitat (Type 2)			Minimally sensitive key fish habitat (Type 3)	
	Seagrass	Saltmarsh	Subtidal rocky reef	Intertidal rocky shore	Mangrove	Intertidal sand and mudflat	Deepwater soft sediment	Open water
Removal of habitat	High	Moderate	Moderate	Moderate	Moderate	Moderate	High	High
Turbidity	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Moderate
Sedimentation	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	N/A
Mobilisation of contaminants	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Low
Introduction/spread of marine pests	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate
Altered hydrodynamics	Moderate	Low	Moderate	Moderate	Low	Moderate	Moderate	Moderate
Underwater noise	Moderate	N/A	Moderate	N/A	Low	Low	Moderate	Moderate
Boat strike to marine mammals and reptiles	Moderate	N/A	Moderate	N/A	N/A	N/A	Moderate	Moderate
Spill of contaminants	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate

Impacts to marine threatened species and ecological communities

A risk assessment relating to the potential hazards to threatened species and ecological communities within the marine biodiversity study area is summarised in Table 19-17.

Threatened or protected species, populations or endangered ecological communities listed under the *Fisheries Management Act 1994*, *Biodiversity Conservation Act 2016* or *Environment Protection and Biodiversity Conservation Act 1999* that are most likely to be affected by the project are those that would reside, forage or transit through habitat that would be affected during construction activities. This includes the Black Rockcod and White's Seahorse because of their potential to reside in high and medium relief rocky reef, although only a few individuals of these species would occur in the small areas of these habitats where individuals would potentially be harmed.

Some marine mammals, marine turtles and sharks could also occur in the project area because of their potential to either forage on or transit through seagrass, rocky reef or deep water soft sediment habitats, but their potential to occur in the small parts of these habitats where species could be harmed by the project would be low given that these habitats are generally considered suboptimal for these species. As marine mammals and marine turtles can be observed above the water, impacts due to boat strikes to marine mammals and turtles would be manageable.

As the potential for impacts during the construction phase of the project would be largely limited to the temporary disturbance of individuals of marine species, the potential for significant impacts to any threatened species would be minor and would not affect the viability of local populations of listed species. Notwithstanding, as a safeguard for White's Seahorse that may occur within affected areas, pre-construction surveys of potentially affected areas would be carried out by suitably qualified and experienced marine ecologists to search for and relocate White's Seahorse individuals (and other Syngnathids) to nearby unaffected habitat.

During operation of the project, the sill formed by the immersed tube tunnels would be steeper than the natural sills that occur within Middle Harbour (refer to Section 19.3.6). However, the tunnels would be confined to much deeper waters than the natural sills. As such, it is considered that the additional sill created by the tunnel structure would not be an impediment to fish passage during operation.

In summary, the project is not expected to have a significant impact on any marine threatened species, populations or endangered ecological communities.

Table 19-17 Risk assessment for threatened marine species and ecological communities

Hazard	Threatened marine species (grouped)			
	Fish (specifically Black Rockcod and White's Seahorse)	Mammals	Reptiles	Sharks
Removal of habitat	Moderate	Moderate	Moderate	Moderate
Turbidity	Moderate	Moderate	Moderate	Moderate
Sedimentation	Moderate	N/A	Moderate	Moderate
Mobilisation of contaminants	Moderate	Low	Low	Low
Introduction/spread of marine pests	Moderate	N/A	Low	Low
Altered hydrodynamics	Moderate	Moderate	Moderate	Moderate
Underwater noise	Moderate	Moderate	Moderate	Moderate
Boat strike to marine mammals and reptiles	N/A	Moderate	Moderate	N/A
Spill of contaminants	Moderate	Low	Low	Low

19.5.6 Matters of national environmental significance

Matters of national environmental significance were considered for the assessments carried out as part of Appendix S (Technical working paper: Biodiversity development assessment report) and Appendix T (Technical working paper: Marine ecology).

Threatened species and ecological communities listed under the *Environment Protection and Biodiversity Conservation Act 1999* that are known or considered highly likely to occur in the construction footprint and project area/marine biodiversity study area include:

- *Syzygium paniculatum*
- Large-eared Pied Bat
- Grey-headed Flying-fox
- White-bellied Sea Eagle
- Subtropical and temperate coastal saltmarsh
- *Posidonia australis* seagrass meadows of the Manning-Hawkesbury ecoregion
- Black Rockcod
- White's Seahorse.

The Significant Impact Assessments completed for these matters of national environmental significance concluded that the project would not have a significant impact on these species. As such, the project does not require referral to the Australian Government Minister for the Environment.

An additional Matter of National Environmental Significance, Coastal Upland Swamps in the Sydney Basin Bioregion, does not occur within the construction footprint but may be impacted by groundwater drawdown as a result of the project. The Significant Impact Assessment for Coastal Upland Swamps in the Sydney Basin Bioregion concluded that the project would not have a significant impact on this threatened ecological community. As such, the project does not require referral to the Australian Government Minister for the Environment.

19.6 Environmental management measures

Environmental management measures relating to biodiversity impacts are outlined in Table 19-18. The required biodiversity offsets for the project are outlined in Section 19.6.1 below.

Additional measures relevant to the management of biodiversity impacts are also outlined in other chapters of the environmental impact statement, including:

- Chapter 10 (Construction noise and vibration)
- Chapter 16 (Geology, soils and groundwater)
- Chapter 17 (Hydrodynamics and water quality)
- Chapter 22 (Urban design and visual amenity).

Table 19-18 Environmental management measures –biodiversity

Ref	Phase	Impact	Environmental management measure	Location
B1	Design	Removal of native vegetation and threatened species habitat	The area required and layout of Flat Rock Drive construction support site (BL2) will be refined during further design development and construction planning to avoid direct impacts on PCT 1841, where feasible and reasonable.	BL
B2	Design	Injury and mortality of fauna	Connectivity measures will be designed during further design development in accordance with the <i>Wildlife Connectivity Guidelines: Managing wildlife connectivity of road projects</i> (Draft) (Roads and Maritime, 2011c) and consider measures to facilitate the crossing of native fauna species including the Eastern Pygmy-possum, Red-crowned Toadlet, Southern Brown Bandicoot and Rosenberg's Goanna. Maintenance requirements for underpasses and rope crossings will be developed during further design development and incorporated into an Operational Environmental Management Plan or existing Environmental Management System as relevant.	BL
B3	Design	Injury and mortality of fauna	Fauna exclusion fencing would be designed to exclude small fauna species from the road corridor such as Eastern Pygmy-possum and will be installed for the full extent of the Wakehurst Parkway within the construction footprint. The design specifications of the fauna exclusion fence will be developed during further design development including the need for access gates to manage any fauna on the roadside of the fauna exclusion fence based on best available knowledge from other Transport for NSW projects.	BL

Ref	Phase	Impact	Environmental management measure	Location
B4	Design and operation	Noise, vibration and light impacts	Artificial light impacts on native fauna in the operational phase of the project will be minimised where feasible and reasonable through further design development, where the project adjoins tracts of fauna habitat (eg along the Wakehurst Parkway) consistent with the requirements of <i>Australian Standards and Guidelines 4282 – 2019 Control of the obtrusive effects of outdoor lighting</i> .	BL/GHF
B5	Pre-construction	Impacts to marine species	Pre-construction surveys of potentially affected marine habitat areas will be carried out as close as practicable to 24 hours prior to commencement of works by suitably qualified and experienced marine ecologists to search for White's Seahorses (and other Syngnathids) and relocate them to nearby habitat.	BL
B6	Pre-construction	Removal of native vegetation and threatened species habitat	Vegetation removal including the clearing of native vegetation and fauna habitat will be further minimised during further design development and construction planning, where feasible and reasonable.	BL/GHF
B7	Pre-construction and construction	Impacts on the Large-eared Pied Bat	Activity-specific controls will be developed to manage impacts from high noise and vibration generating activities (eg controlled blasting and rock hammering) on Large-eared Pied Bat along the Wakehurst Parkway. The controls will be prepared by a suitably qualified and experienced microbat specialist and implemented during surface road works as required.	BL
B8	Pre-construction	Impact to aquatic environments	Any dewatering activities will be undertaken in accordance with the <i>Technical Guideline: Environmental Management of Construction Site Dewatering</i> (RTA, 2011), in a manner that prevents pollution of waters. Dewatering of the stormwater harvesting dam at Balgowlah Golf Course will be carried out with consideration of native fauna and appropriate measures will be implemented to relocate native aquatic fauna as required.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
B9	Pre-construction and construction	Underwater noise impacts to marine species	Prior to commencement of impact piling appropriate management measures to minimise noise impacts on fish and aquatic organisms will be developed by a suitably qualified and experienced marine ecologist and implemented during impact piling works. The measures will include investigation and contingency actions should distressed or dead fish be observed within or adjacent to the construction footprint during piling works.	BL
B10	Construction	Removal of native vegetation and threatened species habitat	Vegetation removal along the Wakehurst Parkway will be timed to avoid the winter breeding period for the Eastern Pygmy-possum (May to July), where feasible and reasonable.	BL
B11	Construction	Removal of native vegetation and threatened species habitat	Vegetation removal will be carried out in accordance with <i>Guide 4: Clearing of vegetation and removal of bushrock of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011).	BL/GHF
B12	Construction	Removal of native vegetation and threatened species habitat	The unexpected species find procedure included in <i>Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011) will be followed if threatened ecological communities, flora or fauna species, not assessed in the biodiversity development assessment report, are identified in the construction footprint.	BL/GHF
B13	Construction	Removal of native vegetation and threatened species habitat	Vegetation will be re-established within the construction footprint, where feasible, in accordance with <i>Guide 3: Re-establishment of native vegetation of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011).	BL/GHF
B14	Construction	Removal of native vegetation and threatened species habitat	Pre-clearing surveys for threatened fauna species will be carried out in accordance with <i>Guide 1: Pre-clearing process of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011). This will include inspections of hollows and dead timber for Eastern Pygmy-possum.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
B15	Construction	Removal of threatened flora species	Prior to clearing, the location of the individual of <i>Syzygium paniculatum</i> next to the Wakehurst Parkway will be confirmed. If the individual is outside the construction footprint, but in close proximity to the boundary, the need for a site-specific exclusion zone will be investigated to minimise potential indirect impacts. Should the individual be within the construction footprint, further design investigation will be carried out to determine if impacts can be avoided where reasonable and feasible.	BL
B16	Construction	Removal of threatened flora species	Pre-clearing surveys for threatened flora species will be carried out in accordance with <i>Guide 1: Pre-clearing process</i> of the <i>Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011).	BL/GHF
B17	Construction	Noise, vibration and light impacts	Mitigation measures such as quieter construction methods or the use of temporary noise barriers in close proximity to the construction activities will be used wherever feasible and reasonable to minimise noise impacts to the Grey-headed Flying-fox camp. For the Kitchener Street construction support site (BL11), the arrangement of the site layout should maximise acoustic shielding (ie locations of site sheds, offices and fixed structures) to minimise noise impacts from within the site to the direction of the Grey-headed Flying-fox camp.	BL
B18	Construction	Noise, vibration and light impacts	Where feasible and reasonable, noise intensive works with the potential of impacting the Grey-headed Flying-fox camp (ie demolition involving rock hammering or resurfacing works) should be programmed to avoid September to February.	BL

Ref	Phase	Impact	Environmental management measure	Location
B19	Construction	Noise, vibration and light impacts	A person experienced in flying-fox behaviour (ie able to identify each stage of the reproductive cycle, ABLV-vaccinated and trained to rescue flying-foxes if required) will monitor disturbance levels within the Grey-headed Flying-fox camp at Balgowlah during construction activities that result in noise levels at the camp that exceed the pre-construction ambient noise levels. Monitoring would occur at representative periods (eg fortnightly) while pups are being carried (August-February).	BL
B20	Construction	Noise, vibration and light impacts	Adaptive management measures to minimise impacts on Grey-headed Flying-foxes will be developed in consultation with Department of Planning, Industry and Environment (Environment, Energy and Science) and an appropriately qualified expert in Grey-headed Flying-fox biology and behaviour, if Grey-headed Flying-fox behaviour during monitoring suggests that disturbance levels are high.	BL
B21	Construction	Noise, vibration and light impacts on fauna	Controlled blasting, rock hammering and other potential high noise generating activities along the Wakehurst Parkway will be managed to minimise noise and vibration levels to adjacent fauna habitat where practicable, including but not limited to: <ul style="list-style-type: none"> • Use of noise suppression devices on plant and equipment in accordance with the manufacturer's specifications • Regularly maintain plant and equipment to minimise noise levels when in use • Substituting plant or processes to reduce noise. 	BL
B22	Construction	Injury and mortality of fauna	Fauna will be managed in accordance with <i>Guide 9: Fauna handling of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011).	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
B23	Construction	Injury and mortality of fauna	Pre-clearing surveys for non-threatened fauna species will be carried out in accordance with <i>Guide 1: Pre-clearing process of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011). Surveys will also include human made structures that have been identified as potentially providing habitat for microbats and are subject to demolition or modification.	BL/GHF
B24	Construction	Injury and mortality of fauna	An observer qualified to spot Little Penguins will be used during marine construction activities. A stop-work procedure will be developed by a suitably qualified and experienced ecologist and implemented upon evidence of the species in the proximity of the works area.	BL
B25	Construction	Invasion and spread of weeds, pests, pathogens and disease	Weed species will be managed in accordance with <i>Guide 6: Weed management of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011).	BL/GHF
B26	Construction	Invasion and spread of weeds, pests, pathogens and disease	Pathogens will be managed in accordance with <i>Guide 2: Exclusion zones of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011).	BL/GHF
B27	Construction	Removal of aquatic habitat	Aquatic habitats will be protected in accordance with <i>Guide 10: Aquatic habitats and riparian zones of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011) and the <i>Policy and guidelines for fish habitat conservation and management</i> (NSW DPI, 2013). This will include flow and sufficient fish passage to be maintained similar to current conditions during instream works where reasonable and feasible.	BL/GHF
B28	Construction	Impacts to marine vegetation and sensitive habitat	Transit routes for vessels entering and departing from construction support sites will be marked out with consideration for propeller wash and distances to sensitive marine habitats.	BL

Ref	Phase	Impact	Environmental management measure	Location
B29	Construction	Impacts to marine vegetation and sensitive habitat	Exclusion zones will be implemented to avoid disturbance to sensitive marine habitats not proposed to be directly impacted by the project. These include any intertidal sand and mudflats, intertidal rocky shore, subtidal rocky reef and seagrass habitats with potential to occur within or next to transit routes and vessel movements. Routine inspections and maintenance of exclusion measures will be carried out.	BL
B30	Construction	Impacts to marine vegetation and sensitive habitat	Scour protection measures including possible velocity reduction from wastewater treatment plant discharge will be implemented where reasonable and feasible to avoid scour impacts on the marine environment.	BL
B31	Construction	Impacts to marine vegetation and sensitive habitat	To minimise the potential impact of turbidity (suspended sediment) on sensitive marine vegetation and habitats silt curtains will be installed around seagrass patches and subtidal rocky reef contained within the Zone of Influence as described in the Appendix T (Technical working paper: Marine ecology).	BL
B32	Construction	Impacts to marine vegetation and sensitive habitat	Silt curtains will be monitored for effectiveness particularly following inclement weather and maintenance carried out when required. Records of monitoring and maintenance will be kept.	BL
B33	Construction	Impacts to marine vegetation and sensitive habitat	To avoid direct damage to seagrass and subtidal rocky reef from silt curtain movement, there will be a suitable buffer distance between marine habitat and the silt curtain to account for curtain movement due to tides and currents and to prevent shading of the marine vegetation from the silt curtain. The silt curtain will be anchored to bare sediment where practicable to avoid movement.	BL
B34	Construction	Impacts to marine vegetation and sensitive habitat	Subtidal rocky reef habitat removed along the shoreline at the Middle Harbour north cofferdam (BL8) and intertidal rocky shore, sand and mudflat habitats removed at the Spit West Reserve construction support site (BL9) will be rehabilitated and restored as close as possible to pre-construction conditions where feasible and reasonable.	BL

Ref	Phase	Impact	Environmental management measure	Location
B35	Construction	Invasion and spread of marine pests, pathogens and disease	Locally sourced vessels and equipment will be used where feasible and reasonable. Any vessels sourced internationally will be inspected for potential marine pests prior to departing from their previous port. Construction contractors will need to demonstrate that due diligence has been taken to avoid introducing marine pests, pathogens or disease from internationally sourced vessels and/or construction equipment prior to departure.	BL
B36	Construction	Invasion and spread of marine pests, pathogens and disease	A targeted survey will be conducted of the dredge footprint to locate any areas of the marine algal pest <i>Caulerpa taxifolia</i> . If <i>Caulerpa taxifolia</i> is identified within the dredging footprint, surface sediments from these areas will be disposed of onshore rather than in the marine environment.	BL
B37	Construction	Impacts to marine species	A stop work procedure will be developed in accordance with the recommendations in Appendix T (Technical working paper: Marine ecology) to mitigate potential impacts to marine mammals and reptiles within the vicinity of impact piling works.	BL
B38	Construction	Impacts to marine species	Salvage of live fish and other native marine organisms (eg large, mobile macroinvertebrates) will occur during cofferdam dewatering and will be carried out by suitably qualified and experienced marine ecologists. All salvaged organisms will be immediately relocated to similar habitat nearby.	BL

19.6.1 Biodiversity offsets

The required ecosystem credits for the project in relation to native vegetation to be removed (direct impacts) is summarised in Table 19-19.

Offsets for indirect impacts are in addition to *Biodiversity Assessment Method* credit obligations and are at the discretion of the Minister for Planning and Public Spaces (DPIE, 2019). For indirect impacts resulting in isolated patches, offsets were calculated by reducing vegetation integrity values for these areas to zero, effectively treating these areas as direct impacts. The potential required ecosystem credits for indirect impacts from the project in relation to native vegetation is summarised in Table 19-20.

Species credits would be required as part of the biodiversity offsets for the project, as outlined below. Species that require species credits are listed in the Threatened Biodiversity Data Collection (DPIE (EES), 2020a). Offsets are identified and a preliminary strategy is provided in Appendix S (Technical working paper: Biodiversity development assessment report).

Offsets required for the potential threatened species impacted by the project that require species credits are summarised in Table 19-21.

The *Policy and guidelines for fish habitat conservation and management* (NSW DPI, 2013) specify that significant environmental impacts (direct and indirect) are to be offset by environmental compensation on a minimum 2:1 basis for all key fish habitat lost. A greater compensation ratio may be considered if offsets cannot be sourced in the vicinity of the impact or are not of the same habitat type as that impacted.

The project would potentially impact about 15 metres of Burnt Bridge Creek as a result of the culvert extension works and scour protection. Assuming an average bed width of about four metres in the affected area, this would equate to about 60 square metres of Type 2 key fish habitat. According to the *Policy and guidelines for fish habitat conservation and management* (NSW DPI, 2013) this would result in an offset requirement of about \$6900. Final offset calculations would be carried out following further design development. Refer to Annexure D (Freshwater ecology impact assessment) of Appendix S (Technical working paper: Biodiversity development assessment report) for further discussion on aquatic offsets.

Table 19-19 Native vegetation offsets – ecosystem credits (direct impacts)

Zone	Plant community type (PCT) name	Area impacted (ha)	Ecosystem credits required
1250 Moderate/ Good	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	0.20	6
1292 Moderate/ Good	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	0.40	10
1783 Moderate/ Good	Red Bloodwood - Scribbly Gum / Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	4.23	100
1786 Moderate/ Good - Good	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (Duffys Forest endangered ecological community)	1.01	35
1786 Moderate/ Good - Moderate		0.37	7
1824 Moderate/ Good	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	6.18	154
1841 Moderate/ Good	Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	1.37	39
1841 Revegetation		1.29	21
1845 Moderate/ Good	Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	0.39	19
Total ecosystem credits required			391

Table 19-20 Native vegetation offsets – ecosystem credits (indirect impacts)

Zone	PCT name	Area impacted (ha)	Ecosystem credits required
Isolated patches			
1783 Moderate/ Good	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	0.05	1
1786 Moderate/ Good - Good	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (Duffys Forest endangered ecological community)	0.17	6
1824 Moderate/ Good	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	0.01	1
New edges			
1250 Moderate/ Good	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	0.22	1
1783 Moderate/ Good	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	2.59	12
1786 Moderate/ Good - Good	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (Duffys Forest endangered ecological community)	1.19	8
1824 Moderate/ Good	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	4.20	21
Total ecosystem credits required			50

Table 19-21 Threatened species offsets – species credits

Species	Vegetation zone name	Individuals/ Area (ha)	Species credits
Magenta Lilly Pilly (<i>Syzygium paniculatum</i>)	1250_Mod_Good	1 individual	2
Red-crowned Toadlet (<i>Pseudophryne australis</i>)	1250_Mod_Good 1783_Mod_Good 1824_Mod_Good	0.98 ha	24
Eastern Pygmy-possum (<i>Cercartetus nanus</i>)	1250_Mod_Good 1783_Mod_Good 1786_Mod_Good-Good 1786_Mod_Good-Moderate 1824_Mod_Good 1845_Mod_Good	12.38 ha	403
Large-eared Pied-bat (<i>Chalinolobus dwyeri</i>)	1250_Mod_Good 1292_Mod_Good 1783_Mod_Good 1786_Mod_Good-Good 1786_Mod_Good-Moderate 1824_Mod_Good 1841_Mod_Good 1845_Mod_Good	13.68 ha	670
Total species credits required			1099

The impacts of a development and gains in biodiversity values at biodiversity stewardship sites are measured in biodiversity credits.



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 20

Land use and property

20 Land use and property

This chapter considers the potential impacts of the project on land use and property from the construction and operation of the project and identifies measures which address these impacts.

The Secretary's environmental assessment requirements as they relate to land use and property, and where in the environmental impact statement these have been addressed, are in Table 20-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to land use and property are included in Section 20.5.

Table 20-1 Secretary's environmental assessment requirements – land use and property

Secretary's requirement	Where addressed in EIS
Environmental impact statement	
<p>1. The EIS must include, but not necessarily be limited to, the following:</p> <ul style="list-style-type: none"> b. a description of the project and all components and activities (including ancillary components and activities) required to construct and operate it, including: <ul style="list-style-type: none"> – land use changes as a result of the proposal and the acquisition of privately owned, Council and Crown lands, and impacts to Council and Crown lands 	<p>Impacts to properties, including property acquisitions and future land uses during construction and operation is discussed in Section 20.4.</p>
Socio-economic, Land Use and Property	
<p>1. The proponent must assess social and economic impacts (of all phases of the project) in accordance with the current guidelines (including cumulative construction and operational impacts of the proposal and major projects in the vicinity of the project) and in consultation with relevant land owners (such as the Ports Authority of NSW and those land owners whose property is being acquired).</p>	<p>Socio economic impacts as a result of the project are presented in Section 21.4 and Section 21.5 of Chapter 21 (Socio-economics). Chapter 27 (Cumulative impacts) assesses the cumulative construction and operational impacts of the proposal and major projects in the vicinity of the project.</p> <p>A summary of consultation conducted for the project is provided in Chapter 7 (Stakeholder and community engagement) and Section 21.2.3 of Chapter 21 (Socio-economics).</p>
<p>2. The proponent must assess impacts from construction and operation on potentially affected properties, businesses, recreational users and land and water users, including amenity impacts (including from cumulative and extended construction time frames and construction fatigue), property acquisitions/adjustments, future land uses,</p>	<p>Impacts to properties, including property acquisitions and future land uses during construction and operation is discussed in Section 20.4.</p> <p>Section 21.4 and Section 21.5 present the socio-economic impacts as a result of the project.</p>

Secretary's requirement	Where addressed in EIS
<p>access, relevant statutory rights, and community severance and barrier impacts resulting from the project.</p>	<p>Chapter 27 (Cumulative impacts) assesses the cumulative construction and operational impacts of the proposal and major projects in the vicinity of the project.</p>
<p>3. Where an immersed tube method (IMT) of construction is proposed for use in Middle Harbour, the Proponent must:</p> <p>a. provide details of how reductions to current harbour depths will be avoided</p>	<p>Section 5.2.3 of Chapter 5 (Project description) describes how, due to the profile of the harbour bed of Middle Harbour, the immersed tube tunnel units would sit both partially within a trench and on the bed of the Middle Harbour.</p> <p>Section 9.4.4 or Chapter 9 (Operational traffic and transport) indicates that shallow water depths at the entrance to Middle Harbour control navigation in the vicinity of the proposed tunnel crossing. The tops of the immersed tube tunnels would not interfere or restrict with maritime activities.</p>
<p>b. provide details confirming the level of protection for the IMTs will be similar to or better than that of the existing Sydney Harbour Tunnel</p>	<p>As discussed in Chapter 6 (Construction work) an additional concrete layer would be provided to protect the top of the completed tunnel units from marine activities during operation, including falling or dragging anchors. Section 23.3.4 of Chapter 23 (Hazards and risks) details the risks associated with interactions between maritime traffic and the immersed tube tunnels.</p> <p>Chapter 4 (Project development and alternatives) provides a justification for selection of the immersed tube tunnel method for the crossing of Middle Harbour.</p>
<p>c. identify impacts to ship scheduling in consultation with the Harbour Master; and</p>	<p>Due to depths constraints at the entrance to Middle Harbour, shipping does not occur in locations where construction works are proposed.</p> <p>Chapter 8 (Construction traffic and transport) and Chapter 9 (Operational traffic and transport) outline marine traffic impacts related to the construction and operation of the immersed tube tunnel respectively.</p> <p>Chapter 8 (Construction traffic and transport) specifies the consultation requirements with the Harbour Master to minimise impacts during construction.</p> <p>Impacts of closures in Middle Harbour on businesses are discussed in Section 21.4 and Section 21.5.6 of Chapter 21 (Socio-economics) and Appendix U (Technical working paper: Socio-economic assessment), including Annexure B.</p>

Secretary's requirement	Where addressed in EIS
d. provide details of full mission simulation which takes in account, movement of tunnel units past the Spit Bridge and within Middle Harbour.	Outcomes of the simulation report are outlined in Section 8.4.3 of Chapter 8 (Construction traffic and transport).
4. The Proponent must assess potential impacts on utilities (including communications, electricity, gas, fuel and water and sewerage) and the relocation of these utilities.	Chapter 5 (Project description) outlines utilities and services management for the project and Appendix D (Utilities management strategy) provides a detailed description of utilities likely to be impacted and a framework for utility installations, relocations, adjustments and protection.
5. Where the project is predicted to impact on utilities the Proponent must undertake a utilities management strategy, identifying management options, including relocation or adjustment of the utilities.	Appendix D (Utilities management strategy) provides a detailed description of utilities likely to be impacted and a framework for utility installations, relocations, adjustments and protection.
6. A draft Community Consultation Framework must be prepared identifying relevant stakeholders, procedures for distributing information and receiving/responding to feedback and procedures for resolving stakeholder and community complaints during construction and operation. Key issues that must be addressed in the draft Framework include, but are not limited to: <ul style="list-style-type: none"> a. traffic management (including property access, pedestrian access) b. landscaping/urban design matters c. construction activities including out of hours work; and d. noise and vibration mitigation and management. 	Chapter 7 (Stakeholder and community engagement) provides the content for the framework and a Community consultation framework is provided in Appendix E (Community consultation framework).

20.1 Legislative and policy framework

The assessment of land use and property impacts has been carried out taking into account the following legislation, policies, guidelines and strategic planning documents:

- The *Native Title Act 1993* (Cwlth) and *Aboriginal Land Rights Act 1983* provide a framework for the protection of native title rights on certain Crown lands. There are no Crown lands subject to a native title claim within the project footprint
- *Greater Sydney Region Plan: A Metropolis of Three Cities – Connecting People* (Greater Sydney Commission, 2018a)
- *Our Greater Sydney 2056: North District Plan – Connecting Communities* (Greater Sydney Commission, 2018b)
- *Our Greater Sydney 2056: Eastern City District Plan – Connecting Communities* (Greater Sydney Commission, 2018c)
- *Guidelines for developments adjoining land and water managed by the Office of Environment and Heritage* (Office of Environment and Heritage (OEH), 2013).

The above policies and strategic planning documents are further described in Chapter 3 (Strategic justification and project need). The *Guidelines for developments adjoining land and water managed by the Office of Environment and Heritage* are discussed in Section 20.4.2.

The following local strategic planning statements and plans are also relevant to current and future land use in the project footprint:

- *North Sydney Local Strategic Planning Statement* (North Sydney Council, 2020a)
- *Draft Local Strategic Planning Statement* (Willoughby City Council, 2019)
- *Mosman Local Strategic Planning Statement: Enhancing Mosman* (Mosman Council, 2020)
- *Towards 2040 – Local Strategic Planning Statement* (Northern Beaches Council, 2020)
- *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a)
- *Northern Beaches Hospital Precinct Structure Plan* (Northern Beaches Council, 2017b).

Local strategic planning statements have been developed by councils in response to new legislative requirements introduced by the NSW Government in 2018, for all councils to respond to the priorities and actions identified in the NSW Government's regional and district plans. The statements outline the 20 year vision for land-use in the local area, the special character and values that are to be preserved and how change will be managed into the future for each council.

North Sydney Local Strategic Planning Statement provides a 20 year vision for land use planning within the North Sydney local government area. North Sydney Council aims to ensure that the North Sydney local government area continues to be an attractive place for residents, businesses, workers and visitors, and North Sydney residents to continue to enjoy high levels of amenity and liveability with good access to transport, job opportunities and areas of unique scenic and recreational quality. North Sydney Council is carrying out a planning study for the Military Road Corridor in response to the significant level of development interest within the precinct in recent years which seek to challenge existing planning controls.

Willoughby City Council's *Local Strategic Planning Statement* identifies 20 planning priorities and sets out a 20 year vision for land use planning in Willoughby local government area, considering both economic and social needs of the community.

The *Mosman Local Strategic Planning Statement: Enhancing Mosman* sets out a 20 year vision for land use planning in Mosman outlining how growth and change will be managed to maintain the high levels of environmental amenity, liveability and landscape quality that characterises Mosman. Fourteen planning priorities are identified, including a priority to improve access to, from and within Mosman, and to encourage active transport. The congestion of Spit-Military Roads is identified as a significant issue.

Towards 2040 – Local Strategic Planning Statement sets out a 20 year vision for land use planning in the Northern Beaches, with thirty planning priorities are identified. The connectivity of the Northern Beaches local government area is constrained by limited access into and out of the Northern Beaches, particularly by public transport, which is limited in most areas. Northern Beaches Council identifies coordination of land use with transport as essential to achieving the aims of the strategy.

The *Northern Beaches Sportsground Strategy* is a 15 year plan to provide a single approach to the management and long term planning of sporting facilities on the Northern Beaches. The Strategy has been informed by the *Northern Beaches Sportsgrounds and Golf Courses Discussion Paper* (Northern Beaches Council, 2017c) which was prepared in response to independent analyses commissioned by Council to review sportsgrounds supply and demand, and assess the feasibility of golf courses on the Northern Beaches. The strategy is further discussed in Section 20.4.2.

The *Northern Beaches Hospital Precinct Structure Plan* has been prepared by Northern Beaches Council in response to the NSW Government's significant investment in public infrastructure in Frenchs Forest including the new Northern Beaches Hospital. The area around the new Northern Beaches Hospital in Frenchs Forest has been identified by the NSW Government as a Planned

Precinct with a focus on providing priority infrastructure including schools, parks, transport, hospitals and road upgrades. The plan presents the strategic land use planning framework for the Frenchs Forest precinct and is further discussed in Section 20.4.2.

20.2 Assessment methodology

The assessment methodology for impacts on land use and property included the following key tasks:

- Reviewing key strategic planning policies and documents relevant to the project footprint and nearby areas to identify future land uses, planning controls and developments
- Reviewing the local environment and identifying existing land uses and properties within and around the project footprint
- Assessing the potential impacts on properties including those that would need to be acquired to construct and operate the project
- Assessing the potential impacts on existing and likely future land uses during construction and operation of the project
- Identifying measures to avoid, minimise and manage impacts on land use and property
- Identifying potential future uses of land required for construction but not required for operation.

20.3 Existing environment

20.3.1 Overview

The project would traverse the Lower North Shore and Northern Beaches region of metropolitan Sydney within the North Sydney, Willoughby, Mosman and Northern Beaches local government areas. A diverse range of development types and land use zones are currently located within and around the project footprint including residential, commercial, mixed uses, industrial and maritime, infrastructure and recreational open space.

The land use zones within the project footprint are defined under the following environmental planning instruments and are shown in Figure 20-1 to Figure 20-5:

- North Sydney Local Environmental Plan 2013 (North Sydney LEP 2013)
- Willoughby Local Environmental Plan 2012 (Willoughby LEP 2012)
- Mosman Local Environmental Plan 2012 (Mosman LEP 2012)
- Warringah Local Environmental Plan (Warringah LEP 2011) (now part of the Northern Beaches local government area)
- Manly Local Environmental Plan 2013 (Manly LEP 2013) (now part of the Northern Beaches local government area)
- Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005 (Sydney Harbour SREP).

Low and medium density residential land use zones are prominent in the suburbs of Cammeray, Naremburn, Northbridge, Seaforth and Balgowlah. Medium and high density residential land uses are generally located in the suburbs of Naremburn, Artarmon and Willoughby.

Industrial land use is concentrated around the Gore Hill Freeway in Artarmon. Local centres occupy parts of Northbridge and Balgowlah.

Environmental conservation and environmental management land use zones exist along the foreshore areas of Middle Harbour in Northbridge, Seaforth and Mosman, including the shoreline of Beauty Point and Pearl Bay, Seaforth Bluff and Clive Park.

There are a number of private and public recreation areas within and near the construction footprint. The largest of these are located in Artarmon (Artarmon Park), Cammeray (Cammeray Park and Cammeray Golf Course), Willoughby (Bicentennial Reserve), Northbridge (Flat Rock Reserve), Mosman (Spit West Reserve) and Balgowlah (Balgowlah Golf Course). Parts of Middle Harbour within and around the construction footprint are also used for recreation activities, and there are existing moorings within Middle Harbour and Pearl Bay, directly west of the Spit West Reserve foreshore.

Social infrastructure in the vicinity of the project is discussed in more detail in Chapter 21 (Socio-economics).

20.3.2 Cammeray to Northbridge

Existing land use

Existing land use in the area from Cammeray to Northbridge is characterised by areas of high and medium density residential development in Cammeray and Crows Nest, while Northbridge comprises mostly of general and low density residential development. ANZAC Park Public School and KU Cammeray Preschool are located to the east and west of the project respectively (refer to Figure 20-1).

Major road infrastructure located in this area includes the Warringah Freeway.

Local and neighbourhood centres are concentrated along Miller Street in Cammeray and Sailors Bay Road in Northbridge (refer to Figure 20-1).

Public recreation areas within the construction footprint between Cammeray and Northbridge include:

- Cammeray Golf Course at Cammeray
- Flat Rock Reserve at Northbridge.

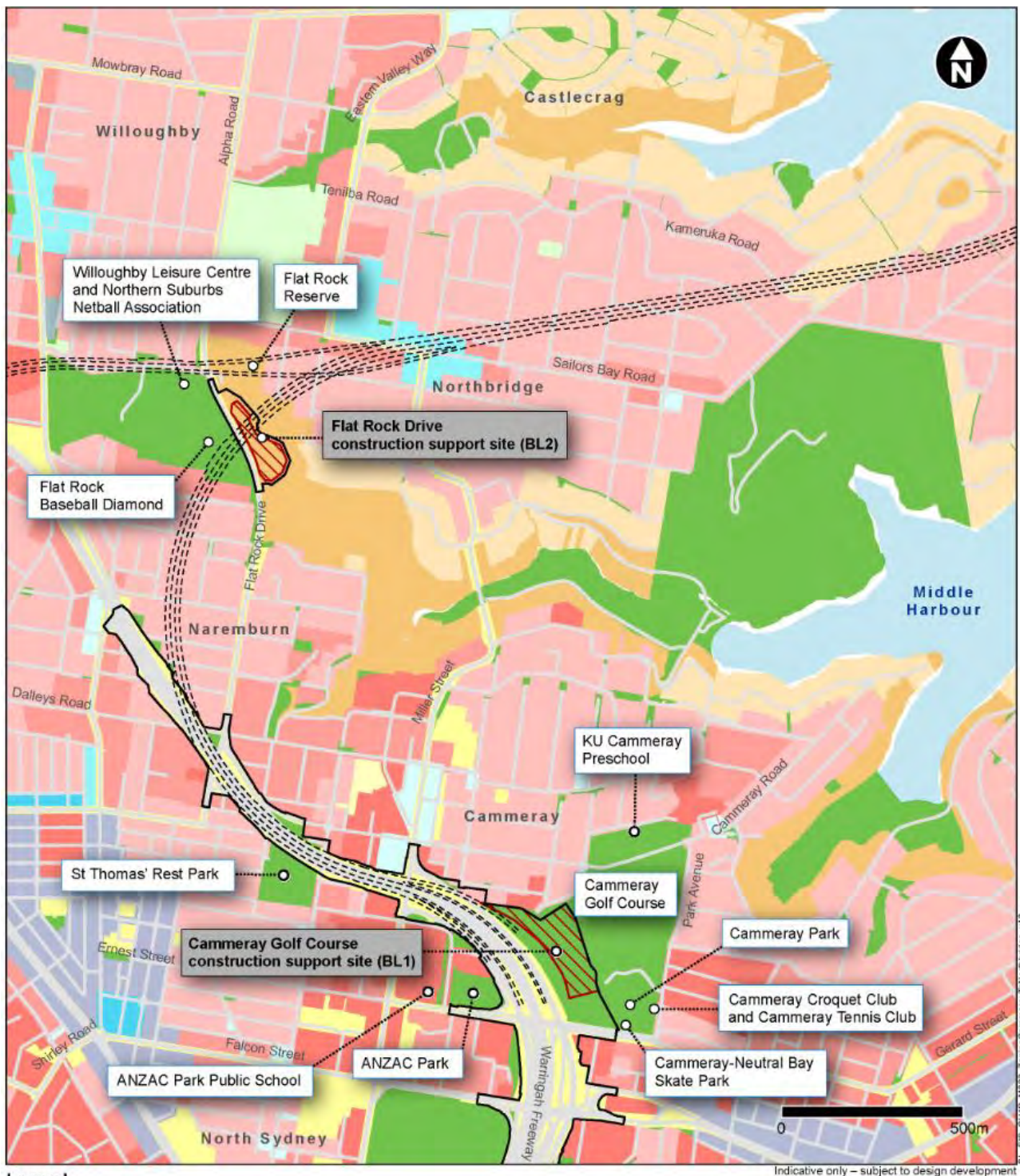
Recreation areas located near the construction footprint between Cammeray and Northbridge include:

- ANZAC Park, Cammeray Park, Cammeray Croquet Club, Cammeray Tennis Club, Cammeray-Neutral Bay Skate Park, St Thomas' Rest Park at Cammeray and Crows Nest
- Flat Rock Baseball Diamond (also referred to as Bicentennial Reserve Baseball Diamond), Willoughby Leisure Centre and Northern Suburbs Netball Association at Willoughby.

Refer to Figure 20-1 for the location of the above recreation areas relative to the construction footprint.

Land use zoning

Land use zones in the area from Cammeray and Northbridge are defined under the North Sydney LEP 2013 and Willoughby LEP 2012, are shown in Figure 20-1.



Indicative only – subject to design development

Legend

Operational features

----- Beaches Link (tunnel section)

Construction features

Construction footprint
 Construction support site

Land use zoning

B1 Neighbourhood Centre
 B2 Local Centre
 B3 Commercial Core
 B4 Mixed Use
 B5 Business Development
 E2 Environmental Conservation
 E4 Environmental Living

R2 Low Density Residential
 R3 Medium Density Residential
 R4 High Density Residential
 RE1 Public Recreation
 RE2 Private Recreation
 SP1 Special Activities
 SP2 Infrastructure

Figure 20-1 Land use and zoning – Cammeray to Northbridge

20.3.3 Gore Hill Freeway and surrounds

Existing land use

There is a clear distinction in land uses on either side of the Gore Hill Freeway. The south side of the freeway (within the Artarmon industrial area) is characterised by general and light industrial development, while medium and high density residential development dominates the north side of the freeway. Community land uses are located on both sides of the Gore Hill Freeway including several child care centres, Artarmon Public School, Artarmon NSW Ambulance Superstation and the Royal North Shore Hospital.

Public recreation areas located within the construction footprint around the Gore Hill Freeway Connection in Artarmon include Artarmon Park (refer to Figure 20-2). Artarmon Reserve, Thomson Park, Cleland Park and Naremburn Park are located in the vicinity of the construction footprint at Artarmon.

Significant road and rail infrastructure located in this area includes the Gore Hill Freeway, Lane Cove Tunnel and the T1 North Shore and Western and T9 Northern rail lines between St Leonards and Artarmon train stations and the Sydney Metro City & Southwest which is currently under construction (refer to Figure 20-2).

Land use zoning

Land use zones in the area around the Gore Hill Freeway are defined under the Willoughby LEP 2012, and are shown in Figure 20-2).

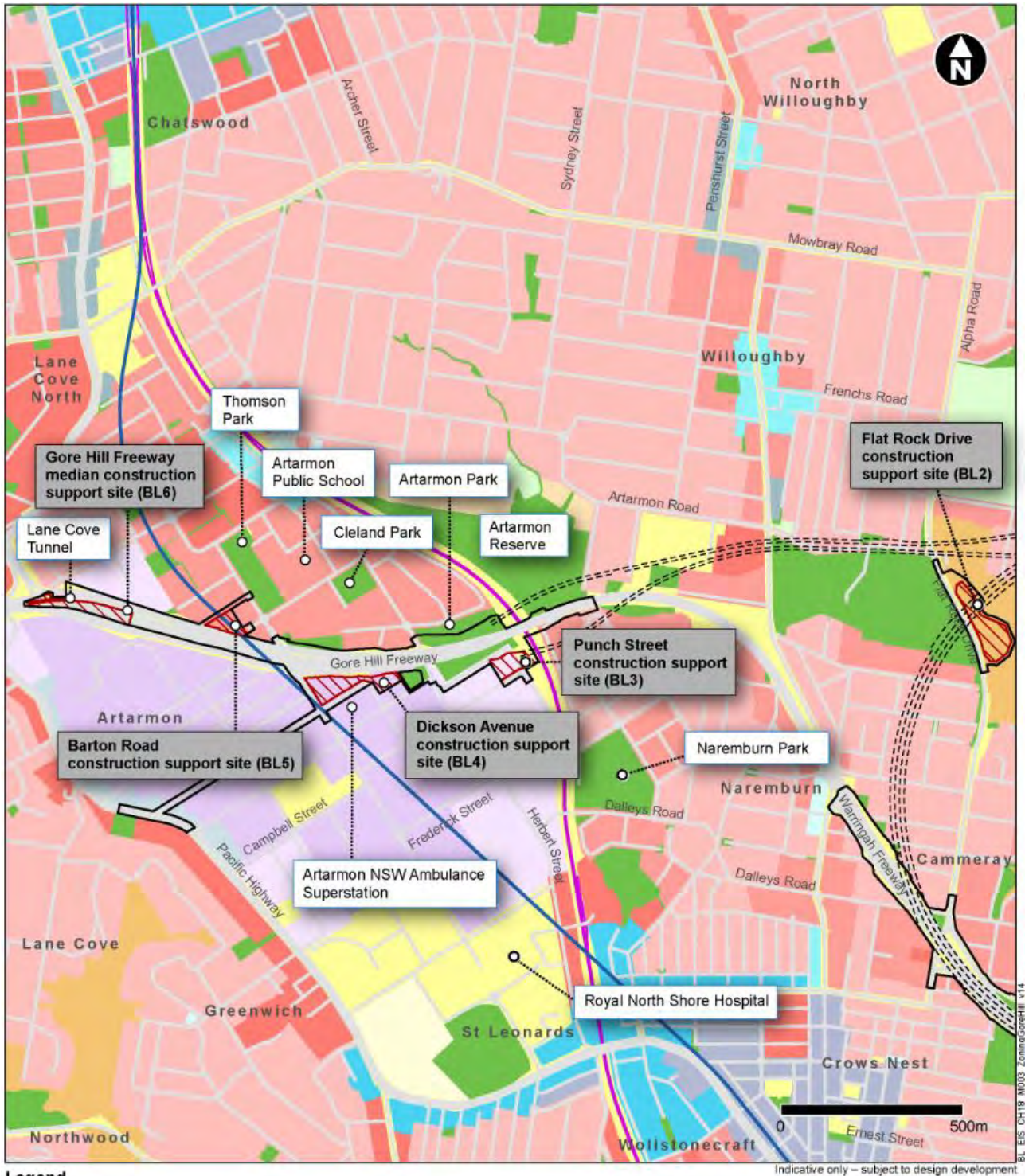


Figure 20-2 Land use and zoning – Gore Hill Freeway and surrounds

20.3.4 Northbridge to Seaforth

Existing land use

The area between Northbridge and Seaforth includes Middle Harbour and its foreshores. This area also encompasses the Spit West Reserve in Mosman (refer to Figure 20-3).

Land use zones along the foreshore of Middle Harbour in Northbridge mostly comprise environmental conservation and public recreation, including Clive Park. The foreshore of Middle Harbour in Seaforth mostly comprises low density residential development, including several properties that have jetties in Middle Harbour. Middle Harbour is used for recreation activities and by groups such as the Northbridge Sailing Club, Mosman Rowing Club and Middle Harbour Yacht Club.

Land at the Spit West Reserve in Mosman is used for public recreation and open space (refer to Figure 20-3). The D'Albora Marina and Mosman Rowing Club are both located at the Spit West Reserve. A number of commercial and private recreation land use zones are located on the eastern side of The Spit adjacent to Spit West Reserve, including restaurants, cafes, and yacht and sailing clubs. There are also several restaurants directly south of the Spit Bridge near to D'Albora Marina.

The major item of road infrastructure in this area is Spit Road, including the Spit Bridge. The Spit Bridge has scheduled daily openings to allow boats above the clearance height to pass through (refer Chapter 8 (Construction traffic and transport) for further details).

There are numerous Transport for NSW moorings licensed to private boat owners in Middle Harbour and Pearl Bay, directly west of the Spit West Reserve foreshore. The Spit West Reserve car park located off Spit Road and south of the Spit Bridge currently provides car parking spaces for the various marine and recreational uses that exist within and around the Spit West Reserve. There is also an existing off-road shared path that extends along the foreshore of Middle Harbour adjacent to the Spit West Reserve.

Land use zoning

Land use zones in the area between Northbridge and Seaforth are defined under the Willoughby LEP 2012, Manly LEP 2013 and Mosman LEP 2012 and are shown in Figure 20-3.



Legend

Indicative only – subject to design development

Operational features

----- Beaches Link (tunnel section)

Construction features

- Construction footprint
- Construction support site

Land use zoning

- B1 Neighbourhood Centre
- E2 Environmental Conservation
- E3 Environmental Management
- E4 Environmental Living

- R2 Low Density Residential
- R3 Medium Density Residential
- RE1 Public Recreation
- RE2 Private Recreation
- SP2 Infrastructure
- W1 Natural Waterways

Figure 20-3 Land use and zoning – Northbridge to Seaforth

20.3.5 Seaforth to Balgowlah

Existing land use

Land use in the area from Seaforth to Balgowlah is predominantly low density residential development. This area includes educational facilities, such as Northern Beaches Secondary – College Balgowlah Boys Campus, St Cecilia’s Catholic Primary School and Seaforth Public School (refer to Figure 20-4).

Major road infrastructure located in this area includes Burnt Bridge Creek Deviation, Manly Road, Condamine Street and Sydney Road. Both Sydney Road and Burnt Bridge Creek Deviation border the Balgowlah Golf Course. The Burnt Bridge Creek shared path extends between Sydney Road and Condamine Street adjacent the southbound lanes of Burnt Bridge Creek Deviation and along the western boundary of the Balgowlah Golf Course.

Balgowlah Golf Course is the only public recreation area within the construction footprint between Seaforth and Balgowlah. Balgowlah Oval is directly adjacent to the construction and operational footprints of the project (refer to Figure 20-4).

Land use zoning

Land use zones in the area between Seaforth and Balgowlah are defined under the Manly LEP 2013 and Warringah LEP 2011, and are shown in Figure 20-4.



Legend

Operational features

----- Beaches Link (tunnel section)

Construction features

▭ Construction footprint

▨ Construction support site

Land use zoning

B1 Neighbourhood Centre

B2 Local Centre

E1 National Parks and Nature Reserves

E2 Environmental Conservation

E3 Environmental Management

R1 General Residential

R2 Low Density Residential

RE1 Public Recreation

RE2 Private Recreation

SP1 Special Activities

SP2 Infrastructure

Figure 20-4 Land use and zoning – Seaforth to Balgowlah

20.3.6 Seaforth to Frenchs Forest

Existing land use

Land use zones adjoining the Wakehurst Parkway in the area around Seaforth mostly comprise low density residential development on the eastern side of the Wakehurst Parkway. Further to the north, land use zones adjoining the Wakehurst Parkway comprise environmental conservation, national parks and nature reserves to the west including the Garigal National Park and Manly Warringah War Memorial Park known as Manly Dam Reserve (refer to Figure 20-5).

Major road infrastructure located in this area includes Frenchs Forest Road and the Wakehurst Parkway, of which the latter is classified as a regional road by Transport for NSW. The infrastructure land use zoning for the Wakehurst Parkway includes space on both sides of the road corridor to accommodate road widening (refer to Figure 20-5). The land between Seaforth and Frenchs Forest, which includes the suburbs of Killarney Heights and Allambie Heights, is mostly zoned and used for public recreation. These include the Wakehurst Golf Course and Manly Dam Reserve to the east of the Wakehurst Parkway, and the Garigal National Park to the west (refer to Figure 20-5). There is a Sydney Water site on the eastern side of the Wakehurst Parkway at Killarney Heights.

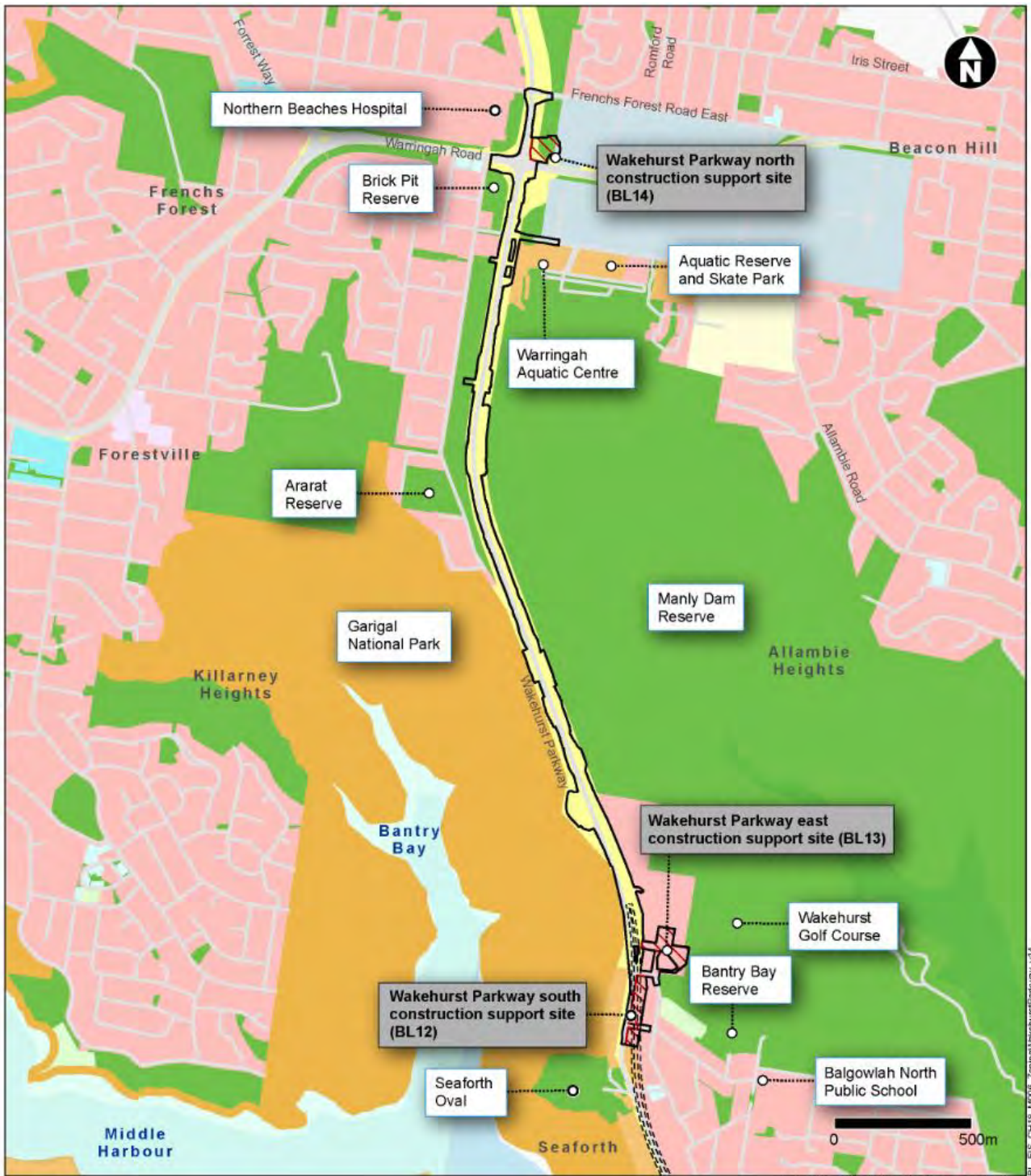
Land use adjoining the Wakehurst Parkway in the area around Frenchs Forest mostly comprises low density residential and areas for public recreation on the western side, while on the eastern side there is Frenchs Forest business hub and public recreation areas. Land use at the corner of the Wakehurst Parkway and Warringah Road has changed to incorporate the Northern Beaches Hospital (refer to Figure 20-5). The area surrounding the hospital has been identified as a Planned Precinct by the NSW Government within the *Northern Beaches Hospital Precinct Structure Plan*.

A Transport for NSW owned site compound previously used for the Northern Beaches Hospital road upgrade project is located within the road reserve at the north eastern corner of the Warringah Road and the Wakehurst Parkway intersection. The Northern Beaches Hospital road upgrade project was completed in August 2020 and revegetation works were carried out within the eastern section of the site as part of decommissioning. This included planting with species consistent with the Duffys Forest endangered ecological community. The project proposes to re-use this site as the Wakehurst Parkway north construction support site (BL14) and for tunnel support facilities during operation. The revegetated area would remain fenced off and protected from disturbance.

Public recreation areas near the construction footprint on either side of the Wakehurst Parkway include Seaforth Oval, Seaforth Bowling Club, Bantry Bay Reserve, Wakehurst Golf Course, Manly Dam Reserve, Ararat Reserve, Brick Pit Reserve, Warringah Aquatic Centre and Aquatic Reserve (including skate park).

Land use zoning

Land use zones in the area between Seaforth and Frenchs Forest are defined under the Manly LEP 2013 and Warringah LEP 2011, and are shown in Figure 20-5.





Legend

Operational features

----- Beaches Link (tunnel section)

Construction features

-  Construction footprint
-  Construction support site

Land use zoning

-  B1 Neighbourhood Centre
-  B2 Local Centre
-  B7 Business Park
-  E1 National Parks and Nature Reserves
-  E2 Environmental Conservation
-  IN2 Light Industrial

-  R2 Low Density Residential
-  RE1 Public Recreation
-  RE2 Private Recreation
-  SP1 Special Activities
-  SP2 Infrastructure
-  W1 Natural Waterways

Indicative only – subject to design development

Figure 20-5 Land use and zoning – Seaforth to Frenchs Forest

20.4 Assessment of potential impacts

The project has the potential to impact on properties and land use in the following ways:

- Occupation of surface properties, including temporary use during construction and permanent acquisition for operational infrastructure
- Acquisition of substratum (below ground) land for the project tunnels
- Return of residual land (full or partial lots) required for construction but not for operation of the project
- Disruption of existing activities and limitations on the development potential of directly affected properties
- Changes in public open space availability
- Ground movement impacts to properties during construction and operation of the project.

Further assessment of impacts to boat moorings and jetties are discussed in Chapter 8 (Construction traffic and transport) and Chapter 21 (Socio-economics).

20.4.1 Property

Acquisition and temporary use of surface properties

The project has been designed and developed to minimise property acquisitions and has prioritised the use of Transport for NSW land where possible. Notwithstanding this, some temporary use and permanent acquisition of properties would be required. All property acquisitions required for the project would be carried out in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991*, and in accordance with the land acquisition reforms announced by the NSW Government in 2016. Temporary use of properties would be managed through leasing or licensing arrangements or property acquisition where lease arrangements are not practical (refer to Table 20-3 for details). Where required, discussions would be held with affected landowners concerning the purchase, lease or license of land. Landowners and tenants of landowners affected by acquisition would be supported by access to counselling services throughout the process and a community relations support toll-free telephone line would be established to respond to any community concerns.

It is anticipated that the project would require full and partial acquisitions of 54 properties (excluding land owned by Transport for NSW). The anticipated properties required are summarised in Table 20-2. As of 15 September 2020, eight of these (private residential properties Balgowlah and Seaforth) had been acquired. The remaining 46 properties include:

- Twenty eight private residential properties
- Twelve private commercial properties
- Six government-owned properties.

Properties anticipated to be acquired by the project are shown in Figure 20-6 to Figure 20-10. Impacts of property acquisition are further discussed in Chapter 21 (Socio-economics).

Transport for NSW currently owns a number of properties at Seaforth between the Wakehurst Parkway, Kirkwood Street and Judith Street that were acquired in the 1970s and 1980s for the Warringah Transport Corridor that was proposed at the time. The properties are vacant lots. These properties would be utilised to facilitate this project, but as they are historical acquisitions and were not acquired specifically to facilitate this project, they are not included in Table 20-2. The acquisition of land for construction activities may result in residual land that would not be required for operational infrastructure or activities. The future use of this land is discussed below.

Part of Cammeray Golf Course would be occupied by temporary construction support sites and permanent operational infrastructure for the Western Harbour Tunnel and Beaches Link program of

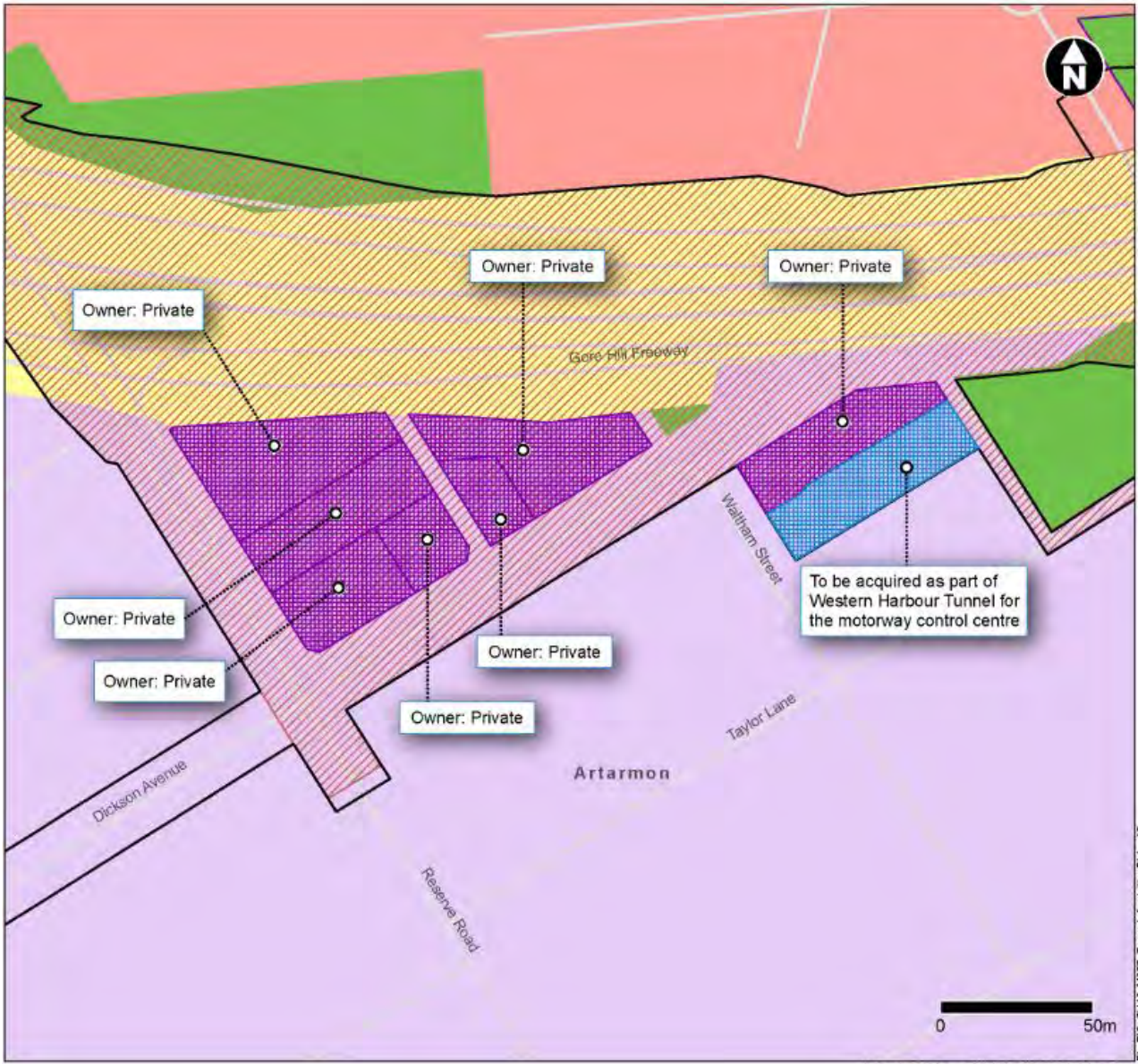
works. Due to proposed construction staging, the temporary and permanent land take at the golf course required for the Beaches Link component would occur as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Consequently, this property is not included in Table 20-2.

Table 20-2 Anticipated property acquisition required for the project

Location	Ownership	No. of property acquisitions ¹		Properties acquired for Beaches Link (as of 15 September 2020)
		Full property acquisition	Partial property acquisition	
Beaches Link component				
Artarmon	Private – commercial	8	-	-
	Government	-	1	-
Balgowlah	Private – residential	28	-	7
	Government	-	2	-
Seaforth and Killarney Heights	Private - residential	-	-	1
	Government	1	-	-
Frenchs Forest	Government	-	1	-
Total for Beaches Link component		37	4	8
Gore Hill Freeway Connection component				
Artarmon	Private – commercial	4	-	-
	Government	-	1	-
Total for Gore Hill Freeway Connection component		4	1	-
Total		41	5	8

Notes:

1. Multiple parent lots and strata titles may exist within each property.



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Indicative only – subject to design development

Legend








Operational features		Construction features		Land use zoning	
	Operational footprint		Construction footprint		IN1 General Industrial
			Property to be acquired for the Western Harbour Tunnel & Warringah Freeway Upgrade project		R3 Medium Density Residential
					RE1 Public Recreation
					SP2 Infrastructure

Figure 20-6 Property acquisitions for the project at Artarmon (around Dickson Avenue)

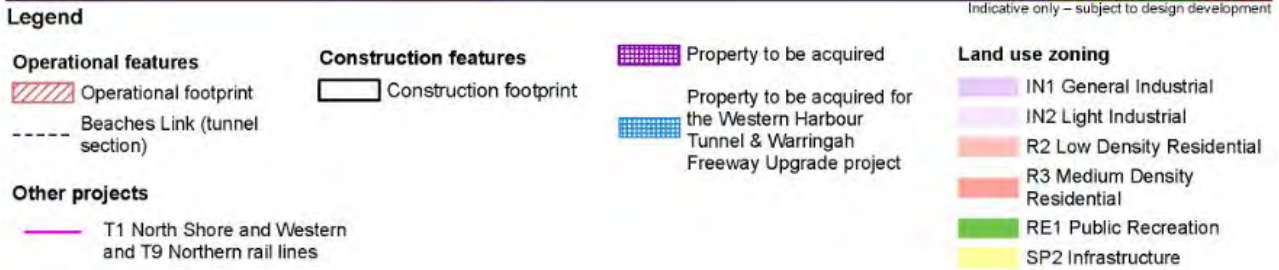
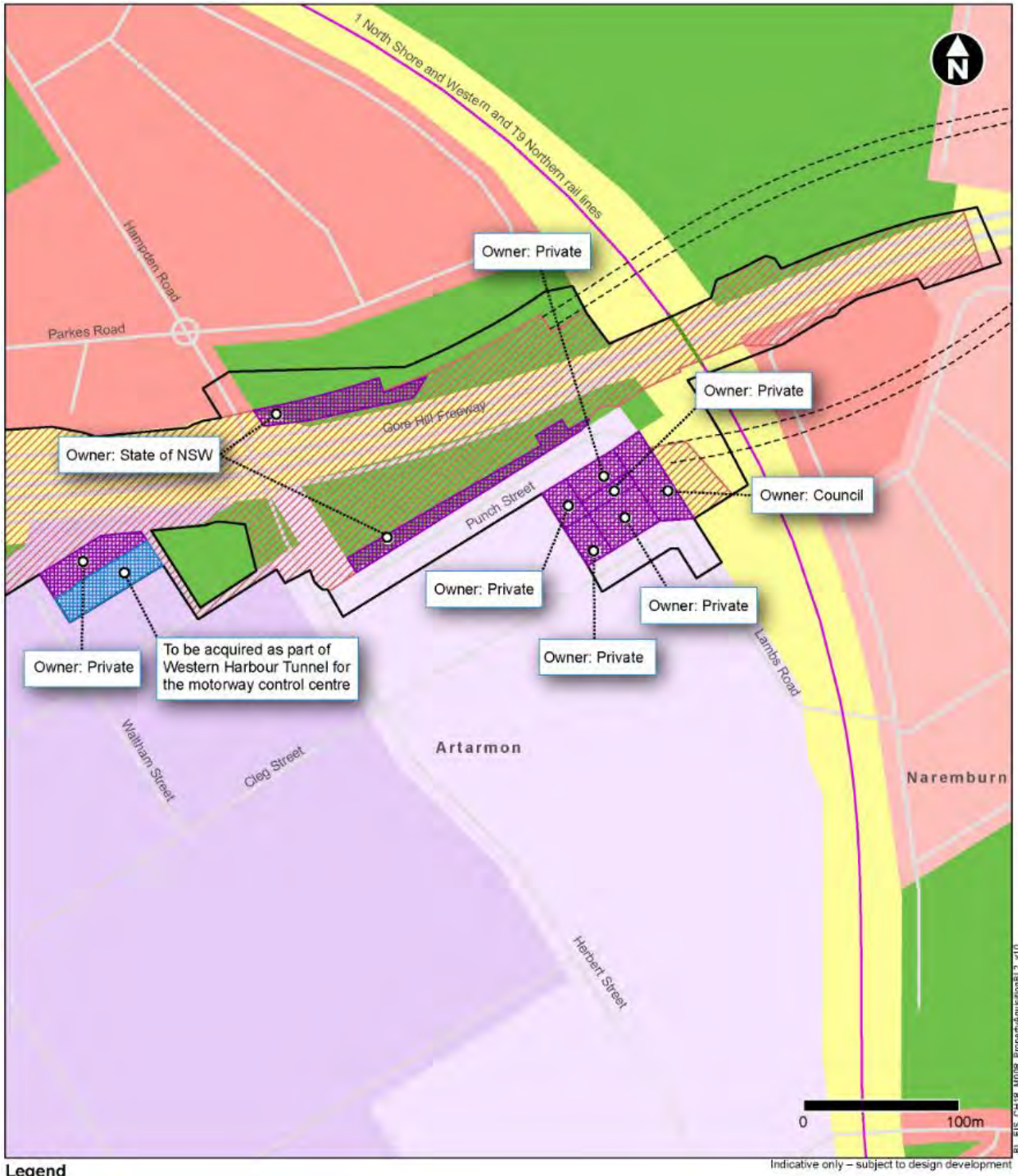


Figure 20-7 Property acquisitions for the project at Artarmon (around Punch Street)



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Legend

- Operational features**
- Operational footprint
 - Beaches Link (tunnel section)

- Construction features**
- Construction footprint

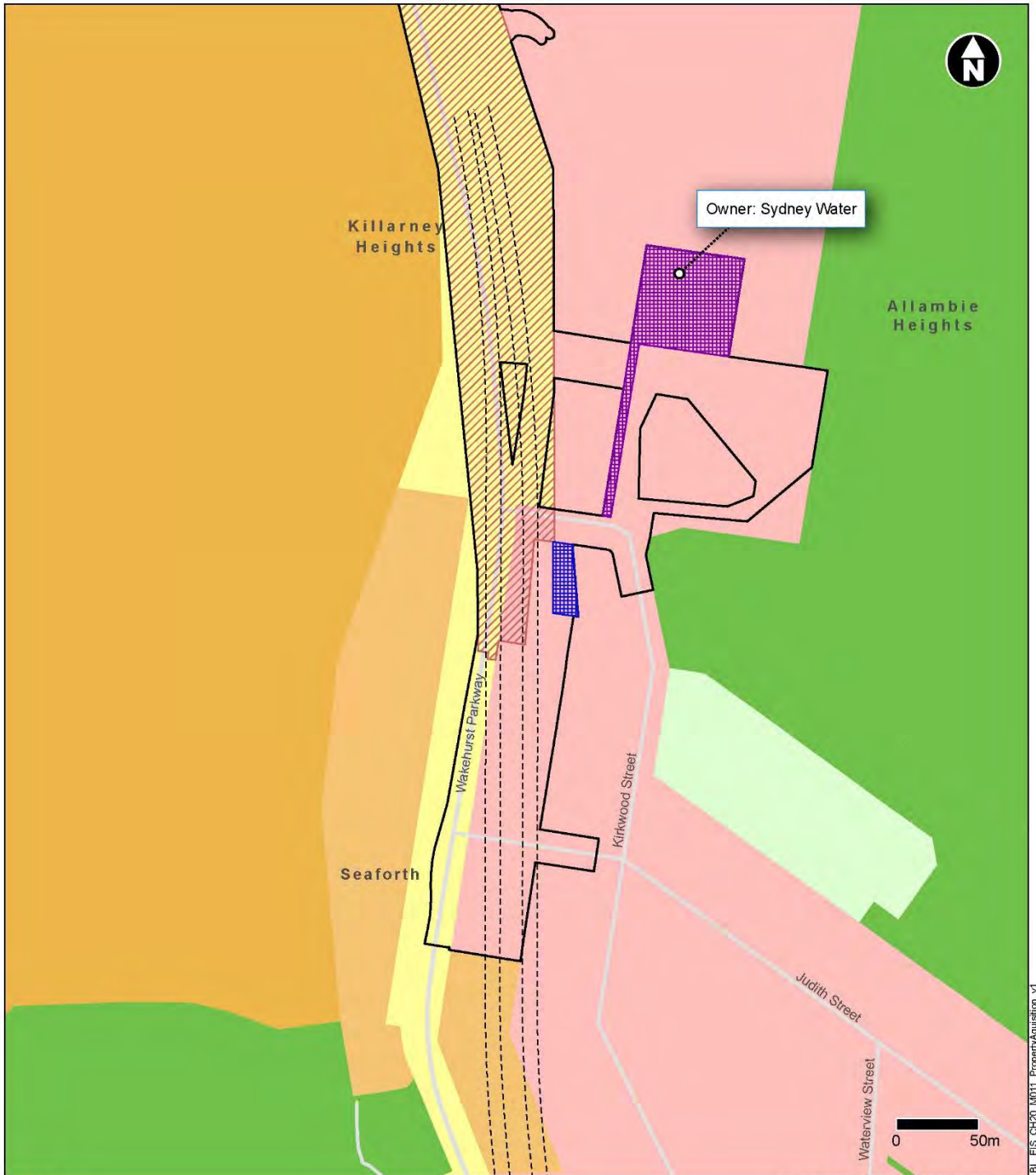
- Property to be acquired
- Acquired property

- Land use zoning**
- B1 Neighbourhood Centre
 - B2 Local Centre
 - R1 General Residential

- R2 Low Density Residential
- RE1 Public Recreation
- RE2 Private Recreation
- SP2 Infrastructure

Indicative only – subject to design development

Figure 20-8 Property acquisitions for the project at Balgowlah



BL_EIS_CH20_M011_PropertyAcquisition_V1

Indicative only – subject to design development

Legend

- | | | | |
|---|---|--|---|
| <p>Operational features</p> <ul style="list-style-type: none"> Operational footprint Beaches Link (tunnel section) | <p>Construction features</p> <ul style="list-style-type: none"> Construction footprint | <ul style="list-style-type: none"> Property to be acquired Acquired property | <p>Land use zoning</p> <ul style="list-style-type: none"> E1 National Parks and Nature Reserves E2 Environmental Conservation R2 Low Density Residential RE1 Public Recreation RE2 Private Recreation SP2 Infrastructure |
|---|---|--|---|

Figure 20-9 Property acquisitions for the project at Seaforth and Killarney Heights



BL_EIS_CH18_M010_PropertyAcquisitionBL4_Y11

Legend

Operational features
 Operational footprint

Construction features
 Construction footprint

Property to be acquired

Land use zoning
 B7 Business Park
 E2 Environmental Conservation
 R2 Low Density Residential
 RE1 Public Recreation
 SP2 Infrastructure

Figure 20-10 Property acquisitions for the Beaches Link component at Frenchs Forest

Temporary leases

Lease agreements identified in Table 20-2 would mainly be required for temporary construction support sites. Leased land would be rehabilitated in consultation with the relevant landowners, which are councils and government agencies, and returned as soon as practicable at the completion of construction. It is expected that following construction, sites would generally continue to be used consistent with their existing use. Table 20-3 provides a summary of the property leases associated with temporary construction support sites.

Table 20-3 Summary of anticipated property leases required for the project

Location	Construction support site	Pre-construction land use	Current land use zoning	Council/ government agency
Beaches Link component				
Northbridge	Flat Rock Drive construction support site (BL2)	Flat Rock Reserve	E2 Environmental Conservation SP2 Infrastructure	Willoughby City Council
Mosman	Spit West Reserve construction support site (BL9)	Spit West Reserve	RE1 Public Recreation ¹	Mosman Council
Balgowlah	Balgowlah Golf Course construction support site (BL10)	Balgowlah Golf Course	RE1 Public Recreation RE2 Private Recreation	Northern Beaches Council
Killarney Heights	Wakehurst Parkway east construction support site (BL13)	Manly Dam Reserve	R2 Low density residential	Northern Beaches Council
	Wakehurst Parkway east construction support site (BL13)	Sydney Water site	R2 Low density residential	Sydney Water
Gore Hill Freeway Connection component				
Artarmon	Barton Road construction support site (BL5)	Vacant land	R3 Medium Density Residential	Willoughby City Council
	Temporary works site for construction of on ramp	Artarmon Park	RE1 Public Recreation	Willoughby City Council

Notes:

1. Land use zoning relevant to the project. Other land use zonings apply to this lot but would not be impacted by the project.

Residual land

Residual land comprises lots that are created either when a property is only partially acquired to construct or operate the project or when land acquired to facilitate construction of the project is not required for the operational footprint.

Local environmental plans place minimum lot size requirements and other restrictions on parcels of land to be used for specified types of development. As such, the creation of a residual lot has the potential to affect the development potential of the land. Minimum lot sizes most often apply to land zoned for residential purposes but can also apply to other land use zonings. Residual land that would be created as a result of the project and its anticipated future treatment is summarised in Table 20-4.

Any future development of residual land beyond that included in the project description in Chapter 5 (Project description) would be subject to separate assessment and approval in accordance with the *Environmental Planning and Assessment Act 1979* and is beyond the scope of this project.

Table 20-4 Anticipated residual land created by the project

Location	Pre-construction land use	Current land use zoning	Project use and anticipated future treatment
Beaches Link component			
Cammeray	Cammeray Golf Course	RE1 Public Recreation	<p>Part of Cammeray Golf Course would be occupied by temporary construction support sites and permanent operational infrastructure for the Western Harbour Tunnel and Beaches Link program of works. The land required for the project would be acquired and/or leased as part of the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Works to restore the golf course would be completed as part of the project.</p> <p>Both the Beaches Link and Gore Hill Freeway Connection project and the Western Harbour Tunnel and Warringah Freeway Upgrade project have been designed and developed to minimise impacts to Cammeray Golf Course. The configuration of the temporary construction support sites and the permanent operational infrastructure for both projects, whether implemented at the same time or at different times, would allow the site to continue to be used as a golf course. Amendments to the configuration of the golf course would be required to achieve this outcome, which would be carried out during construction of the projects. Golfing activities would be disrupted during the reconfiguration works. Transport for NSW have engaged and consulted with the golf course operator and landowner and this would continue to during further design development and implementation of the project to ensure the operation of the golf course during construction and operation of the project is possible.</p>
Balgowlah	Private – residential	R1 General Residential	<p>Thirty four residential properties on Dudley Street at Balgowlah would be required for use during construction as part of the Balgowlah Golf Course construction support site (BL10) and the connection to and from Burnt Bridge Creek Deviation. Six of the properties have been acquired as of 15 September 2020, with the remaining 28 properties proposed to be acquired prior to construction. During construction, the land to the east and north of the proposed access road not required for construction would be repurposed as part of the new open space and recreation facilities at Balgowlah. Land required as part of Balgowlah Golf Course construction support site (BL10) but not required permanently for operational</p>

Location	Pre-construction land use	Current land use zoning	Project use and anticipated future treatment
			<p>infrastructure would be repurposed as soon as practicable at the completion of construction. This land would form part of new and improved open space and recreation facilities at Balgowlah described further in Section 20.4.2.</p> <p>Refer to Figure 20-11 for further detail on anticipated treatment of the residual land as part of the new and improved open space and recreation facilities.</p>
Killarney Heights	Sydney Water site	R2 Low density residential	<p>This site is currently a non-operational part of the Sydney Water Bantry Bay Reservoir site. Transport for NSW would acquire this parcel of land from Sydney Water for use as part of the Wakehurst Parkway east construction support site (BL13).</p> <p>The site would be rehabilitated and revegetated as soon as practicable after construction completion and would be handed over to Northern Beaches Council to manage for use by the community as part of the Manly Dam Reserve. This would add about 4000 square metres of new public space to the Manly Dam Reserve.</p>

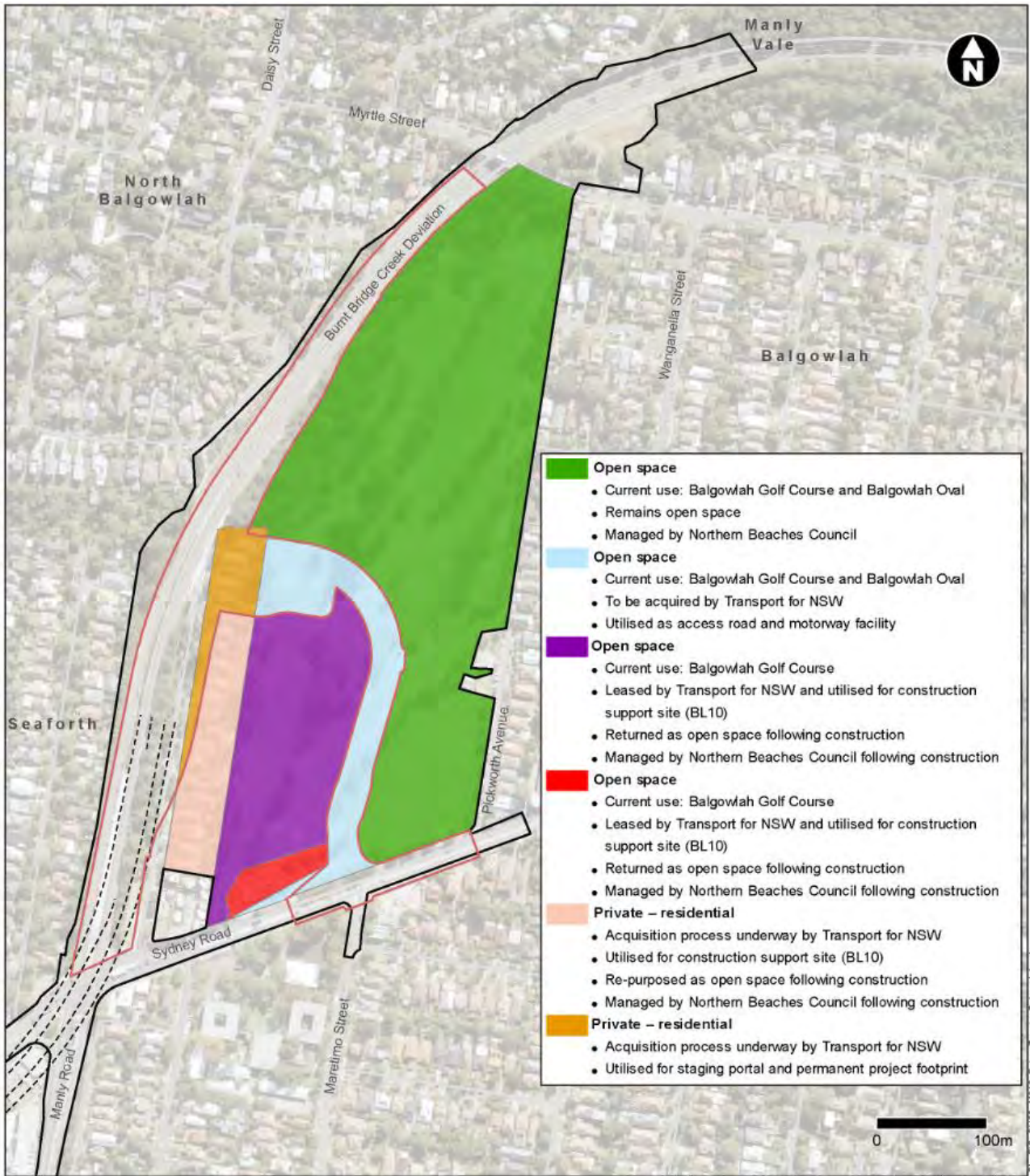
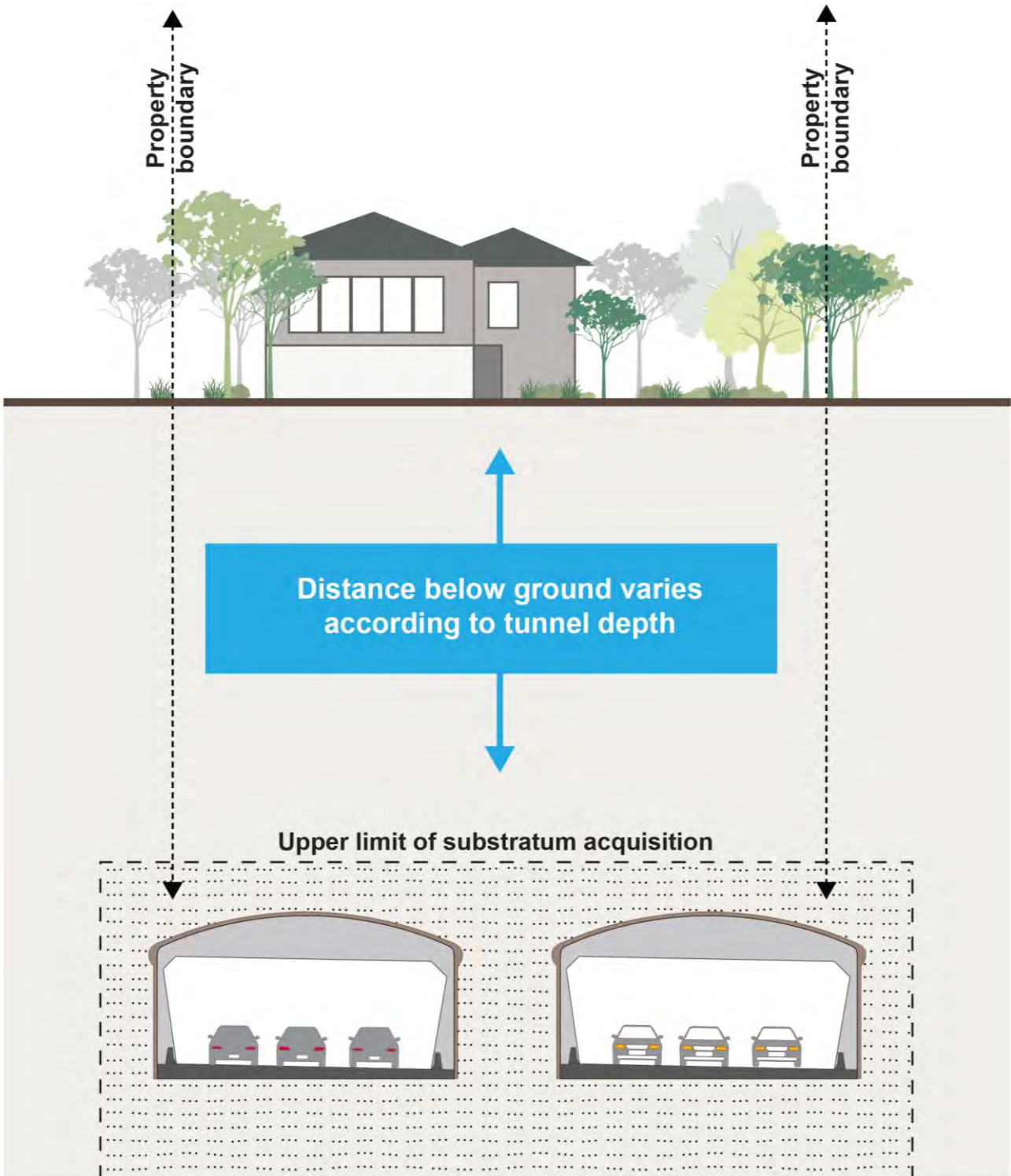


Figure 20-11 Property acquisition, temporary leases and use of residual land associated with the open space and recreation facilities at Balgowlah

Acquisition of substratum

The construction and operation of the project would require the acquisition of land below the surface of the ground where the mainline and ramp tunnels would be located. This is called substratum acquisition and is illustrated in Figure 20-12.



Legend


 Substratum acquisition envelope

Figure 20-12 Example of substratum acquisition

Substratum acquisition would consist of a stratum acquisition envelope around the tunnels, including any associated ground support that may be required. In some circumstances, the introduction of the tunnels has the potential to limit development above the tunnels. For example, depending on the depth of the tunnels, the ability to construct basement levels in buildings above the tunnels may be restricted. However, this is generally only the case where the tunnel depth is shallow, near tunnel portals. Tunnel portal locations are described in Chapter 5 (Project description). Otherwise, substratum acquisition does not generally affect the future use of property at the surface. Subject to council regulations and approvals, landowners would generally be able to:

- Carry out improvements, such as installing a swimming pool
- Dig deeper foundations for a new building or second storey additions.

Where substratum acquisition is required, Transport for NSW would contact owners of affected properties. Transport for NSW has the authority to acquire the subsurface land, under the *Roads Act 1993*. The *Land Acquisition (Just Terms Compensation) Act 1991* provides that compensation is not payable for substratum acquisition of land or easements unless specific circumstances as detailed in that Act apply. Appendix C of the *Roads and Maritime Services land acquisition information guide* (Roads and Maritime Services, 2014b) sets out in detail the compensation provisions of the *Land Acquisition (Just Terms Compensation) Act 1991* relating to substratum acquisition.

Ground movement impacts

Excavation below ground has the potential to result in ground movement at the surface (settlement). Depending on the amount and nature of the ground movement, settlement may present a risk to nearby buildings and other structures during construction and operation of the project.

An assessment of potential ground movement impacts associated with the project is provided in Chapter 16 (Geology, soils and groundwater). The assessment identified the worst case risk of settlement impacts to buildings as 'very slight', where any damage can be easily treated during normal decoration. The areas where the most settlement is predicted to occur would be in the vicinity of the tunnel alignment, primarily above Flat Rock Reserve, the Wakehurst Parkway tunnel portal, and at the Burnt Bridge Creek Deviation tunnel portal, though no buildings are present at these locations. As such, the risk of building impacts due to settlement is therefore very low during both construction and operation of the project. Environmental management measures to manage the potential impacts from ground movement are included in Chapter 16 (Geology, soils and groundwater).

20.4.2 Land Use

Potential land use impacts during construction

The occupation of land for construction works and temporary construction support sites associated with the project has the potential to impact the use and development potential of affected land. While the occupation of land for construction might occur over four to five years, these impacts would be temporary in nature, except for sites that are subsequently used for operational infrastructure (refer to Table 20-6). Table 20-5 outlines the potential land use impacts at each construction site and temporary construction support site required for the project.

The occupation and use of land during construction could also result in impacts associated with traffic and transport, noise and vibration, air quality and social and economic values. Consideration of these impacts is provided in Chapter 8 (Construction traffic and transport), Chapter 10 (Construction noise and vibration), Chapter 11 (Operational noise and vibration), Chapter 12 (Air quality) and Chapter 21 (Socio-economics). Utility relocations, adjustments and protection are discussed in Chapter 5 (Project description) and Appendix D (Utilities management strategy).

Table 20-5 Potential land use impacts during construction

Construction location	Potential impacts on land use during construction
Cammeray to Northbridge	
<p>Cammeray Golf Course construction support site (BL1)</p>	<p>The Cammeray Golf Course construction support site (BL1) would temporarily occupy a portion of the existing golf course adjacent to the Warringah Freeway, and residential properties to be acquired (as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project) along Morden Street in Cammeray. The site would be located on NSW Government owned land that is zoned for public recreational use associated with the Cammeray Golf Club.</p> <p>This site would be used for the construction and fitout of motorway facilities at the Warringah Freeway and would provide tunnel and construction support for the Beaches Link component of the project. However, the site would initially be established as a temporary construction support site for the Western Harbour Tunnel and Warringah Freeway Upgrade project.</p> <p>Transport for NSW proposes to address the potential impacts to the Cammeray Golf Course as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project in a manner that maintains the ability of the site to be used for golf-related activities during the construction and operational phases of that project. Transport for NSW is consulting with the golf club, and Department of Planning, Industry and Environment (Crown Lands) and North Sydney Council (the trustee) to achieve this. At the completion of construction, some land at the site would be used on an ongoing basis for the operation of permanent project infrastructure. This area would be smaller than the footprint during construction.</p> <p>The adjoining Cammeray Park sportsground, tennis club, croquet club and skate park would remain operational during construction and would not be directly impacted during construction.</p>
<p>Flat Rock Drive construction support site (BL2)</p>	<p>The Flat Rock Drive construction support site (BL2) would be located in Flat Rock Reserve in Northbridge. The site is on Council-owned land and is zoned for environmental conservation.</p> <p>During construction, the site would temporarily occupy a small portion (about 10 per cent) of the reserve and would preclude the use of the site for environmental conservation and public open space and recreation activities. At the end of construction, the impacted portion of the reserve would be rehabilitated in consultation with Willoughby City Council and the community, and returned to the landowner. The temporary use of this land would have a negligible impact on the continued use of the wider Flat Rock Reserve area and Flat Rock Gully area for public open space and recreational use, as access to these areas would be maintained at all times during the construction and rehabilitation works. Upon completion, the site and adjacent areas within Flat Rock Reserve could remain zoned for environmental conservation.</p>

Construction location	Potential impacts on land use during construction
Gore Hill Freeway and surrounds	
Surface road works (Gore Hill Freeway Connection)	<p>Surface road works for the Gore Hill Freeway Connection would be carried out on and adjacent to the Gore Hill Freeway at Artarmon. Construction activities carried out along the road corridor would generally be on land owned by Transport for NSW and zoned for infrastructure related uses. Land use impacts would be negligible for works carried out on land zoned SP2 Infrastructure.</p> <p>The Gore Hill Freeway Connection would also require surface works to be carried out on land zoned for public recreation, notably in the area adjacent to Punch Street and the Gore Hill Freeway in Artarmon. There is an existing shared path at this location that provides connectivity between Artarmon Reserve and the Artarmon industrial area, as well as car parking along Punch Street. Pedestrians and cyclists would be required to detour around work sites for the duration of construction. Surface works would also be carried out within Artarmon Park along the north side of the Gore Hill Freeway. Works are unlikely to impact the recreational use of Artarmon Park, as the impacted area is steeply sloped and vegetated with dense scrub. The adjoining Artarmon Reserve would not be impacted. At the completion of construction, part of the land zoned for public recreation would be converted to permanent project infrastructure.</p>
Punch Street construction support site (BL3)	<p>The Punch Street construction support site (BL3) would occupy land within the Artarmon industrial area, adjacent to the T1 North Shore and Western line and T9 Northern line rail corridors and south of the Gore Hill Freeway in Artarmon. The site would be a tunnel support and project management site and would be located on land that is zoned for both light industrial and infrastructure related uses.</p> <p>The site would temporarily change the existing land use at this location from light industrial to construction infrastructure. The temporary construction support site would require the permanent acquisition of several industrial properties located on Punch Street, Lambs Road and Cleg Street. The total number of property acquisitions at this location has been minimised where possible. While the temporary construction support site would result in the loss of some existing light industrial and commercial businesses, impacts to the continued viability of the Artarmon industrial area more broadly are anticipated to be minor. Further, the construction activities would not preclude the continued operation of light industrial and commercial uses on land that adjoins or is located in proximity to the temporary construction support site within the Artarmon industrial area.</p> <p>During construction, Lambs Road between Punch Street and Cleg Street would be closed to allow construction vehicles to access to the site. Existing access to this section of Lambs Road is via Cleg Street and Punch Street and access impacts due to this closure would be minor (refer to Chapter 8 (Construction traffic and transport)).</p> <p>At the completion of construction, remaining land at the site would be used on an ongoing basis for the operation of permanent project infrastructure.</p>

Construction location	Potential impacts on land use during construction
Dickson Avenue construction support site (BL4)	<p>The Dickson Avenue construction support site (BL4) would occupy land within the Artarmon industrial area adjacent to the Gore Hill Freeway, Dickson Avenue and Reserve Road in Artarmon. The site would mostly be located on land that is zoned for general industrial uses. The site would also occupy a small portion of land that is zoned for public recreation located at the eastern end of Dickson Avenue.</p> <p>The site would temporarily change the existing land use at this location from general industrial and public recreation to construction infrastructure. The temporary construction support site would require the permanent acquisition of several industrial and commercial properties located on Reserve Road, Waltham Street and Dickson Avenue. While the temporary construction support site would result in the loss of several general industrial and commercial businesses, the project would not impact upon the continued viability of the broader Artarmon industrial area.</p> <p>The permanent acquisition of a small portion of public recreation zoned land located at the eastern end of Dickson Avenue would have a negligible land use impact as the land is currently severed from any expansive open space area and is located adjacent the Gore Hill Freeway corridor. The site is unsuitable for public open space and recreation activities in its current state.</p> <p>At the completion of construction, remaining land at the site would be used on an ongoing basis for the operation of permanent project infrastructure including surface connections between the Gore Hill Freeway, Dickson Avenue and Reserve Road.</p>
Barton Road construction support site (BL5)	<p>The Barton Road construction support site (BL5) would occupy land bordered by the Gore Hill Freeway, Butchers Lane and medium density residential development in Artarmon. The site would mostly be located on land that is zoned medium density residential. The site would also occupy a small portion of land that is zoned for infrastructure related uses located adjacent to the Gore Hill Freeway corridor.</p> <p>Land that would comprise the site is part owned by Transport for NSW and is currently vacant land. The remainder of the site is owned by Willoughby City Council. This land would also be required for the duration of construction.</p> <p>The site would temporarily change the existing land use at this location to construction infrastructure. In the longer term, the land has been identified by Willoughby City Council as an appropriate location for affordable housing.</p> <p>The site would be rehabilitated and reinstated at the completion of construction in consultation with Willoughby City Council. The temporary use of this land for construction purposes would not impact on its future development potential. Any future development would be subject to separate assessment and approval in accordance with the <i>Environmental Planning and Assessment Act 1979</i> and is beyond the scope of this project.</p>

Construction location	Potential impacts on land use during construction
Gore Hill Freeway median construction support site (BL6)	<p>The Gore Hill Freeway median construction support site (BL6) would be located within the Gore Hill Freeway median and above the Lane Cove Tunnel portals in Artarmon. The site would comprise vacant land owned by Transport for NSW and zoned for infrastructure related uses.</p> <p>The site would temporarily be used for equipment storage to support the Gore Hill Freeway Connection. The temporary use of this land for construction activities would have a negligible impact as the land would be used in accordance with the current zoning.</p>
Northbridge to Seaforth	
Middle Harbour south cofferdam (BL7)	<p>The Middle Harbour south cofferdam construction support site (BL7) and Middle Harbour north cofferdam construction support site (BL8) would be temporarily located in Middle Harbour off Northbridge and Seaforth, respectively. Marine exclusion zones would be set up around these two sites, with controlled navigation channels provided through the main works area to facilitate the safe passage of all vessels and recreational users.</p>
Middle Harbour north cofferdam (BL8)	<p>Construction activities associated with these sites including works such as dredging and immersed tube tunnel unit placement would require the establishment of maritime speed restrictions around the construction equipment. This has the potential to result in minor increases to transit times for vessels that travel through Middle Harbour. Construction is not expected to have substantial impacts on vessel travel times as private vessels would be given right of way and speed restriction zones would be limited to areas in the immediate vicinity of construction vessels.</p> <p>The Northbridge Sailing Club makes use of Middle Harbour upstream of the Spit Bridge and would need to consider relocating sailing courses away from the marine works exclusion zones during construction. Exclusion zones and course routes would be clearly marked by buoys and project commercial craft associated with the project would be required to give way to recreational craft which is contrary to normal maritime protocols. Opportunities to minimise and manage potential impacts, including the relocation of sailing courses to upstream of the Middle Harbour crossing, would be investigated prior to construction in consultation with the club. Sites would be managed in accordance with the environmental management measures outlined in Chapter 8 (Construction traffic and transport).</p> <p>Private recreational users with vessels located upstream of the Spit Bridge may also be impacted by exclusions zones and closures of the navigation channel. Closures would occur midweek to minimise the impact on other waterway users including recreational boating traffic. During installation of the outer two immersed tube tunnel units, full closure of the channel would not be required and smaller vessels would be provided an escort to ensure safe passage around the construction works.</p> <p>Three jetties connected to separate properties at Seaforth would be inaccessible for the duration of construction due to exclusion zone established around Middle Harbour north cofferdam construction support site (BL8). The bed of the harbour occupied by the private foreshore structures is leased from Transport for NSW. Transport for</p>

Construction location	Potential impacts on land use during construction
	<p>NSW would consult with the owners of these properties to determine alternative arrangements. About 10 moorings located off Seaforth and leased from Transport for NSW would also need to be temporarily relocated due to the establishment of Middle Harbour north cofferdam construction support site (BL8). Potential temporary impacts on vessel movements and marine activities in Middle Harbour are further considered in Chapter 8 (Construction traffic and transport).</p>
<p>Spit West Reserve construction support site (BL9)</p>	<p>The Spit West Reserve construction support site (BL9) would be mainly located in the water west of Spit West Reserve in Mosman with a small land-based site located directly adjacent. The land-based component of Spit West Reserve construction support site (BL9) would be located on land zoned for public recreation.</p> <p>The water-based component of the site would require the temporary relocation of about 55 swing moorings leased from Transport for NSW in Middle Harbour, including in Pearl Bay and those located adjacent to Spit West Reserve. Relocations would be managed in accordance with the environmental management measures outlined in Chapter 8 (Construction traffic and transport).</p> <p>The land-based component of the site would require a portion of Spit West Reserve adjacent to the existing car park to be temporarily leased for the duration of construction, therefore temporarily changing the existing land use at this location from public recreation and open space to construction infrastructure. Recreational users of Spit West Reserve would be required to use alternative parts of the reserve, which could include areas to the north and south of the temporary construction support site. The existing shared user path located along the foreshore of Middle Harbour would be temporary diverted around the site with connectivity along the reserve maintained.</p> <p>The Mosman Rowing Club located to the south of the site may be required to make minor modifications to existing courses to ensure an adequate clearance is maintained around the water-based component of the temporary construction support site (including the floating immersed tube tunnel casting facility). A controlled right of way would be provided to rowers through the main works. The club would be consulted during construction planning to develop suitable environmental management measures, as described in Chapter 8 (Construction traffic and transport).</p> <p>The Spit West Reserve construction support site car park would provide limited parking for construction supervisory staff. The Spit West Reserve public car park would not be utilised by construction workers. Instead, workers at this site would either use public transport or would be transported to the site by shuttle bus (where required) from the Balgowlah Golf Course construction support site (BL10). The impacted portion of Spit West Reserve would be rehabilitated in consultation with Mosman Council and returned to the landowner at the completion of construction. The temporary use of this land would not impact on the continued use of the site for open space and public recreational use at the completion of construction.</p>

Construction location	Potential impacts on land use during construction
Seaforth to Balgowlah	
Surface road works at Balgowlah	<p>Surface road works at Balgowlah would include the realignment and widening of Burnt Bridge Creek Deviation, and creation of new access road intersections at Burnt Bridge Creek Deviation and the existing intersection of Sydney Road and Maretimo Street. The surface road works would facilitate the widening of Burnt Bridge Creek Deviation, resulting in the establishment of permanent project infrastructure on public recreation zoned land at Balgowlah Golf Course.</p> <p>The surface road works would be carried out on land that is zoned SP2 infrastructure and RE1 Public Recreation. Works carried out within the road corridor and on land zoned SP2 Infrastructure would be consistent with the existing land use and zoning.</p>
Balgowlah Golf Course construction support site (BL10)	<p>The Balgowlah Golf Course construction support site (BL10) would encompass part of the Balgowlah Golf Course and parts of the properties acquired along Dudley Street. The site would be required for construction of the motorway tunnel connection to the Burnt Bridge Creek Deviation, new motorway facilities, the new access road and the new and improved open space and recreation facilities. Users of the golf course would need to use nearby alternative courses including Wakehurst Golf Course, Manly Golf Course and Warringah Golf Course, all located within two kilometres of the site and which provide equivalent recreation facilities.</p> <p>Residual land, primarily to the east and north of the new access road would progressively become available through the construction period, which would facilitate re-purposing it to the new and improved open space and recreation facilities. This would allow it to be handed over progressively for use by the community, consistent with the existing recreational land use and zoning. The new open space and recreation facilities to the west of the proposed access road, between the access road and the widened Burnt Bridge Creek Deviation, would be constructed and handed over to Northern Beaches Council after completion of the project. Construction of the new and improved public open space and recreation facilities is discussed further in Chapter 6 (Construction work).</p> <p>The existing clubhouse building is proposed to be removed for the new and improved open space and recreation facilities. However, consideration would be given to re-purposing the building for the wider community during the dedicated consultation process for the new and improved open space and recreation facilities jointly led by Transport for NSW and Northern Beaches Council.</p> <p>At the completion of construction, part of the existing Balgowlah Golf Course site would be occupied and used on an ongoing basis for the operation of permanent project infrastructure as shown in Figure 20-11.</p>

Construction location	Potential impacts on land use during construction
Kitchener Street construction support site (BL11)	<p>The Kitchener Street construction support site (BL11) would occupy land next to the Burnt Bridge Creek Deviation and directly north of the Kitchener Street bridge in Balgowlah. The site would support the surface road works at Balgowlah and would be located predominantly on vacant land zoned for public recreation. The site would also occupy land zoned for general residential land use.</p> <p>The land zoned for public recreation is currently vacant and is not used for public recreation purposes. Consequently, the temporary change of land use to construction infrastructure would be negligible. The site would be rehabilitated and reinstated at the completion of construction. The land zoned for general residential is owned by Transport for NSW and it may be used by the project as a site office and amenities. This would be confirmed during further design development and construction planning.</p>
Seaforth to Frenchs Forest	
Surface road works at Killarney Heights and Frenchs Forest	<p>Surface road works at Seaforth, Killarney Heights and Frenchs Forest would mostly involve the realignment and upgrade of the Wakehurst Parkway including integration of the project with road network upgrades completed as part of the Northern Beaches Hospital road upgrade project.</p> <p>Construction activities carried out along the Wakehurst Parkway would mostly be carried out on land owned by Transport for NSW and zoned for infrastructure related uses. Consequently, there would be no impact on land use and/or the development potential of land at Killarney Heights and Frenchs Forest. Construction works would not encroach within the adjoining environmental conservation zones or into the Garigal National Park.</p>
Wakehurst Parkway south construction support site (BL12)	<p>The Wakehurst Parkway south construction support site (BL12) would occupy land east of the Wakehurst Parkway between a point just south of Judith Street and the northern end of Kirkwood Street at Seaforth. The site would be located on land owned by Transport for NSW that is zoned and used for low density residential development.</p> <p>The temporary construction support site would temporarily change the existing land use from low density residential to construction infrastructure. At the completion of construction, all of the remaining land at the site would be rehabilitated and reinstated and made available for other uses. Reinstatement of the site may require the replacement of boundary fences for existing residential properties along Kirkwood Street located adjacent to the site. Any future development on the affected land would be subject to separate assessment and approval in accordance with the <i>Environmental Planning and Assessment Act 1979</i> and is beyond the scope of this project.</p>

Construction location	Potential impacts on land use during construction
<p>Wakehurst Parkway east construction support site (BL13)</p>	<p>The Wakehurst Parkway east construction support site (BL13) would occupy two portions of land east of the Wakehurst Parkway and north of Kirkwood Street currently owned by Sydney Water. The temporary construction support site would comprise both portions of land as one support site. One portion of land is surrounding the main Bantry Bay Reservoir site mostly north of the existing water tanks and would be leased by Transport for NSW from Sydney Water. The site would be temporarily used as a temporary construction support site for the duration of construction. The temporary occupation of this land would not affect the existing land use zoning that is applicable to the site. Sydney Water facility operations and the on-site Telstra tower would remain operational for the duration of construction activities at the site. All existing structures would be protected. The land to be leased would be rehabilitated in consultation with Sydney Water and returned to the landowner at the completion of construction.</p> <p>The other portion of the site would be located wholly on vacant non-operational Sydney Water owned land immediately north of the existing water tanks zoned for low density residential. Transport for NSW would acquire this non-operational part of the Bantry Bay Reservoir site from Sydney Water. This land would be rehabilitated and revegetated as soon as practicable after construction and would be handed over to Northern Beaches Council to manage for use by the community as part of the Manly Dam Reserve. This would add about 4000 square metres of new public space to the Manly Dam Reserve.</p> <p>A smaller portion of land required for the access road to and from the support site forms part of the Manly Dam Reserve, which is Crown land. This land would be leased, and rehabilitated and returned to Northern Beaches Council at the end of construction.</p>
<p>Wakehurst Parkway north construction support site (BL14)</p>	<p>The Wakehurst Parkway north construction support site (BL14) would occupy Transport for NSW owned land at the north east corner of the Wakehurst Parkway and Warringah Road in Frenchs Forest. The site would be located on land that is partly zoned for public recreation and partly zoned for infrastructure related uses. This site was previously used as a temporary construction support site for the Northern Beaches Hospital road upgrade project. As such, potential construction land use impacts would be considered negligible. Following construction, the site would be used for operation of the northern tunnel support facilities.</p>

Potential land use impacts during operation

The project has the potential to permanently impact land use and the development potential of surrounding areas during operation. Permanent land use changes as a result of the project would occur largely in response to the physical introduction of permanent project infrastructure at Cammeray, Artarmon, Balgowlah, Killarney Heights and Frenchs Forest. The location of operational infrastructure has been developed with consideration of existing land use zones and future development to minimise permanent impacts, and is discussed further in Table 20-6.

Surrounding land would also be affected by the operation of the project. The operation of ventilation outlets at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway has the potential to influence development patterns for existing and future elevated receptors (for example, those receptors within multi-storey residential buildings) and is discussed further in Table 20-7.

The permanent changes in land use due to the project would also have the potential to result in indirect impacts associated with traffic and transport, noise and vibration, air quality and social and economic values. Consideration of these potential impacts is provided in Chapter 9 (Operational traffic and transport), Chapter 11 (Operational noise and vibration), Chapter 12 (Air quality) and Chapter 21 (Socio-economics).

Table 20-6 Potential land use impacts during operation

Operational infrastructure	Potential impacts on land use during operation
Cammeray to Northbridge	
<ul style="list-style-type: none"> • Surface connections at the Warringah Freeway • Underground connections to the Western Harbour Tunnel • Ventilation outlet and motorway facilities at the Warringah Freeway 	<p>Permanent project infrastructure would be established within the existing Cammeray Golf Course adjacent to the Warringah Freeway which would change a portion of the existing land use from public recreation to permanent transport infrastructure for the project. This would reduce the amount of land available for public recreational use. However, the layout would enable Cammeray Golf Course to be retained in a modified form that enables continuation of golf-related activities. Transport for NSW is consulting with Cammeray Golf Club, Department of Planning, Industry and Environment (Crown lands) and North Sydney Council (the trustee) to achieve this outcome.</p> <p>Operation of the ventilation outlet and motorway facilities at the Warringah Freeway might also place restrictions on future development because of the impact on potential elevated receivers. This issue is discussed further in the following section.</p>
Gore Hill Freeway and surrounds	
<ul style="list-style-type: none"> • Connections to and from the motorway tunnel to the Gore Hill Freeway/Lane Cove Tunnel and Reserve Road • Realignment and upgrade of the Gore Hill Freeway • Modifications and upgrades to road bridges • Minor changes to local roads • Realignment and reconstruction of shared user infrastructure 	<p>The Gore Hill Freeway Connection component of the project would connect and integrate the Beaches Link tunnels with the Gore Hill Freeway/Lane Cove Tunnel and Reserve Road at Artarmon providing added connectivity. Surface road works would also include realignment and upgrade of the existing motorway and minor changes to the surrounding road network.</p> <p>Operational infrastructure including the ventilation outlet and motorway facilities at the Gore Hill Freeway, air supply facility and wastewater treatment plant would be located adjacent the eastern extent of the Gore Hill Freeway Connection on land currently bordered by Punch Street, Lambs Road and Cleg Street. The project infrastructure would be established within the Artarmon industrial area on land zoned for light industrial uses. While the project would reduce the amount of land that would otherwise be used for light industrial activities, the project is not expected to impact on the continued viability of the Artarmon industrial area more broadly. Further, the project would not preclude the continued operation of light industrial and/or commercial uses on land that adjoins or is located in proximity to the project infrastructure within the Artarmon industrial area.</p> <p>Changes to local roads within the Artarmon industrial area would include removal of the connection between Punch Street and Lambs Road, with the conversion of Punch Street to a cul-de-sac. The creation of a cul-de-sac at Punch Street would have a minor impact on connectivity throughout the north eastern portion of the Artarmon industrial area.</p> <p>Construction of the westbound off ramp connecting to Reserve Road would require the conversion of Dickson Avenue to a cul-de-sac, directly east of the intersection with Reserve Road in Artarmon. Access to the existing</p>

Operational infrastructure	Potential impacts on land use during operation
<ul style="list-style-type: none"> • Wastewater treatment plant • Ventilation outlet and motorway facilities at the Gore Hill Freeway • Motorway control centre at the Gore Hill Freeway 	<p>properties on Dickson Avenue would be provided from Hesky Lane. While the cul-de-sac at Dickson Avenue would be a permanent change to the road network, access would be retained to all potentially affected properties and impacts to the existing general industrial and warehousing land uses would be minor. The creation of a cul-de-sac at Dickson Avenue would have a minor impact on connectivity throughout the eastern portion of the Artarmon industrial area.</p> <p>Permanent project infrastructure would also include new and upgraded connections to the existing road network along the Gore Hill Freeway corridor. This infrastructure would be established within the existing road corridor on land zoned for infrastructure related uses.</p> <p>The existing motorway creates a barrier between adjoining areas and restricts north-south connectivity for pedestrians and cyclists to the existing overpasses. While the project would not remove this barrier, the project would provide a positive contribution to the local area by providing new and upgraded active transport infrastructure that would improve connectivity across and around the Gore Hill Freeway. This would include the replacement of the shared user path along the southern side of the Gore Hill Freeway, replacement of the existing pedestrian footpath along the eastern side of the Reserve Road bridge, and a new pedestrian footpath adjacent to the cycle path behind the southern abutment of the Reserve Road bridge.</p>
Northbridge to Seaforth	
<ul style="list-style-type: none"> • Immersed tube tunnels 	<p>Operational infrastructure in the area between Northbridge and Seaforth would include immersed tube tunnels for the crossing of Middle Harbour. The immersed tube tunnels would sit on both excavated rock within a trench and piles driven into the bed of the harbour maintaining between 16 metres and 22 metres of water depth over the tunnels, depending on the distance from the shore. The immersed tube tunnels would not introduce navigational impacts for water-based activities and operations carried out in Middle Harbour as marine vessels using Middle Harbour are already restricted by the relatively shallow harbour entrance at The Spit. Further, there would be no land use impacts during operation to foreshore land along Middle Harbour in Northbridge and Seaforth.</p> <p>No other permanent operational infrastructure would be established at surface level in the area between Northbridge and Seaforth. Works would otherwise comprise subsurface tunnelling that would not introduce any permanent impacts to existing land uses, current land use zones or the strategic land use direction of the area.</p>

Operational infrastructure	Potential impacts on land use during operation
Seaforth to Balgowlah	
<ul style="list-style-type: none"> • New access road connecting Burnt Bridge Creek Deviation and Sydney Road • Road widening works and minor changes to local roads • New and upgraded active transport infrastructure • Ventilation outlet and motorway facilities at the Burnt Bridge Creek Deviation. 	<p>The project would introduce permanent land use impacts on the land at Balgowlah Golf Course as a result of:</p> <ul style="list-style-type: none"> • The construction and alignment of tunnel portals within the Burnt Bridge Creek Deviation road corridor • The construction of a new access road through the existing golf course that would connect Burnt Bridge Creek Deviation and Sydney Road, and provide local access to the new and improved open space and recreation facilities • Establishment of a ventilation outlet and motorway facilities at the Burnt Bridge Creek Deviation • Realignment and reconstruction of the shared path on the south eastern side of Burnt Bridge Creek Deviation between the Kitchener Street bridge and Dudley Street • Construction of a new shared user path along the eastern side of the new access road between Burnt Bridge Creek Deviation and Sydney Road. <p>Engagement with Northern Beaches Council as part of the project has identified potential for Balgowlah Golf Course and residual land from the Dudley Street properties to be developed as new and improved open space and recreation facilities, which would align with the <i>Northern Beaches Sportsground Strategy</i> (Northern Beaches Council, 2017a) and address the current under supply of sporting grounds available for public use in the local area.</p> <p>A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.</p> <p>The design of permanent operational infrastructure established at the Balgowlah Golf Course has been optimised to increase the opportunities for the use of the remaining land as new open space and recreation facilities. Including residual land from properties acquired along Dudley Street, the project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities.</p> <p>An indicative layout of the new and improved open space and recreation facilities at Balgowlah is provided in Figure 5-28 of Chapter 5 (Project description) and provides for a mix of active and passive recreation needs that address the current, and growing, shortfall in recreation facilities within the local area.</p>

Operational infrastructure	Potential impacts on land use during operation
	<p>Works at Balgowlah would also include new and upgraded active transport infrastructure to improve connectivity across and around the Burnt Bridge Creek Deviation, the new access road and new and improved open space and recreation facilities. This would include the realignment and reconstruction of the shared user path along the southern side of the Burnt Bridge Creek Deviation between a location south of the Kitchener Street bridge and the new intersection of the Burnt Bridge Creek Deviation with the new access road. The realigned and reconstructed shared user path would be connected with the existing shared user path at Dudley Street. Improvements would also include the extension of the existing shared user underpass beneath the Burnt Bridge Creek Deviation to the north of Dudley Street, and a new at-grade pedestrian crossing of the new access road at the intersection with Sydney Road. The final pedestrian and cycle facilities would be determined during further design development and consideration of the consultation process described above for the new and improved open space and recreation facilities at Balgowlah.</p>
Seaforth to Frenchs Forest	
<ul style="list-style-type: none"> • Surface works to connect and integrate the project with the surrounding road network • Realignment and widening of the Wakehurst Parkway • New pedestrian underpasses beneath the Wakehurst Parkway • New fauna underpasses beneath the Wakehurst Parkway • Demolition and reconstruction of the pedestrian bridge near Aquatic Drive • Shared user path between Warringah Road and Kirkwood Street 	<p>The Wakehurst Parkway would be realigned and upgraded to allow connection to the ramp tunnels with the surface and widened between the ramp tunnels and Warringah Road in Frenchs Forest to improve capacity and safety. The works would be carried out entirely within the existing road reserve and Transport for NSW owned land zoned for infrastructure related uses. There would be no impact on existing land uses.</p> <p>The Wakehurst Parkway between Seaforth and Frenchs Forest currently creates a barrier between adjoining areas which largely severs east-west connectivity for fauna, pedestrians and cyclists where there is no dedicated crossing location. The project would provide a positive contribution to the local area by providing new and upgraded active transport infrastructure that would improve connectivity and user safety along and across the Wakehurst Parkway. This would include a new shared user path along the eastern side of the Wakehurst Parkway between Seaforth and Frenchs Forest, three new shared user underpasses of the Wakehurst Parkway, reconstruction and lengthening of the existing pedestrian overpass across the Wakehurst Parkway near Warringah Road, and a new shared user bridge over a drainage culvert and existing fauna underpass near Warringah Road. The project would also provide new and replaced fauna crossing infrastructure along the Wakehurst Parkway. Further detail on proposed fauna, pedestrian and cycle facilities is provided in Chapter 5 (Project description).</p> <p>The ventilation outlet and motorway facilities at the Wakehurst Parkway at Killarney Heights would be located above the ramp tunnel portals to the Wakehurst Parkway and on land within the existing road corridor that is zoned for infrastructure related uses. The ventilation outlet and motorway facilities are considered to be compatible with the existing land use zone. Land use zones surrounding the ventilation outlet and motorway facilities include national parks and nature reserves, public recreation and low density residential. These land use zones do not support multi-storey development and therefore any potential impacts from the ventilation</p>

Operational infrastructure	Potential impacts on land use during operation
<ul style="list-style-type: none"> • Minor changes to local roads • Ventilation outlet and motorway facilities at the Wakehurst Parkway • Tunnel support facility at Frenchs Forest. 	<p>outlet and motorway facilities on future elevated receptors are not expected at this location. Further discussion on elevated receptors is provided below.</p> <p>Northern Beaches Council has adopted the <i>Northern Beaches Hospital Precinct Structure Plan (2017b)</i> which provides the overarching strategic land use planning framework for the area surrounding the Northern Beaches Hospital precinct. Part of the project would be located within the area covered by the structure plan, including the connection from the Wakehurst Parkway to Warringah Road in Frenchs Forest. The project would support the future land use planning framework that is envisioned under the structure plan and would improve connectivity to and from the Northern Beaches Hospital precinct.</p>

The project would involve the operation of ventilation outlets and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and the Wakehurst Parkway (refer to Chapter 5 (Project description)).

Table 20-7 identifies land use zones and applicable height restrictions, if any, in an area of around 300 metres from each of the project ventilation outlets. It also outlines potential implications for existing and future land use planning.

The permanent changes in land use due to the project would also have the potential to result in indirect impacts associated with traffic and transport, noise and vibration, air quality and social and economic values. Consideration of these impacts is provided in Chapter 9 (Operational traffic and transport), Chapter 11 (Operational noise and vibration), Chapter 12 (Air quality) and Chapter 21 (Socio-economics). The air quality impact assessment (refer to Chapter 12) and the human health impact assessment (refer to Chapter 13) demonstrate that operation of the motorway facilities and ventilation outlets would not result in unacceptable air quality impacts or an unacceptable impact to human health for existing or future buildings (including elevated receptors) up to a height of 20 metres in the vicinity of the proposed ventilation outlets. However, there would be potential impacts for any future buildings above 20 metres in height and within 300 metres of the outlets that would need to be considered by the relevant local council as part of future development applications (refer to Chapter 12 (Air quality)).

Table 20-7 Existing building height restrictions around project ventilation outlets and motorway facilities

Ventilation outlet	Relevant land use zones within 300 metres of the ventilation outlet	Existing height restrictions within 300 metres of the ventilation outlet	Potential implications for existing and future planning controls
<p>Ventilation outlet at the Warringah Freeway</p>	<p>Land use zones for the area around the ventilation outlet at the Warringah Freeway are shown in Figure 20-1 and include the following within 300 metres of the ventilation outlet:</p> <ul style="list-style-type: none"> • Predominantly R4 High Density Residential and R3 Medium Density Residential, with some pockets of R2 Low Density Residential • A small area of B4 Mixed Use zone at the western end of Military Road • Several areas of SP2 Infrastructure, including education facilities, places of worship and road infrastructure • Areas of RE1 Public Recreation (including ANZAC Park, St Leonards Park and the Cammeray Golf Course). 	<p>Building height restrictions applicable to land around the ventilation outlet at the Warringah Freeway under the North Sydney LEP 2013 include:</p> <ul style="list-style-type: none"> • A maximum of 12 metres for most land zoned R4 High Density Residential, with some pockets up to 16 metres around Military Road on the eastern side of the Warringah Freeway • A maximum of 8.5 metres for most land zoned R3 Medium Density Residential, with a single site on Lytton Street permitted up to 11 metres • A maximum of 8.5 metres for land zoned R2 Low Density Residential • A maximum of 16 metres for land zoned B4 Mixed Use • Maximum heights for land zoned SP2 Infrastructure (education establishments and places of worship) consistent with surrounding residential zones, being either 8.5 metres or 12 metres. There are no height limits imposed on SP2 Infrastructure (road infrastructure) zones. 	<p>All land use zones within 300 metres of the ventilation outlet, where habitable residential or commercial structures would be permissible, currently have height restrictions of less than 20 metres. Where height restrictions do not exist, particularly in RE1 Public Recreation and SP2 Infrastructure (road infrastructure) zones, development of elevated habitable structures would either be prohibited or inconsistent with the aims of the zone.</p> <p>No additional development controls would be required to manage the interaction between the operation of the ventilation outlet and currently permissible habitable structures in the area. However, if zoning and/or development controls were to be reviewed in the future, the potential for interactions between the project and future development for buildings above 20 metres and within 300 metres of the ventilation outlet would need to be considered.</p>

Ventilation outlet	Relevant land use zones within 300 metres of the ventilation outlet	Existing height restrictions within 300 metres of the ventilation outlet	Potential implications for existing and future planning controls
<p>Ventilation outlet and motorway facilities at the Gore Hill Freeway</p>	<p>Land use zones for the area around the ventilation outlet and motorway facilities at the Gore Hill Freeway are shown in Figure 20-2 and include the following within 300 metres of the ventilation outlet:</p> <ul style="list-style-type: none"> • Predominantly R3 Medium Density Residential and R2 Low Density Residential to the north and east of the ventilation outlet • Predominantly IN1 General Industrial and IN2 Light Industrial to the south of the ventilation outlet • Pockets of RE1 Public Recreation (including Artarmon Park, Artarmon Reserve and Naremburn Park) • SP2 Infrastructure along the T1 North Shore and Western rail line and T9 Northern rail line and the Gore Hill Freeway corridor. 	<p>Building height restrictions applicable to land around the ventilation outlet and motorway facilities at the Gore Hill Freeway under the Willoughby LEP 2012 include:</p> <ul style="list-style-type: none"> • Maximum heights of 8.5 metres, nine metres and 12 metres for land zoned R3 Medium Density Residential or R2 Low Density Residential, depending on location • No specified height restriction for land zoned IN1 General Industrial, IN2 Light Industrial, RE1 Public Recreation or SP2 Infrastructure. 	<p>All land use zones within 300 metres of the ventilation outlet, where habitable residential structures would be permissible, currently have height restrictions of less than 20 metres. Although it is possible that industrial development could be carried out at heights greater than 20 metres in the IN1 General Industrial or IN2 Light Industrial zones, it is anticipated that development at this height would either be undesirable or unlikely to include habitable spaces at or about 20 metres. For other land use zones, particularly in RE1 Public Recreation and SP2 Infrastructure (road infrastructure) zones, development of elevated habitable structures would either be prohibited or inconsistent with the aims of the zone.</p> <p>No additional development controls would be required to manage the interaction between the operation of the ventilation outlet and currently permissible habitable structures in the area. However, if zoning and/or development controls were to be reviewed in the future, the potential for interactions between the project and future development for buildings above 20 metres and within 300 metres of the ventilation outlet would need to be considered.</p>

Ventilation outlet	Relevant land use zones within 300 metres of the ventilation outlet	Existing height restrictions within 300 metres of the ventilation outlet	Potential implications for existing and future planning controls
<p>Ventilation outlet and motorway facilities at the Burnt Bridge Creek Deviation</p>	<p>Land use zones for the area around the ventilation outlet and motorway facilities at the Burnt Bridge Creek Deviation are shown in Figure 20-4 and include the following within 300 metres of the ventilation outlet:</p> <ul style="list-style-type: none"> • Predominantly R1 General Residential to the south and R2 Low Density Residential to the north • Areas of RE1 Public Recreation comprising the Balgowlah Golf Course site, several local parks and the riparian zone along Burnt Bridge Creek • SP2 Infrastructure along the Burnt Bridge Creek Deviation. 	<p>Building height restrictions under the Manly LEP 2013 and Warringah LEP 2011 include:</p> <ul style="list-style-type: none"> • A maximum of 8.5 metres for land zoned R1 General Residential and R2 Low Density Residential in both local government areas • No specified height restriction for land zoned RE1 Public Recreation, or SP2 Infrastructure. 	<p>All land use zones within 300 metres of the ventilation outlet, where habitable residential structures would be permissible, currently have height restrictions of less than 20 metres. Where height restrictions do not exist, particularly in RE1 Public Recreation and SP2 Infrastructure (road infrastructure) zones, development of elevated habitable structures would either be prohibited or inconsistent with the aims of the zone.</p> <p>No additional development controls would be required to manage the interaction between the operation of the ventilation outlet and currently permissible habitable structures in the area. However, if zoning and/or development controls were to be reviewed in the future, the potential for interactions between the project and future development for buildings above 20 metres and within 300 metres of the ventilation outlet would need to be considered.</p> <p>The new and improved open space and recreation facilities at Balgowlah would not be restricted by the ventilation outlet.</p>

Ventilation outlet	Relevant land use zones within 300 metres of the ventilation outlet	Existing height restrictions within 300 metres of the ventilation outlet	Potential implications for existing and future planning controls
<p>Ventilation outlet and motorway facilities at the Wakehurst Parkway</p>	<p>Land use zones for the area around the ventilation outlet and motorway facilities at the Wakehurst Parkway are shown in Figure 20-5 and include the following within 300 metres of the ventilation outlet:</p> <ul style="list-style-type: none"> • R2 Low Density Residential predominantly to the south, but with some small areas to the north of the ventilation outlet • Mainly E1 National Parks and Nature Reserves and E2 Environmental Conservation to the west of the ventilation outlet • Mainly RE1 Public Recreation (Manly Dam Reserve) to the east of the ventilation outlet, with a pocket (Seaforth Oval) to the south and an area of RE2 Private Recreation at the Seaforth Bowling Club • SP2 Infrastructure along the Wakehurst Parkway corridor. 	<p>Building height restrictions under the Manly LEP 2013 and Warringah LEP 2011 include:</p> <ul style="list-style-type: none"> • A maximum of 8.5 metres for land zoned R2 Low Density Residential in both local government areas • No specified height restriction for land zoned RE1 Public Recreation, RE2 Private Recreation, E1 National Parks and Nature Reserves, E2 Environmental Conservation or SP2 Infrastructure. 	<p>All land use zones within 300 metres of the ventilation outlet which habitable residential structures would be permissible currently have height restrictions of less than 20 metres. Development of elevated habitable structures in other relevant land use zones is either prohibited, unlikely to be desirable, or inconsistent with the aims of the zone.</p> <p>No additional development controls would be required to manage the interaction between the operation of the ventilation outlet and currently permissible habitable structures in the area. However, if zoning and/or development controls were to be reviewed in the future, the potential for interactions between the project and future development for buildings above 20 metres and within 300 metres of the ventilation outlet would need to be considered.</p>

Changes in public open space

The following public open space areas would be impacted during construction and operation:

- Cammeray Golf Course
- Flat Rock Reserve
- Artarmon Park
- Spit West Reserve
- Balgowlah Golf Course.

The temporary construction support sites at Flat Rock Reserve and Spit West Reserve would not be needed to operate the project and would be rehabilitated and returned to an equivalent state as soon as practicable at the completion of construction. The project would not impact the ability of these areas to be used in a manner consistent with their existing use as public open space.

Changes in public open space during operation of the project would be limited to the Cammeray and Balgowlah golf courses and Artarmon Park.

As discussed in Table 20-4 and Table 20-6, the changes at Cammeray Golf Course would be managed to ensure it is able to continue to be used for golf-related activities, albeit in a modified form.

The changes at Balgowlah Golf Course due to the project would preclude the continued operation of the golf course. As discussed in Table 20-4 and Table 20-6, engagement with Northern Beaches Council has identified potential for the residual land to be developed as open space and recreation facilities that better address the local government area's current and future needs. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. As part of this consultation process, a community working group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.

Along with residual land from properties acquired along Dudley Street, the project would progressively return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities (refer to Figure 20-11).

As discussed in Table 20-4, changes at Artarmon Park would be limited to the conversion of a portion of land adjacent to the Gore Hill Freeway zoned for public recreation for permanent project infrastructure. This change would not impact the long term viability of the remainder of Artarmon Park, as the impacted area is steeply sloped and vegetated with dense scrub. The adjacent and much larger Artarmon Reserve would not be impacted.

Land managed by the former Office of Environment and Heritage

The *Guidelines for developments adjoining land and water managed by the Office of Environment and Heritage* aim to provide advice to avoid and minimise any direct or indirect adverse impacts on land and water bodies managed by the former the Office of Environment and Heritage (now the Department of Planning, Industry and Environment (Environment, Energy and Science)).

These guidelines have been prepared for use by councils and other planning authorities when they assess development applications. While Clause 94 of the State Environmental Planning Policy (Infrastructure) 2007 provides for development for the purpose of road or road infrastructure facilities to be permissible without consent, as part of best practice, these guidelines have been considered in Table 20-.

Table 20-8 Issues to be considered for projects adjoining Office of Environment and Heritage land

Issues to be considered for projects adjoining Office of Environment and Heritage land	Where addressed in the EIS
Erosion and sediment control	<p>An assessment of the project's impact on soil and land resources, with particular emphasis on soil erosion and sediment transport, is provided in Chapter 16 (Geology, soils and groundwater).</p> <p>Chapter 17 (Hydrodynamics and water quality) assesses the potential impacts on surface water with regard to erosion, siltation, and bank stability. Impacts from scour and erosion on geomorphology are also discussed.</p>
Stormwater runoff	<p>Minimising the effects of proposed stormwater and wastewater management on natural hydrological attributes and on the existing capacity of stormwater systems is described in Chapter 17 (Hydrodynamics and water quality).</p>
Wastewater	<p>The effects of proposed stormwater and wastewater management on surface water quality are assessed in Chapter 17 (Hydrodynamics and water quality). Information on wastewater discharge, including volumes and rates of discharge, are also discussed.</p>
Management implications relating to pests, weeds, and edge effects	<p>Impacts to terrestrial flora, including edge effects, spread of weeds and pathogens is discussed in Chapter 19 (Biodiversity).</p>
Fire and the location of asset protection zones	<p>An assessment of bushfire risks relating to construction and operation is presented in Chapter 23 (Hazards and risks).</p>
Boundary encroachments and access through Office of Environment and Heritage land	<p>The project would not encroach on or require access through Office of Environment and Heritage land.</p>
Visual, odour, noise, vibration, air quality and amenity impacts	<p>Consideration of these impacts is provided in Chapter 8 (Construction traffic and transport), Chapter 10 (Construction noise and vibration), Chapter 11 (Operational noise and vibration), Chapter 12 (Air quality), Chapter 21 (Socio-economics) and Chapter 22 (Urban design and visual amenity).</p> <p>Possible noise, vibration, dust and light spill impacts to native fauna species are discussed in Chapter 19 (Biodiversity).</p>
Threats to ecological connectivity and groundwater-dependent ecosystems	<p>Habitat connectivity is addressed in Chapter 19 (Biodiversity). Impacts to groundwater dependent ecosystems are considered in Chapter 16 (Geology, soils and groundwater) and Chapter 19 (Biodiversity).</p>
Cultural heritage	<p>Impacts to non-Aboriginal heritage are assessed in Chapter 14 (Non-Aboriginal heritage) and impacts to Aboriginal heritage are assessed in Chapter 15 (Aboriginal heritage).</p>

20.5 Environmental management measures

The project has been designed to minimise the requirement for property acquisition as far as practical and optimise the use of land already owned by Transport for NSW. Measures to avoid, minimise or manage land use and property impacts as a result of the project are detailed in Table 20-9.

Additional environmental management measures relevant to the management of land use impacts are also outlined in other chapters of the environmental impact statement, including:

- Chapter 8 (Construction traffic and transport)
- Chapter 9 (Operational traffic and transport)
- Chapter 10 (Construction noise and vibration)
- Chapter 11 (Operational noise and vibration)
- Chapter 12 (Air quality)
- Chapter 13 (Human health)
- Chapter 21 (Socio-economics)
- Chapter 22 (Urban design and visual amenity).

Table 20-9 Environmental management measures - land use and property

Ref	Phase	Impact	Environmental management measure	Location
LP1	All phases	Changes to lease arrangements	Transport for NSW will consult with existing lease holders of properties that will be directly affected by the project regarding any changes to lease arrangements.	BL/GHF
LP2	All phases	Residual land	Identification of residual land of the project will be confirmed during further design development and construction planning. Appropriate strategies for the ongoing management and/or divestment of the residual land will consider the location, land use characteristics, area and adjacent land uses.	BL/GHF
LP3	Pre-construction and construction	Property acquisition	Land acquisition for the project will be carried out in accordance with the <i>Land Acquisition (Just Terms Compensation) Act 1991</i> , the <i>Roads and Maritime Services land acquisition information guide</i> (Roads and Maritime Services, 2014) and <i>Fact sheet: Property acquisition of subsurface lands</i> (Roads and Maritime Services, 2015) and in accordance with the land acquisition reforms announced by the NSW Government in 2016. Transport for NSW will appoint a Personal Manager – Acquisition to help landowners and residents who may be affected by acquisition for the project.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			The Personal Manager – Acquisition will be in regular contact with these individuals to provide updates on the project and respond to questions and queries. Should acquisition for the project be confirmed for a particular property, the Personal Manager – Acquisition will work with the affected landowners and residents to offer assistance and support throughout the acquisition and relocation process.	
LP4	Pre-construction and construction	Residual land at Balgowlah	A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council will take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. This process will start after the environmental impact statement public exhibition period and well in advance of construction commencing. As part of this consultation process, a community reference group will be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.	BL (Balgowlah)
LP5	Construction	Temporary use of land	Land subject to temporary use, including areas of public open space, will be rehabilitated as soon as practicable to an appropriate condition, taking into consideration the location, land use characteristics, area and adjacent land uses or in accordance with the urban design and landscape plan where applicable (environmental management measure V1). Rehabilitation will be carried out in consultation with the relevant landowner, the local council and community (where appropriate).	BL/GHF
LP6	Construction	Access impediments to private property	Where impacts to private property access is unavoidable during construction, landowners or lease holders/tenants where appropriate will be consulted in advance to develop appropriate alternative access arrangements.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
LP7	Operation	Air quality impacts for elevated receivers located around ventilation outlets and motorway facilities	Transport for NSW will assist Northern Beaches Council, North Sydney Council, Willoughby City Council, and the Department of Planning, Industry and Environment (as appropriate) in determining relevant land use considerations applicable to future development in the immediate vicinity of ventilation outlets for inclusion in local environmental plans or development control plans, where required, to manage interactions between the project and future development. This may include procedures for identifying the requirement for consultation with Transport for NSW.	BL/GHF

Beaches Link = BL, Gore Hill Freeway Connection = GHF



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 21

Socio-economics

21 Socio-economics

This chapter considers the potential impacts of the project on socio-economic issues from the construction and operation of the project and identifies management measures which address these impacts.

A detailed socio-economic assessment has been carried out for the project and is included in Appendix U (Technical working paper: Socio-economic assessment).

The Secretary's environmental assessment requirements as they relate to socio-economic issues and where in the environmental impact statement these have been addressed, are in Table 21-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to socio-economics are included in Section 21.6.

Table 21-1 Secretary's environmental assessment requirements – Socio-economic

Secretary's requirement	Where addressed in EIS
Socio-economic, Land Use and Property	
1. The Proponent must assess social and economic impacts (of all phases of the project) in accordance with the current guidelines (including cumulative construction and operational impacts of the proposal and major projects in the vicinity of the project) and in consultation with relevant land owners (such as the Ports Authority of NSW and those land owners whose property is being acquired).	<p>Socio economic impacts as a result of the project are presented in Section 21.4 and Section 21.5.</p> <p>Chapter 27 (Cumulative impacts) assesses the cumulative construction and operational impacts of the project and major projects in the vicinity of the project.</p> <p>A summary of consultation conducted for the project is provided in Chapter 7 (Stakeholder and community engagement) and Section 21.2.3.</p>
2. The Proponent must assess impacts from construction and operation on potentially affected properties, businesses, recreational users and land and water users, including amenity impacts (including from cumulative and extended construction time frames and construction fatigue), property acquisitions/adjustments, future land uses, access, relevant statutory rights, and community severance and barrier impacts resulting from the project.	<p>Impacts to properties, including property acquisitions and future land uses during construction and operation, is discussed in Chapter 20 (Land use and property).</p> <p>Section 21.4 and Section 21.5 present the socio-economic impacts as a result of the project.</p> <p>Chapter 27 (Cumulative impacts) assesses the cumulative construction and operational impacts of the proposal and major projects in the vicinity of the project.</p>
3. Where an immersed tube method (IMT) of construction is proposed for use in Middle Harbour, the Proponent must: <ul style="list-style-type: none"> a. provide details of how reductions to current Harbour depths will be avoided; 	<p>Section 5.2.3 of Chapter 5 (Project description) describes how, due to the profile of the harbour bed of Middle Harbour, the immersed tube tunnel units would sit both partially within a trench and above the bed of the Middle Harbour.</p> <p>Section 9.4.4 of Chapter 9 (Operational traffic and transport) indicates that shallow water depths at the entrance to Middle Harbour control</p>

Secretary's requirement	Where addressed in EIS
	navigation in the vicinity of the proposed tunnel crossing. The tops of the immersed tube tunnels would not interfere with or restrict maritime activities.
<p>b. provide details confirming the level of protection for the IMTs will be similar to or better than that of the existing Sydney Harbour Tunnel;</p>	<p>As discussed in Chapter 6 (Construction work), an additional concrete layer would be provided to protect the top of the completed tunnel units from marine activities during operation, including falling or dragging anchors. Section 23.3.4 of Chapter 23 (Hazards and risks) details the risks associated with interactions between maritime traffic and the immersed tube tunnels.</p> <p>Chapter 4 (Project development and alternatives) provides a justification for selection of the immersed tube tunnel method for the crossing of Middle Harbour.</p>
<p>c. identify impacts to ship scheduling in consultation with the Harbour Master; and</p>	<p>Due to depths constraints at the entrance to Middle Harbour, shipping does not occur in locations where construction works are proposed.</p> <p>Chapter 8 (Construction traffic and transport) and Chapter 9 (Operational traffic and transport) outline impacts related to the construction and operation of the immersed tube tunnel respectively.</p> <p>Chapter 8 (Construction traffic and transport) specifies the consultation requirements with the Harbour Master to minimise impacts during construction.</p> <p>Impacts of closures in Middle Harbour on businesses are discussed in Section 21.4, Section 21.5.6 and Appendix U (Technical working paper: Socio-economic assessment), including Annexure B.</p>
<p>d. provide details of full mission simulation which takes in account, movement of tunnel units past the Spit Bridge and within Middle Harbour.</p>	<p>Outcomes of the simulation report are outlined in Section 8.4.3 of Chapter 8 (Construction traffic and transport).</p>
<p>4. The Proponent must assess potential impacts on utilities (including communications, electricity, gas, fuel and water and sewerage) and the relocation of these utilities.</p>	<p>Chapter 5 (Project description) outlines utilities and services management for the project and Appendix D (Utilities management strategy) provides a detailed description of utilities likely to be impacted and a framework for utility installations, relocations, adjustments and protection.</p>
<p>5. Where the project is predicted to impact on utilities the Proponent must undertake a utilities management strategy, identifying management options, including relocation or adjustment of the utilities.</p>	<p>Appendix D (Utilities management strategy) provides a detailed description of utilities likely to be impacted and a framework for utility installations, relocations, adjustments and protection.</p>

Secretary's requirement	Where addressed in EIS
<p>6. A draft Community Consultation Framework must be prepared identifying relevant stakeholders, procedures for distributing information and receiving/responding to feedback and procedures for resolving stakeholder and community complaints during construction and operation. Key issues that must be addressed in the draft Framework include, but are not limited to:</p> <ol style="list-style-type: none"> traffic management (including property access, pedestrian access); landscaping/urban design matters; construction activities including out of hours work; and noise and vibration mitigation and management. 	<p>Chapter 7 (Stakeholder and community engagement) summarises the content of the Community consultation framework. A Community consultation framework is provided in Appendix E (Community consultation framework).</p>

21.1 Legislative and policy framework

The socio-economic assessment has been prepared to assess the impacts of the project in accordance with the *Environmental Impact Assessment Practice Note – Socio-economic assessment (EIA-N05)* (Practice Note) (Transport for NSW, 2020e). The Practice Note guides the assessment level and process for socio-economic impact assessments and outlines the requirements for establishing the socio-economic baseline.

Chapter 3 (Strategic context and project need) provides a description of national and state strategic planning and transport policies which are relevant to the project. Local council policies relevant to the socio-economic impacts of the project include:

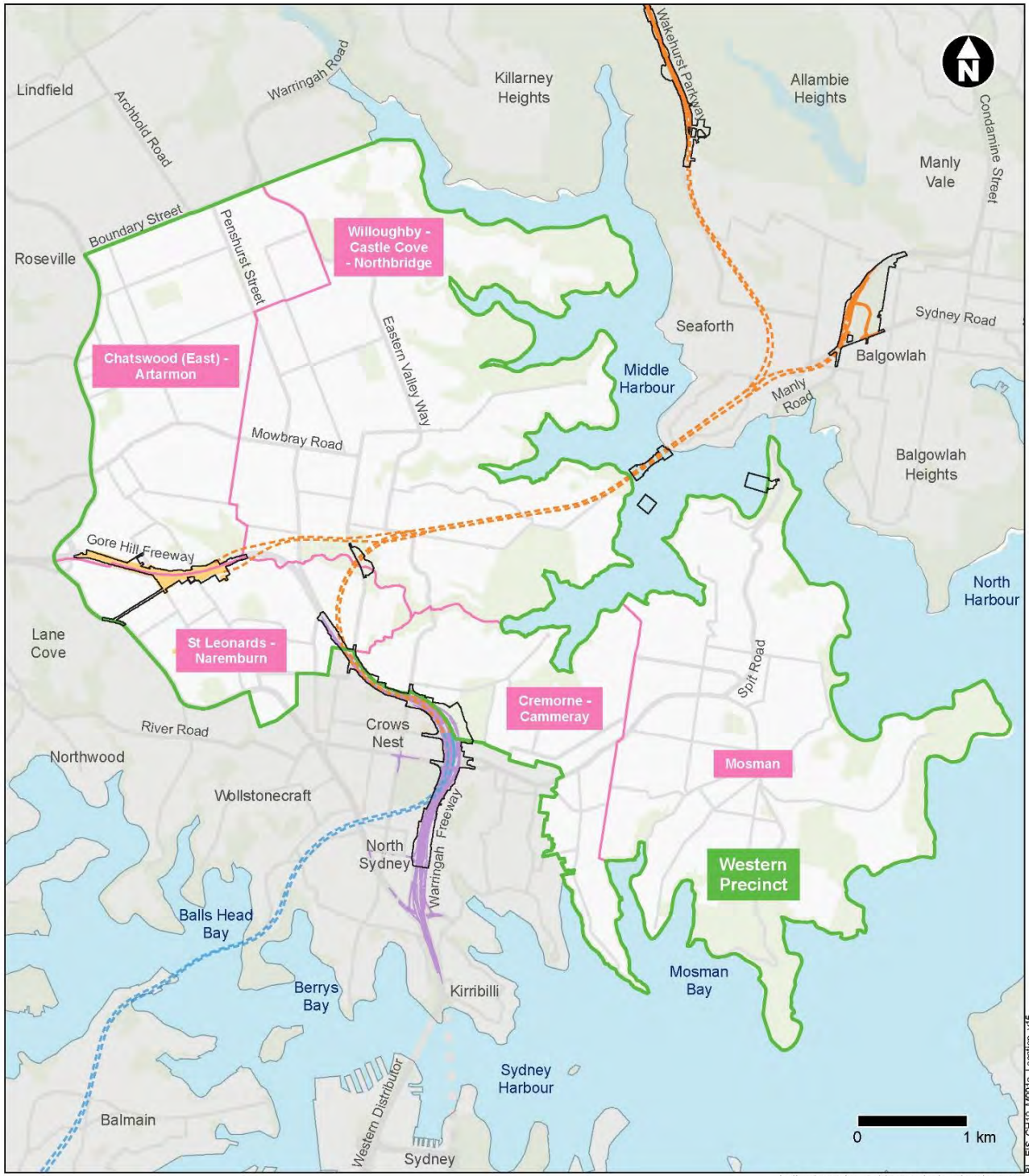
- *North Sydney Community Strategic Plan 2013-2023* (North Sydney Council, 2013)
- *Willoughby City Strategy* (Willoughby City Council, 2013)
- *Shape 2028 Northern Beaches Draft Community Strategic Plan 2017-2028* (Northern Beaches Council, 2018b)
- *Mosman Council Community Strategic Plan 2013-2023* (Mosman Council, 2013).

The project would generally support the actions of these plans by reducing congestion, improving travel times and enhancing the reliability of the road network across Sydney and improving access to and from the north, north-east and north-west of Sydney.

21.2 Assessment methodology

21.2.1 Precinct areas

The socio-economic assessment considers precincts including adjacent waterways, and comprises the Australian Bureau of Statistics (ABS) geographic boundaries (referred to as Statistical Area Level 2s) (SA2s). For the purposes of this assessment, two 'precincts' have been identified located to the north-east and south-west of Middle Harbour, referred to as the Western Precinct (Figure 21-1) and Eastern Precinct (Figure 21-2) Broader regional impacts were also considered, where relevant.



Indicative only – subject to design development

Operational features	Connecting projects	Western precinct
Beaches Link	Western Harbour Tunnel	Precinct boundary
Gore Hill Freeway Connection	Warringah Freeway Upgrade	Statistical area boundary
Construction footprint		

Figure 21-1 Western Precinct

Note: Apart from the motorway facilities, cut and cover structures and tunnelling works in Cammeray, the construction footprint shown on the Warringah Freeway would consist of low impact activities such as traffic control and management, line marking and staged surface roadworks tie-in works, and utility and cable works required to connect to the Western Harbour Tunnel and Warringah Freeway Upgrade project and other local roads.

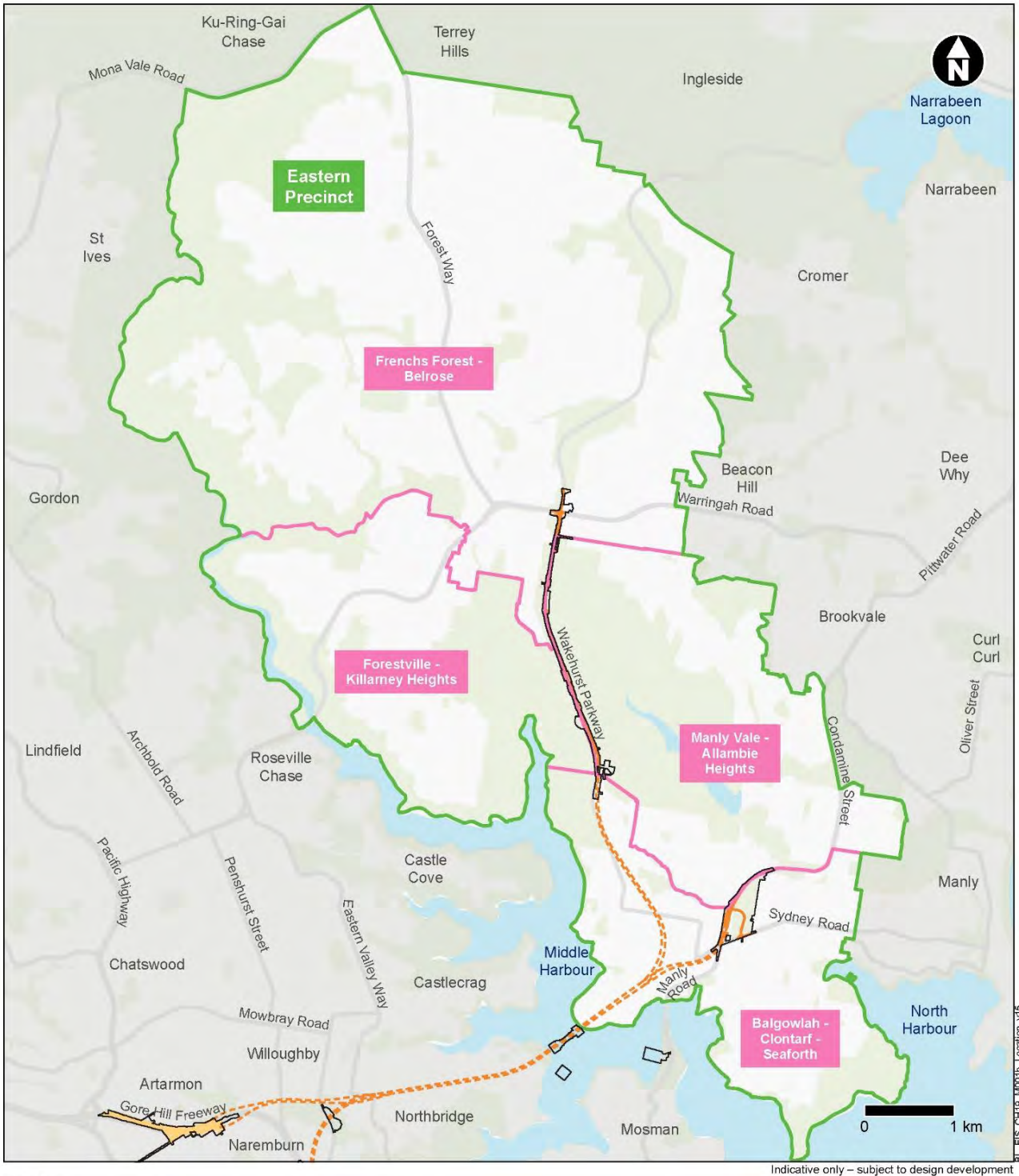


Figure 21-2 Eastern Precinct

21.2.2 Business surveys

A business impact survey was used to inform the business impact assessment to gain a better understanding of the main issues, perceptions and concerns of businesses regarding the project during both construction and operation. The business surveys were conducted in business centres that may be more susceptible to direct or indirect effects of construction and/or operation. All information gathered as part of the business surveys was collated into a database, analysed and summarised in a survey report. Further details are provided within the business impact assessment in Annexure A of Appendix U (Technical working paper: Socio-economic assessment). Further engagement with business stakeholders will be carried out during the environmental impact assessment exhibition period.

21.2.3 Stakeholder consultation

Community and stakeholder engagement, including consultation with relevant land owners (such as the Port Authority of NSW and land owners whose property is being acquired), local communities, businesses and government agencies, has informed the project's development. The socio-economic assessment has been informed by the outcomes of this engagement, including the identification of existing features and values important to the communities considered, and assessment of potential benefits and impacts of the project.

Further details regarding consultation carried out for the project (up to exhibition of the environmental impact statement) is provided in Chapter 7 (Stakeholder and community engagement).

21.2.4 Assessment approach

The socio-economic impact assessment involved identifying, assessing and evaluating changes to, or impacts on, communities, businesses and industry that are likely to occur as a result of the project. The assessment involved:

- Scoping the likely range of potential socio-economic impacts and identifying businesses and communities likely to be affected by the project
- Describing existing socio-economic and business characteristics, values and conditions in the study area. The description of existing socio-economic conditions principally draws on information from the ABS Census of Population and Housing 2016, supplemented with information and data from other publicly available sources and project specialist investigations
- Identifying and evaluating changes to existing socio-economic and business conditions and values in the study area due to the project's construction and operation. Positive and negative social and economic impacts are discussed; however, only negative impacts are assigned a level of significance, in accordance with the process outlined in the Practice Note. The level of significance of potential negative impacts was assessed by considering the sensitivity of the receptor and the magnitude of the proposed works. An evaluation matrix was used to identify the level of significance of the negative impact. Further information on the evaluation matrix is provided in Section 21.2.5. Positive impacts are qualitatively discussed but have not been assigned a level of significance using the evaluation matrix. The assessment considered potential project benefits and impacts relating to:
 - Property impacts, including impacts of property acquisition and temporary lease of property for construction
 - Equity, including the distribution of project benefits and impacts
 - Potential changes to population and demography
 - Employment, including direct and indirect employment impacts
 - Business and industry, including from direct property impacts and changes in the local business environment

- Social infrastructure, including from property acquisition, temporary lease of land, and changes in local access and connectivity and amenity
- Community values, including changes to local amenity, community cohesion, local character and identity, health and safety, and environmental and natural features
- Changes to access and connectivity, including for pedestrians, cyclists, public transport users, maritime transport users, and motorists
- Identifying measures to avoid, minimise or mitigate impacts on communities and community infrastructure and business and industry arising from the project.

21.2.5 Evaluation of significance

Potential negative impacts during project construction and operation have been considered using Table 21-2. The level of significance was determined with consideration of the sensitivity of the existing environment and magnitude of impact compared to the baseline condition. For the methodology adopted, a level of significance has only been assigned to potential negative impacts. Appendix U (Technical working paper: Socio-economic assessment) outlines what qualities contribute to the level of sensitivity for a receiver. The magnitude of an impact is dependent on its scale, intensity, duration and scope of works. When assessing the level of significance of negative impacts, consideration was given to:

- The range of potential direct and indirect impacts during construction and operation
- Cumulative impacts with other projects.

Table 21-2 Assessing the level of significance

		Magnitude			
		High	Moderate	Low	Negligible
Sensitivity	High	High impact	High-moderate impact	Moderate impact	Negligible impact
	Moderate	High-moderate impact	Moderate impact	Moderate-low impact	Negligible impact
	Low	Moderate impact	Moderate-low impact	Low impact	Negligible impact
	Negligible	Negligible impact	Negligible impact	Negligible impact	Negligible impact

21.3 Existing environment

This section provides an overview of the socio-economic characteristics of the two precinct areas assessed with regards to demographic profiles and housing, social infrastructure, community values, employment centres, and access and connectivity.

The existing environment with regard to traffic and transport, noise and vibration, air quality, human health, land use and property and urban design and visual amenity are outlined in Chapter 8 (Construction traffic and transport), Chapter 9 (Operational traffic and transport), Chapter 10 (Construction noise and vibration), Chapter 11 (Operational noise and vibration), Chapter 12 (Air quality), Chapter 13 (Human health), Chapter 20 (Land use and property) and Chapter 22 (Urban design and visual amenity).

21.3.1 Demographic profile

Table 21-3 provides a summary of the demographic profile of the precinct areas. This information has been sourced from the Australian Bureau of Statistics Census 2016.

Table 21-3 Demographic information for precincts

Characteristics	Western Precinct	Eastern Precinct
Population size and growth	<ul style="list-style-type: none"> Population of about 122,694 in 2019 Annual average growth of 1.5 per cent (2014-2019). 	<ul style="list-style-type: none"> Population of about 79,838 in 2019 Annual average growth of 0.7 per cent (2014-2019).
Age profile	<ul style="list-style-type: none"> Slightly higher proportion of residents 65 years and older (about 15 per cent) when compared to Greater Sydney (about 14 per cent) An equal proportion of residents within the young working family of 15-64 years (about 67 per cent) when compared to Greater Sydney (about 67 per cent) A slightly lower proportion of residents under the age of 14 years (about 18 per cent) when compared to Greater Sydney (about 19 per cent). 	<ul style="list-style-type: none"> Higher proportion of residents 65 years and older (about 17 per cent) when compared to Greater Sydney (about 14 per cent) A lower proportion of residents within the young working family of 15-64 years (about 60 per cent) when compared to Greater Sydney (about 67 per cent) A higher proportion of residents under the age of 14 years (about 23 per cent) when compared to Greater Sydney (about 19 per cent).
Cultural diversity	<ul style="list-style-type: none"> About 40.6 per cent of residents were born overseas and 29.9 per cent of people spoke a language other than English Greater Sydney recorded a lower proportion of people born overseas (about 36.8 per cent) and a higher proportion of people who spoke a language other than English (about 35.8 per cent). 	<ul style="list-style-type: none"> About 29.8 per cent of residents were born overseas and 16.4 per cent of people spoke a language other than English Greater Sydney recorded a higher proportion of people born overseas (about 36.8 per cent) and a higher proportion of people who spoke a language other than English (about 35.8 per cent).
Vulnerability/ need for assistance	In 2016, about three per cent of residents needed assistance, compared to about five per cent for Greater Sydney.	In 2016, about 3.7 per cent of residents needed assistance, compared to about five per cent for Greater Sydney.
Dwellings	<ul style="list-style-type: none"> In 2016, there were about 46,734 private dwellings, 48.4 per cent of which were apartment style dwellings, which was higher than the Greater Sydney average (25.9 per cent) Apartment style dwellings were the primary form of housing. 	<ul style="list-style-type: none"> In 2016, there were about 26,061 private dwellings, 13.1 per cent of which were apartment style dwellings, which was lower than the Greater Sydney average (25.9 per cent) Separate houses were the primary form of housing, contributing 71.4 per cent compared to Greater Sydney's 52.5 per cent.

Characteristics	Western Precinct	Eastern Precinct
Vehicle ownership	Of occupied private dwellings: <ul style="list-style-type: none"> About 13.1 per cent did not own a vehicle About 46.9 per cent owned one vehicle About 37.7 per cent owned two or more vehicles. 	Of occupied private dwellings: <ul style="list-style-type: none"> About 4.5 per cent did not own a vehicle About 31.6 per cent owned one vehicle About 61.6 per cent owned two or more vehicles.
Income	Higher personal (\$1172 per week) and household median (\$2423 per week) incomes compared to Greater Sydney (\$719 per week and \$1750 per week respectively).	Higher personal (\$895 per week) and household median (\$2419 per week) incomes compared to Greater Sydney (\$719 per week and \$1750 per week respectively).
Employment	<ul style="list-style-type: none"> Lower rate of unemployment (4.5 per cent) compared to Greater Sydney (6.0 per cent) In 2016, the top four employment industries within the precinct areas included: <ul style="list-style-type: none"> Health care and social assistance Professional, scientific and technical services Retail trade Education and training. 	<ul style="list-style-type: none"> Lower rate of unemployment (3.8 per cent) compared to Greater Sydney (6.0 per cent) In 2016, the top four employment industries, within the precinct areas included: <ul style="list-style-type: none"> Health care and social assistance Professional, scientific and technical services Retail trade Education and training.
Travel to work	For employed residents within the precinct: <ul style="list-style-type: none"> About 39.8 per cent drove to work in a car as either driver or passenger About 28.4 per cent used public transport to get to work (via rail or bus) About 7.8 per cent used active transport (walked and/or cycled). 	For employed residents within the precinct: <ul style="list-style-type: none"> About 57 per cent drove to work in a car as either driver or passenger About 14 per cent used public transport to get to work (via rail or bus) About 3.6 per cent used active transport (walked and/or cycled).

21.3.2 Social infrastructure

Social infrastructure in the precinct areas

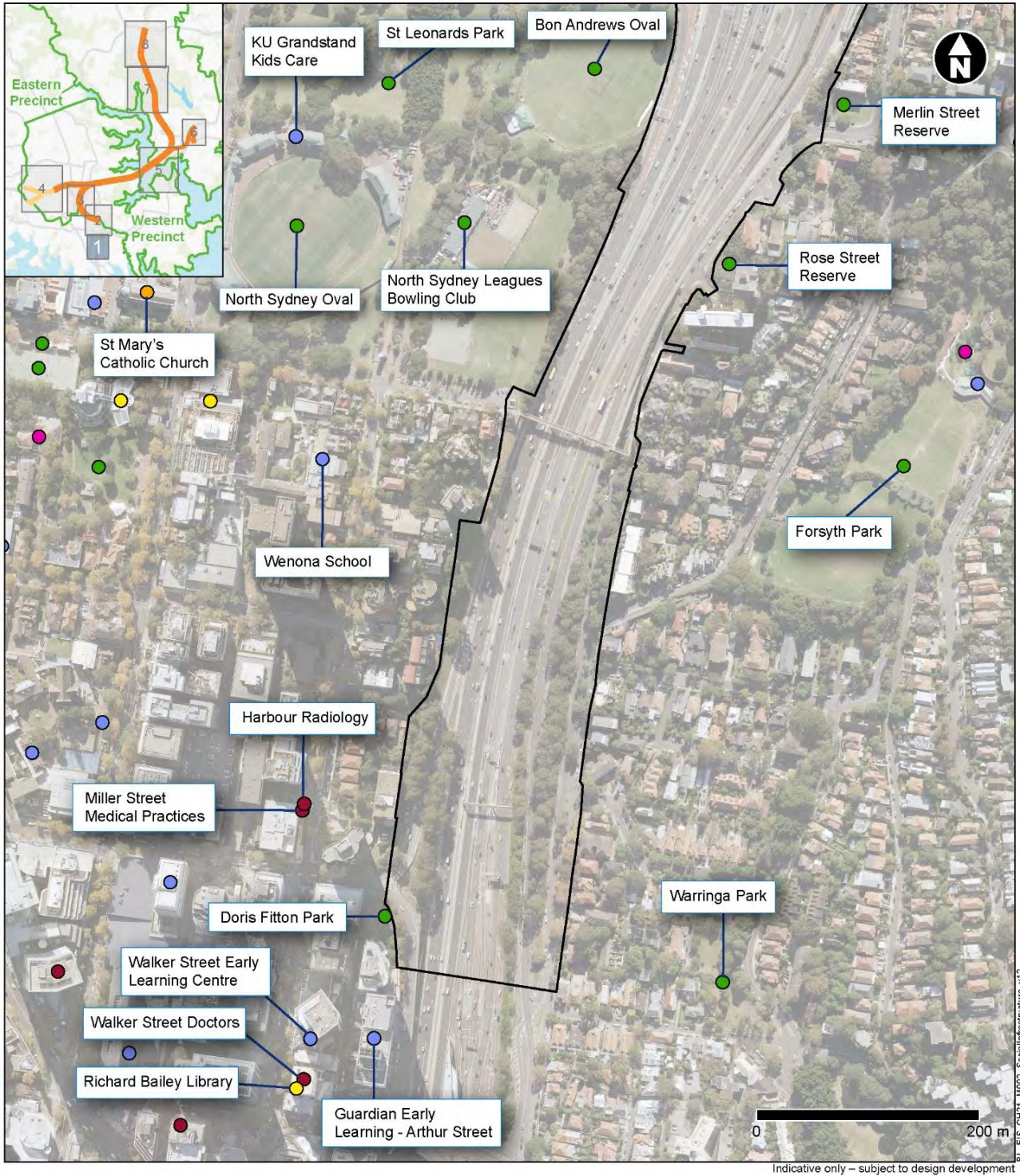
The precinct areas accommodate a wide range of community services and facilities of local and regional importance including education facilities; health, medical and emergency services; sport, recreation, cultural and leisure facilities; and community facilities. Consideration has also been given to social infrastructure within local government areas where required. These include, but are not limited to:

- Major hospitals such as the Mater Hospital at North Sydney, Royal North Shore and North Shore Private hospitals at St Leonards and the Northern Beaches Hospital at Frenchs Forest
- Tertiary education facilities, including TAFE NSW (at St Leonards and Brookvale) and the Australian Catholic University North Sydney Campus

- Regional and state sport and recreation facilities, such as Garigal National Park, which includes numerous bush walking tracks, Artarmon Reserve, Gore Hill Park, Naremburn Park, Flat Rock Reserve, Bicentennial Reserve and golf courses, including Cammeray Golf Course, Wakehurst Golf Course, Northbridge Golf Course and Balgowlah Golf Course
- Major retail, commercial uses, cultural and community support facilities located within the North Sydney, Mosman, Willoughby and Northern Beaches local government areas.

Social infrastructure near the project

Social infrastructure located near surface works and construction activities is shown in Figure 21-3 to Figure 21-10.



Legend

Construction features

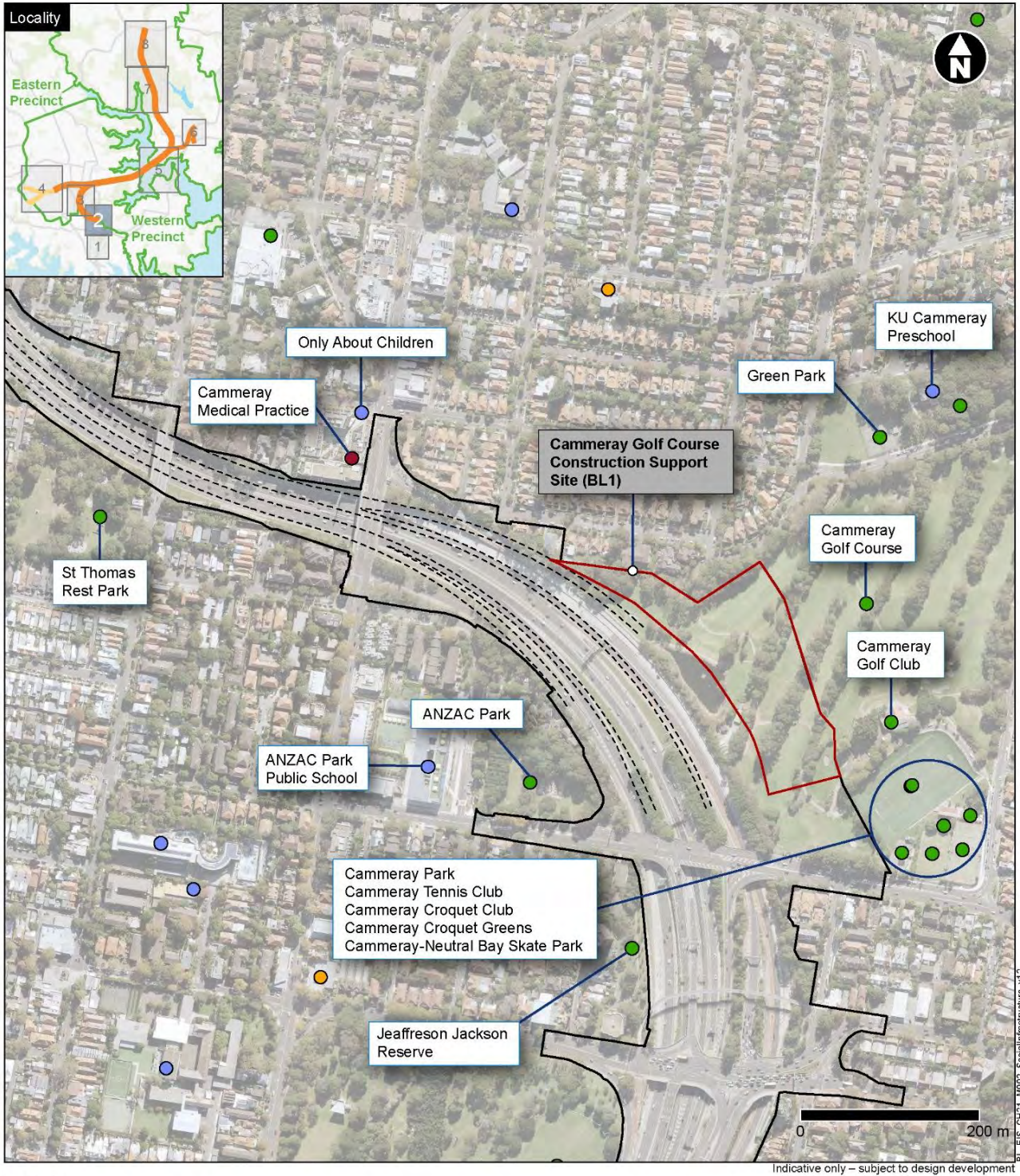
- Tunnel section
- ▭ Construction footprint

Social infrastructure

- Aged care
- Community centre
- Library and performing arts
- Education and child care
- Health, medical and emergency services
- Places of worship
- Sport, recreation and leisure facilities

Figure 21-3 Social infrastructure near the project (map 1)

Note: The Beaches Link construction footprint within this area extends to include low impact construction activities that would be associated with traffic control and management, line marking, tie-in works, and utility and cable works.



Legend

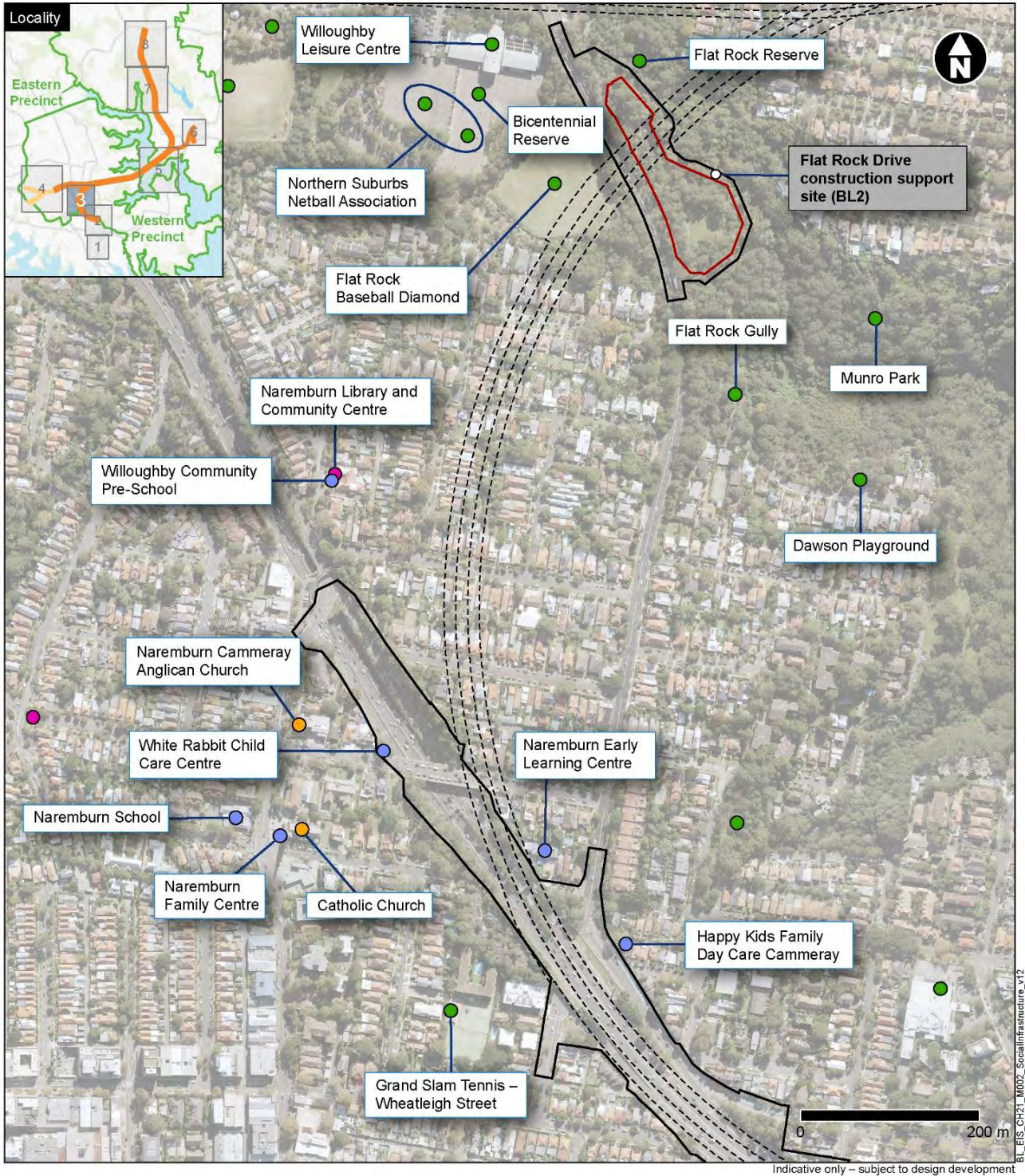
Construction features

- Tunnel section
- ▭ Construction footprint
- ▭ Construction support site

Social infrastructure

- Community centre
- Education and child care
- Health, medical and emergency services
- Places of worship
- Sport, recreation and leisure facilities

Figure 21-4 Social infrastructure near the project (map 2)



Legend

Construction features

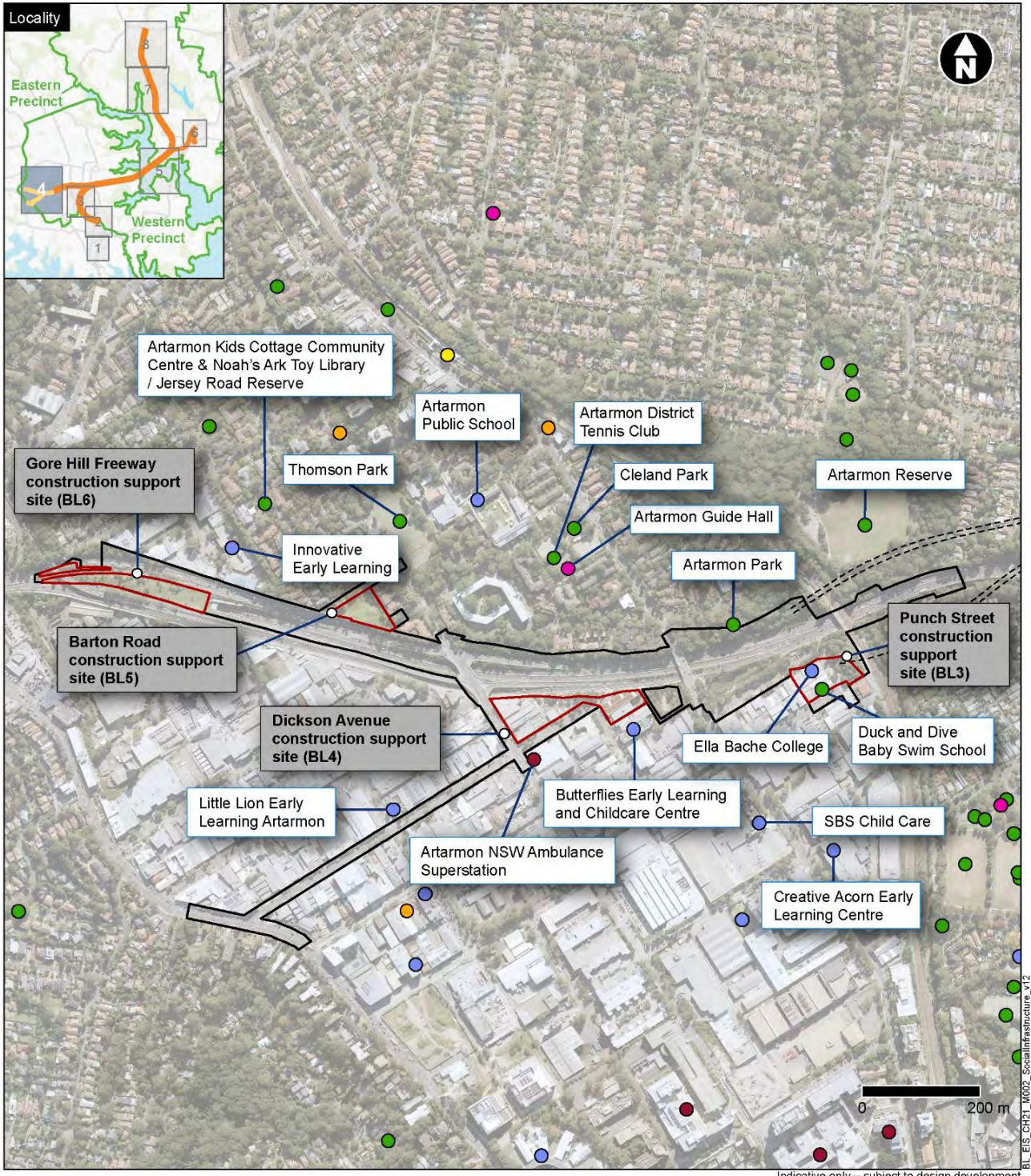
- Tunnel section
- ▭ Construction footprint
- ▭ Construction support site

Social infrastructure

- Community centre
- Library and performing arts
- Education and child care
- Places of worship
- Sport, recreation and leisure facilities

Figure 21-5 Social infrastructure near the project (map 3)

Note: The Beaches Link construction footprint shown on Warringah Freeway within this area extends to include construction activities that would be associated with traffic control and management, line marking, tie-in works and utility and cable works.



Legend

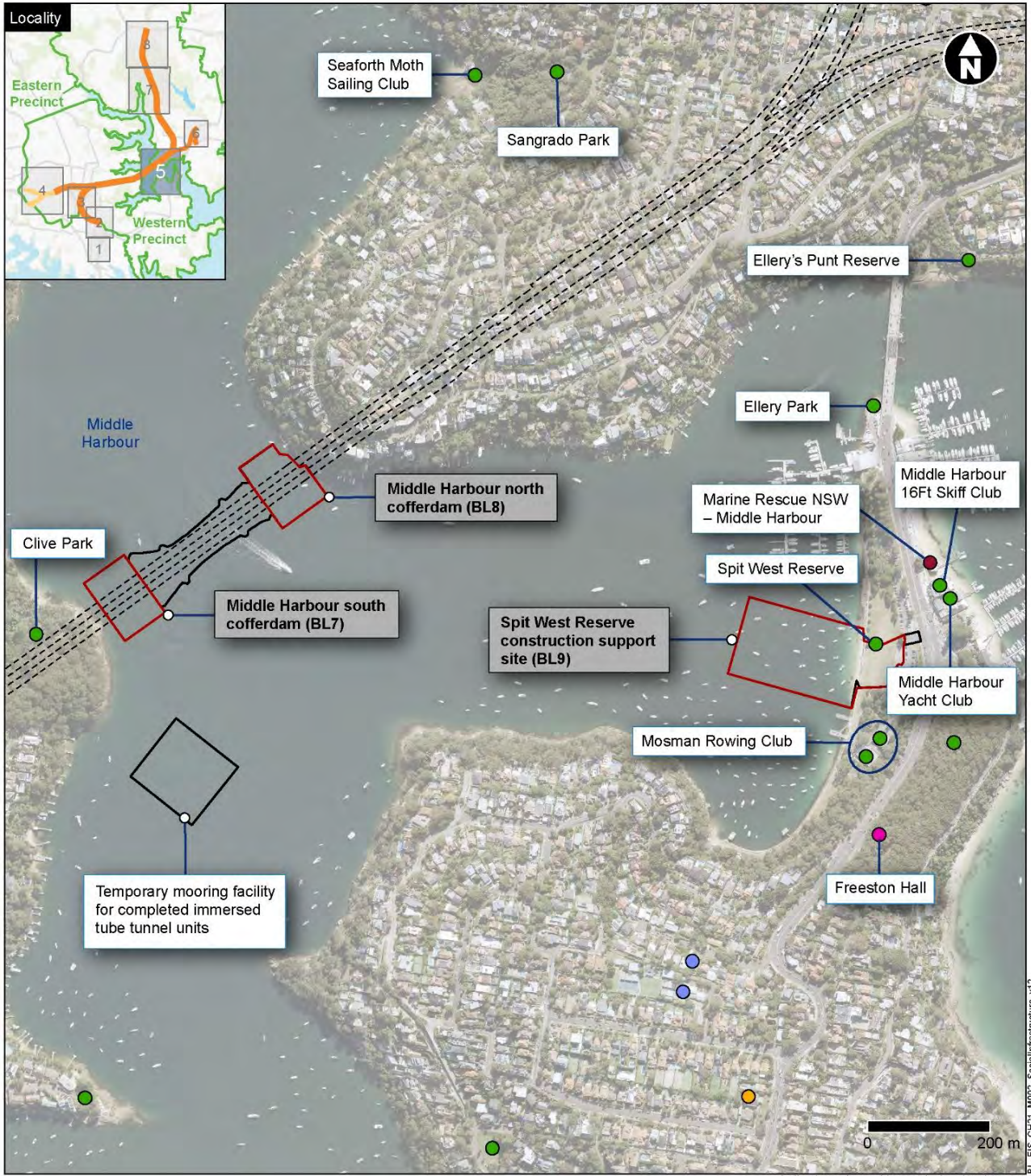
Construction features

- Tunnel section
- ▭ Construction footprint
- ▭ Construction support site

Social infrastructure

- Community centre
- Library and performing arts
- Education and child care
- Health, medical and emergency services
- Places of worship
- Sport, recreation and leisure facilities

Figure 21-6 Social infrastructure near the project (map 4)



Legend

Construction features

- Tunnel section
- ▭ Construction footprint
- ▭ Construction support site

Social infrastructure

- Community centre
- Education and child care
- Places of worship
- Sport, recreation and leisure facilities
- Health, medical and emergency services

Figure 21-7 Social infrastructure near the project (map 5)



Legend

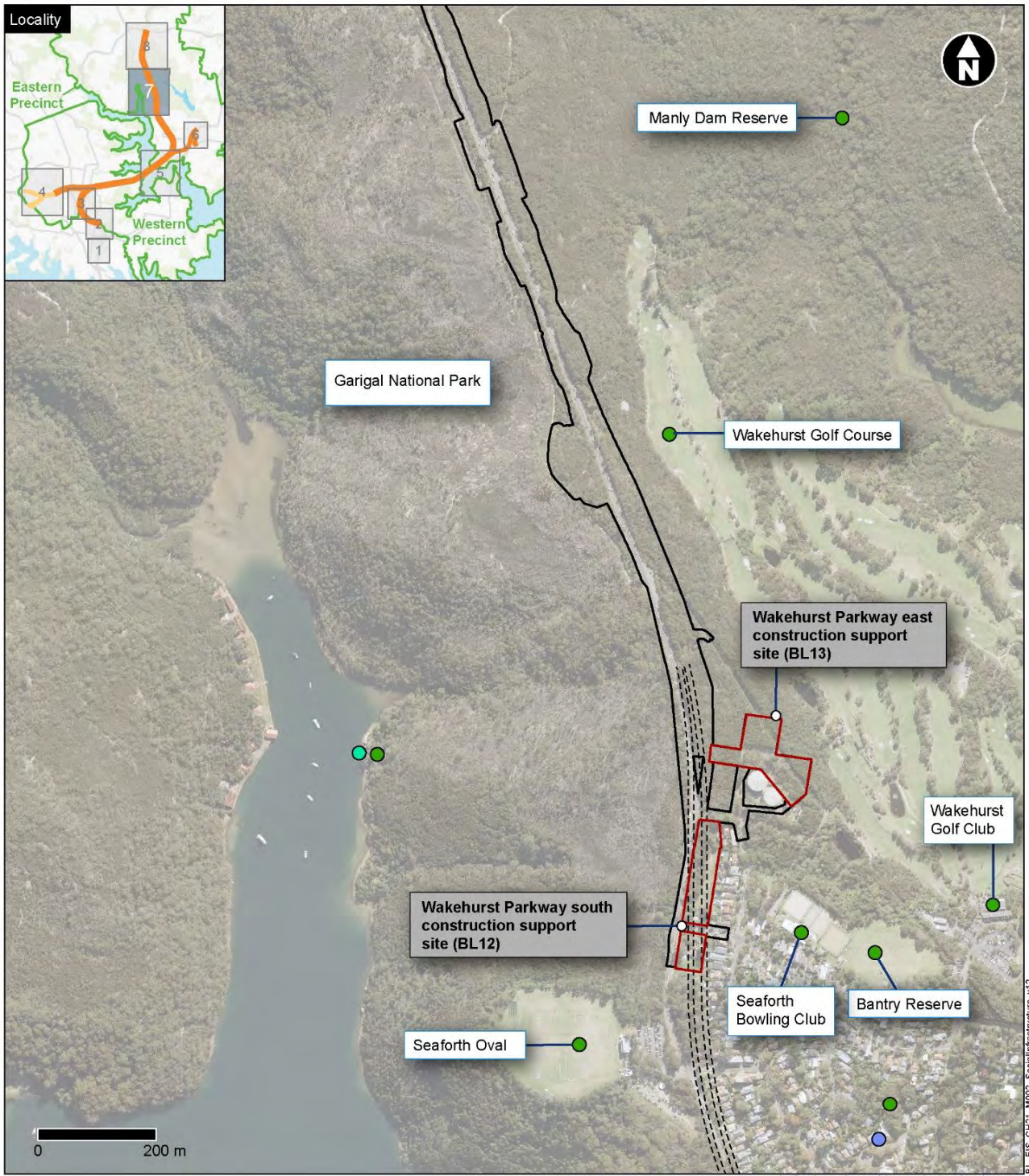
Construction features

- Tunnel section
- ▭ Construction footprint
- ▭ Construction support site

Social infrastructure

- Community centre
- Education and child care
- Health, medical and emergency services
- Places of worship
- Sport, recreation and leisure facilities

Figure 21-8 Social infrastructure near the project (map 6)



Legend

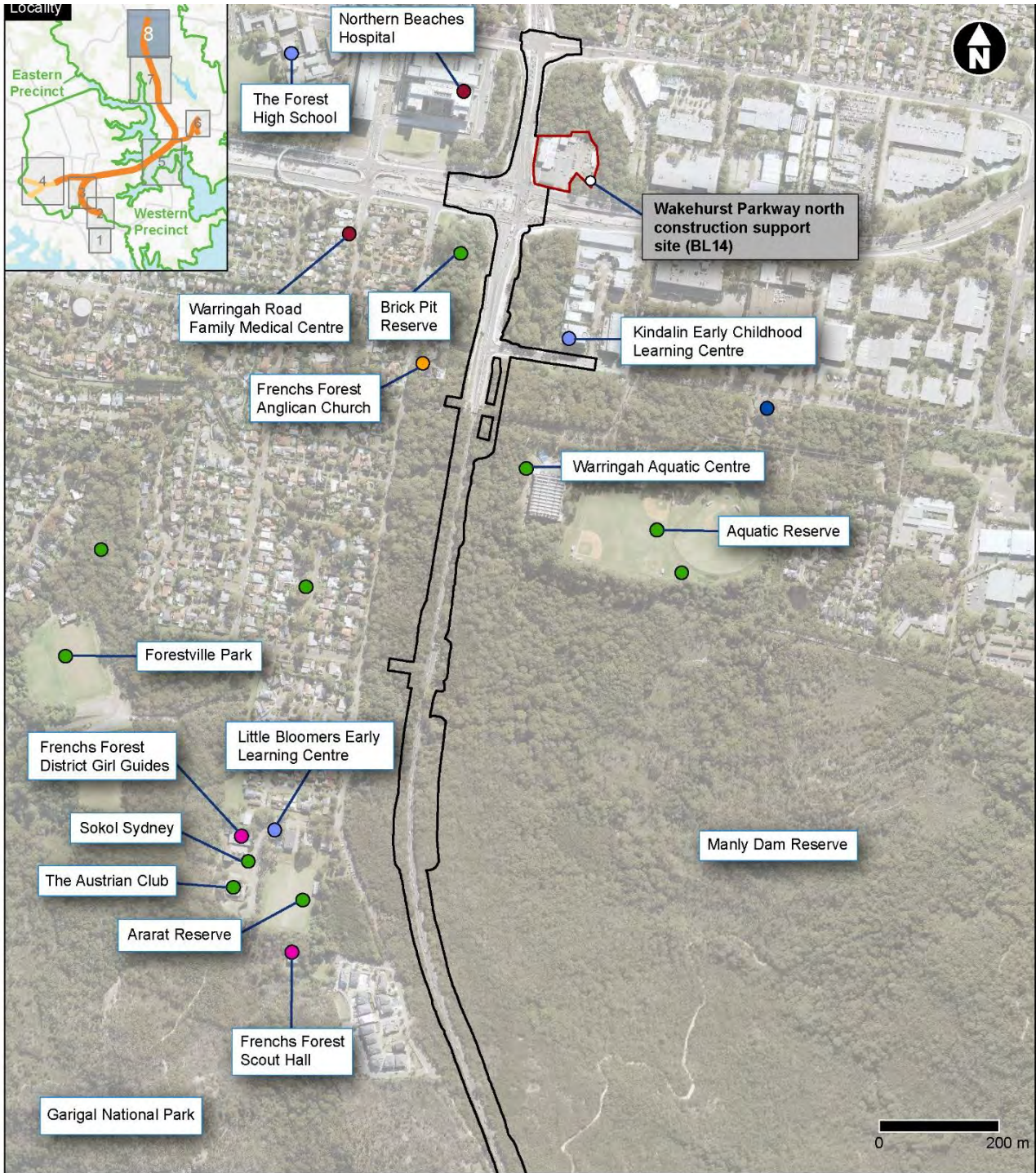
Construction features

- Tunnel section
- ▭ Construction footprint
- ▭ Construction support site

Social infrastructure

- Education and child care
- Sport, recreation and leisure facilities
- Wharf

Figure 21-9 Social infrastructure near the project (map 7)



Indicative only – subject to design development

Legend

Construction features

- Tunnel section
- ▭ Construction footprint
- ▭ Construction support site

Social infrastructure

- Aged care
- Community centre
- Education and child care
- Health, medical and emergency services
- Places of worship
- Sport, recreation and leisure facilities

Figure 21-10 Social infrastructure near the project (map 8)

Middle Harbour community uses

The Middle Harbour accommodates a wide range of community users, community groups and clubs. These are described in Section 8.3.4 of Chapter 8 (Construction traffic and transport).

21.3.3 Community values

This section provides an overview of those values or features within the precinct areas that are likely to be important to local and regional communities within Greater Sydney. This has been informed by the review of existing literature (including council planning and strategy documents), assessment of places likely to be important to community members such as open space, heritage places and recreation facilities, review of community and stakeholder engagement outcomes and observations of the precinct areas.

Local amenity and character

Community values relating to local amenity and character refer to natural and physical qualities and characteristics that contribute to a person's appreciation of their surroundings. They relate to such things as built form and landscape, environmental conditions (such as existing noise levels and air quality), and heritage and cultural features.

Local amenity and character in the precinct areas are generally characterised by a diversity of land and water-based uses including:

- Pockets of high-density residential areas within the Western Precinct, such as at Chatswood and Artarmon, and pockets of medium-density residential at Cremorne and Cammeray
- Predominantly low-density residential areas within the Eastern Precinct, such as at Killarney Heights, Forestville, Allambie Heights, Balgowlah and Frenchs Forest
- Industrial uses at Artarmon adjacent to the Gore Hill Freeway and Pacific Highway
- Local centres and shopping precincts within both precincts, including major shopping centres at Chatswood
- Tourist attractions, such as Taronga Zoo in Mosman
- Parks and recreational facilities such as Cammeray Golf Course, Northbridge Oval, Bicentennial Reserve, Northbridge Golf Course, Balgowlah Golf Course, Wakehurst Golf Course, Waverton Park and Seaforth Oval
- Water based recreational activities and sporting clubs based on Middle Harbour
- Major social infrastructure such as hospitals (including the Royal North Shore Hospital, North Shore Private Hospital and Northern Beaches Hospital), educational uses and cultural facilities (such as places of worship, community centres and libraries)
- Open space areas, reserves and parks that are valued by local and regional communities for their landscape amenity, heritage and recreational values. These include Sydney Harbour National Park, Bradleys Head, Middle Head, Artarmon Park, Flat Rock Reserve, Clive Park, Spit West Reserve, Clontarf Beach and Reserve, Garigal National Park, Manly Dam Reserve and Dobroyd Head.

Community cohesion

Community cohesion refers to the connections and relationships between individuals, groups and neighbourhoods, and is encouraged by the existence of local social infrastructure, a sense of local identity, and opportunities for community participation. Levels of community cohesion and sense of belonging in the communities surrounding the project are expected to be good, with communities having access to a diverse range of local and regional level social infrastructure, strong support networks and a variety of meeting places such as sporting clubs, cafes and local centres that foster and support social interaction.

Community cohesion is also encouraged by connectivity or discouraged by barriers to movement as described in Chapter 20 (Land use and property). Many road corridors and arterial roads within the study area create existing barriers, both real and perceived, to local movement and connectivity within the study area and form boundaries to neighbourhoods, pedestrian and cycle movements and to some local centres. This may influence some people's ability or desire to move through the study area, impacting on their access to services, meeting places and participation in social networks.

Community and social networks are associated with social infrastructure such as schools, places of worship, sporting clubs, water-based clubs at Middle Harbour, and community, environmental, heritage and resident groups. Many of these community and social networks are long-standing and are supported by contributions from volunteers, which further strengthen community cohesion.

Communities in the precinct areas host a variety of local events, including festivals, exhibitions and markets. These provide opportunities to involve local communities and for residents to connect with and participate in community life, helping to foster a sense of community and local identity. These include:

- Local festivals, such as the North Sydney Children's Festival, Emerge Festival at Chatswood and the Festival of Mosman
- Cultural and sporting events, such as the Twilight Food Festival, Spring into Jazz at North Sydney, Sydney Harbour Regatta, Eurofest at Frenchs Forest and Mini-Mos Community Fun Run and Fair
- New Year's Eve, Chinese New Year and Australia Day celebrations
- Weekly and monthly farmer's markets and arts markets, including at North Sydney, Chatswood, Cammeray, Mosman and Frenchs Forest.

Community health and wellbeing

Maintaining a high level of community safety and ensuring people feel safe in public places is likely to be important to communities in the precinct areas. This is anticipated due to concerns raised during community and stakeholder engagement for the project regarding road safety and perceived safety impacts associated with locating construction works or operational infrastructure near local streets and social infrastructure. Concerns were also raised by the community regarding air quality during the operation of the project and potential impacts for local communities, schools and park users near tunnel portals and ventilation outlets. In particular, concerns in relation to the location of the tunnel portals and ventilation outlets and potential air quality impacts for school students and users of open space areas such as Artarmon Public School, Artarmon Park and Balgowlah Golf Course.

21.3.4 Business profile

Business centre profiles

A hierarchy of business centres has been applied to the precinct areas based largely on the hierarchy established in the *Greater Sydney Region Plan* by the Greater Sydney Commission, which identifies three types of centres: metropolitan city centres, strategic centres and local centres. There are no metropolitan city centres in the precinct areas. Chatswood, St Leonards and Frenchs Forest are strategic centres and there are several local centres. These are generally clustered on the main transport routes (such as rail corridors or bus routes) and provide either a specialist service to the broader area or a convenience service for the local community. Some business centres are also within the precinct areas for the Western Harbour Tunnel and Warringah Freeway Upgrade project. A summary of businesses within local centres within each precinct is provided in Table 21-4. Businesses that operate outside of business and industrial zones have not been overviewed in the existing environment description (Section 21.3); however, these have been considered in the assessment of impacts (refer to Section 21.4.7 and Section 21.5.6).

Table 21-4 Summary of business centres

Centre	General description
Western Precinct	
Miller Street, Cammeray	Commercial offices, food and beverage retailers, sports clubs and accommodation services, serving local residents as well as commuters and those visiting for work. Commercial businesses are not likely to rely on passing trade however retail businesses would have some reliance on passing trade.
Military Road Centre, Cremorne	Commercial offices, food and drink retailers, sports clubs and accommodation services, serving local residents as well as commuters and those visiting for work. It includes a car dealership, medical centre and mixed use building. The commercial businesses are not likely to rely on passing trade however retail businesses would have some reliance on passing trade. The car dealership is a destination business, while the medical centre services a neighbourhood catchment. The mixed use spaces service a local neighbourhood and further afield, depending on the businesses using the space.
Military Road Centre, Mosman	A wide variety of businesses including retail and commercial uses. Retail businesses include cafes and restaurants as well as boutique clothing stores. Commercial businesses include interior design and personal services businesses. There are also 'neighbourhood shops' such as convenience stores and pharmacies. The centre caters primarily to a neighbourhood catchment. Commercial businesses are not likely to rely on passing trade however retail businesses would have some reliance on passing trade.
Spit Junction Centre	A wide variety of businesses spanning retail and commercial uses as well as Mosman Council buildings. Retail businesses include cafes and restaurants and clothing stores. Commercial businesses include medical and gym/fitness businesses. Some businesses such as speciality retailers, service both a neighbourhood and wider catchment and are unlikely to be dependent on passing trade. These businesses are destination services as many customers would drive specifically to the businesses. Others, such as cafes, restaurants and medical businesses, cater primarily to a neighbourhood catchment and would have some reliance on passing trade. Large format retailers are also located at Spit Junction including a car dealership and furniture shops and smaller commercial premises (eg allied health services, professional suites, car wash and cafes).
The Spit Centre	A number of maritime related businesses and a small number of commercial businesses. Maritime businesses using The Spit includes three marinas, cafes and restaurants, boat rentals/sales, a commercial diving operation and Middle Harbour Yacht Club. These businesses are primarily destination services as many customers would drive specifically to the businesses. They also service local residents and visitors who visit to enjoy the amenity of the area.
Artarmon Industrial Centre	A large number of automotive businesses (vehicle sales, rental and repair) and film related businesses as well as construction related commercial businesses (such as equipment sale and hire). It includes a gym and fitness facilities, warehouse/storage facilities and commercial businesses. Businesses located in the centre are destination stores as many customers would drive specifically to the businesses and they are unlikely to be dependent on passing trade.

Centre	General description
Eastern Precinct	
Balgowlah Centre	A large shopping centre including retail and commercial businesses. The centre includes clothing, homeware and retail businesses as well as a large supermarket and other food retailers along with commercial businesses such as travel agents, a gym/fitness centre, personal services businesses, and a car wash located in the underground carpark. There are cafes and restaurants, as well as some commercial offices and retail stores, located along Sydney Road. The centre caters primarily to a neighbourhood catchment and would have some reliance on passing trade.
Seaforth Centre	Retail businesses include cafes and restaurants and commercial businesses including estate agents, a veterinary hospital and personal services businesses. A variety of 'neighbourhood shops' such as a post office, Bupa aged care facility and Balgowlah RSL Club are also in this area. The centre caters primarily to a neighbourhood catchment and would have some reliance on passing trade.
Manly Vale Business Centre	A variety of retail businesses (such as cafes, takeaways and restaurants, clothing stores, a pharmacy and homewares stores) and commercial businesses (such as interior designers, professional services businesses, personal services businesses, a doctor's surgery and a cluster of surfboard manufacturers). Some businesses, such as the pharmacy, doctor's surgery and cafes, serve a neighbourhood catchment while those such as interior designers and surfboard manufacturers are destination services as many customers would drive specifically to the businesses. The centre also includes commercial and retail businesses that are largely characterised by having large floorplates, for example supermarkets, furniture stores, wholesalers, hardware stores, construction businesses and specialist retailers. Most businesses in this centre are destination services as customers would drive specifically to the business. Businesses would have some reliance on passing trade.
Forestway Shopping Centre, Frenchs Forest	A large shopping centre comprising retail and commercial businesses such as clothing and homeware retail businesses, a large supermarket and food retailers, cafes and restaurants. The centre also includes commercial businesses such as banks, travel agents, a gym/fitness centre and personal services businesses. There is also a car wash located next to the main building. The centre caters primarily to a neighbourhood catchment and would have some reliance on passing trade.
Frenchs Forest Business Hub Centre	Commercial businesses including corporate offices, gym/fitness centres, sports facilities, storage facilities/warehouses, medical laboratories and distribution centres. It includes bulky goods retailers such as homeware and furniture stores. Many businesses in the centre, such as commercial offices and distribution centres, would not receive customers visiting their premises. Those that do, are destination services as many customers would drive specifically to the businesses. The gym/fitness centres cater mostly to employees working within the centre.

Centre	General description
Warringah Mall Shopping Centre, Brookvale	A large shopping centre consisting of retail (such as clothing, homewares, and food retailers) and commercial businesses (such as travel agents, banks, insurance companies and personal services businesses). There are cafes and restaurants located within a food court and throughout the shopping centre, and a car wash within the carpark. The centre caters primarily to a neighbourhood catchment with some customers travelling from further away, including from the wider Northern Beaches.
Austlink Business Park, Belrose	A diverse range of uses in the Austlink Business Park. Commercial businesses include corporate offices, gym/fitness centres, storage facilities/warehouses and distribution centres. It includes bulky goods retailers such as hardware, homeware and furniture stores. Many businesses in the industrial complex such as commercial offices and distribution centres would not receive customers. Those that do are destination services with customers driving specifically to the businesses. The gym/fitness centres cater mostly to employees working within the centre.

It is noted that, while in or close to the study area, the centres of Warringah Mall and Austlink Business Park were not considered to be directly influenced by the project and were not specifically profiled as part of the business impact assessment (refer to Annexure A of Appendix U (Technical working paper: Socio-economic assessment)).

Maritime businesses

Businesses that rely on the Middle Harbour for operation include:

- Maritime: boat moorings, boat ramps, boat licensing, marine rescue, boat maintenance and repairs, tow boats, marina facilities and fuel services
- Tourism: harbour cruises, outdoor recreation and sporting activity operators, and hire facilities and recreational boat hire
- Commercial: commercial fishing movements (commercial fishing is not allowed in the harbour, however, boats travel in the harbour to moor and distribute catch), charter boats, science and research, refueling and water taxis.

Middle Harbour does not accommodate any major commercial shipping operations, with most of maritime traffic associated with recreational and sporting activities.

A number of boat launching facilities are also available for commercial use throughout Middle Harbour.

Businesses assessed

Businesses within the precinct areas are generally clustered on the main transport routes and provide either a specialist service to the broader area or a convenience service for the local community. The location of the business centres in proximity to the project are shown in Figure 21-11. The locations of temporary construction support sites are also shown, as businesses within close proximity may experience impacts. The precinct areas also contain a wide variety of businesses located outside of a business centre. The top three industries of employment are health care and social assistance; professional, scientific and technical services; and retail trade.

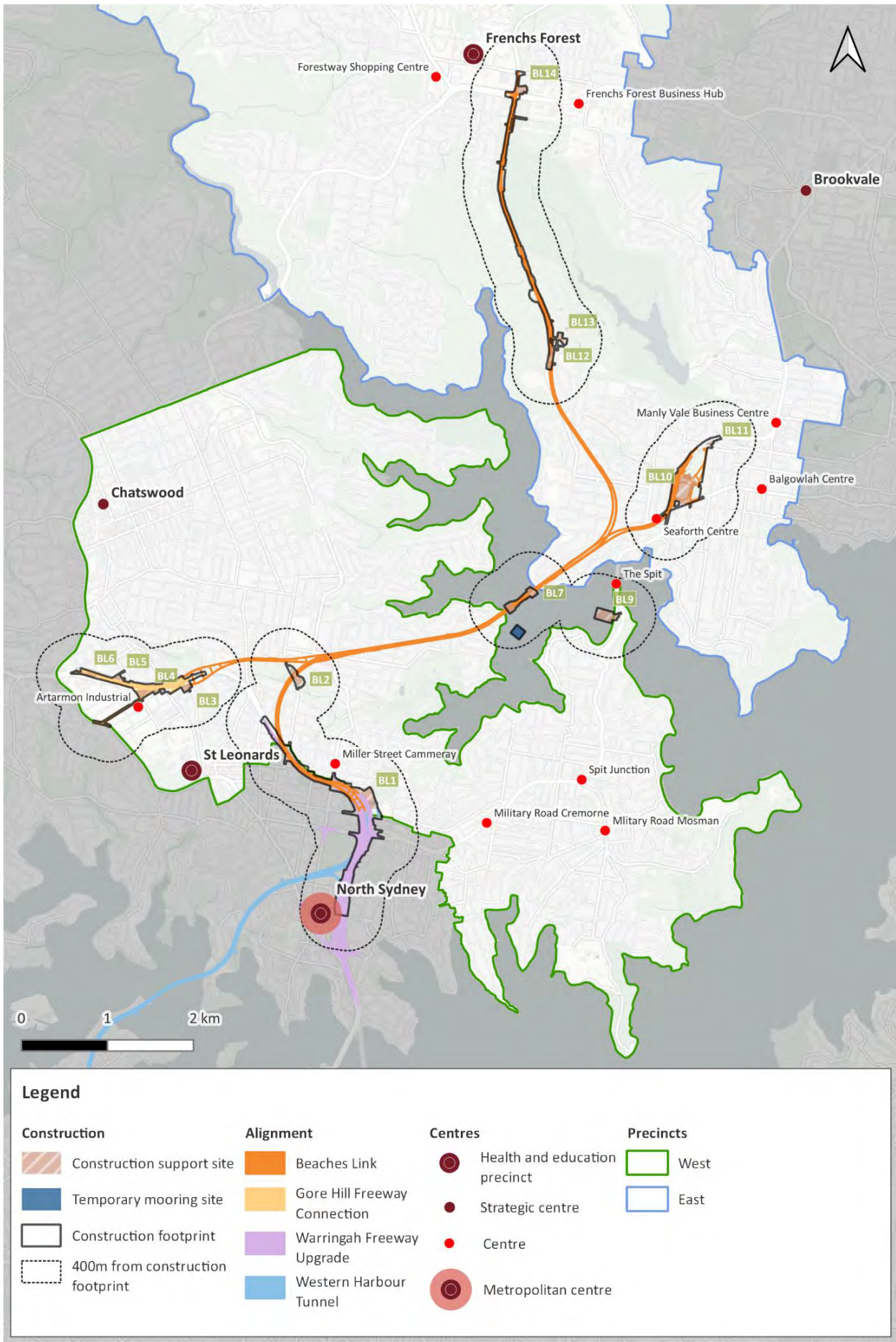


Figure 21-11 Business centres

Businesses survey results

Business survey results revealed that businesses in the area have varying degrees of sensitivity and dependency to project construction and operational aspects. Generally, there was a high perceived dependency (69 per cent) on vehicular passing trade, with 43 per cent of businesses surveyed as highly dependent. Sixty-six per cent of surveyed businesses perceived a dependency on pedestrian and cyclist passing trade. Changes in access to a centre, for example through congestion and changes in travel times (increases or decreases), may result in long-term changes to consumer and worker behaviour. The business survey found that 83 per cent of businesses perceived that they were sensitive to travel time delays, with 39 per cent of the respondents perceived to be majorly sensitive.

The majority of customers and employees surveyed use private vehicles as their primary transport mode. Fifty three per cent of businesses surveyed perceived that during the construction phase, the project would have no discernible positive or negative effects on travel time and access, with 46 per cent of respondents perceiving they would be affected negatively. However, upon operation, 63 per cent of business respondents perceived that the project would be positive for employee and customer access. The majority of businesses (65 per cent) perceived they were dependent on on-street parking, with 39 per cent of businesses recording major dependencies. The potential for the project to impact on deliveries and loading arrangements was also considered in the survey. The impact was considered by businesses to be neutral or positive with 60 per cent of businesses perceiving construction would have a neutral effect and approximately 54 per cent stating that the operation of the project would have a positive effect on servicing and delivery.

The potential for impacts from reduced exposure was perceived to be moderate, with 70 per cent of businesses dependent on business exposure and visibility and 47 per cent majorly dependent. Spit Junction and Frenchs Forest were the surveyed business centres that recorded the highest dependencies.

Changes to the local character and amenity of a place can affect the enjoyment and desirability of the environment, visitation numbers and trends, and consequently the economic activity of a commercial centre and the businesses located there. Overall, 82 per cent of businesses identified that they were dependent on the identity and character of the commercial centre they were located in, with 53 per cent majorly dependent. Fifty three per cent identified that they were dependent on a pleasant visual amenity, 11 per cent had a high sensitivity to noise, 16 per cent had a high sensitivity to air quality and 18 per cent had a high sensitivity to odour.

Overall, the business survey indicated that the majority of businesses perceived the project would have a neutral effect on demand for goods and services. The findings of the business survey assisted in determining the sensitivity of businesses and their ability to adapt and respond to project related changes to the socio-economic environment.

21.3.5 Access and connectivity

A detailed description of the existing traffic and transport environment surrounding the project is provided in Chapter 8 (Construction traffic and transport).

Road network

A number of major arterial roads are located near the project that provide access for communities to employment and infrastructure within the precinct areas, as well as for communities in the Greater Sydney region. Major arterial roads near the project include:

- Warringah Freeway, which passes through Naremburn, Cammeray, St Leonards and North Sydney and provides access to the Sydney CBD
- Pacific Highway, which passes through the precinct areas at Artarmon, St Leonards, Crows Nest and North Sydney
- Military Road, which provides access from North Sydney to Spit Road in Mosman

- Gore Hill Freeway, which passes through the Western Precinct at Artarmon, Naremburn and Willoughby and provides a connection to the Sydney CBD
- Lane Cove Tunnel, which passes through the Western Precinct at Artarmon and provides connectivity to the Sydney CBD and employment centres to the north-west such as Macquarie Park
- Eastern Valley Way/ Flat Rock Drive/ Brook Street, which passes through the Western Precinct at Naremburn and connects St Leonards, Willoughby and the Northern Beaches via Warringah Road
- Willoughby Road, which passes through the Western Precinct at Naremburn and Willoughby and connects St Leonards, Crows Nest and Chatswood (via Mowbray Road)
- Spit Road, which passes through Mosman and provides access to the Northern Beaches
- A8 Manly Road, which passes through Seaforth and provides connections to Mosman, Manly, the Northern Beaches (via Condamine Street/Pittwater Road) and the Forest District (via Frenchs Forest Road/ the Wakehurst Parkway)
- A8 Burnt Bridge Creek Deviation, which passes through Balgowlah and North Balgowlah and provides connections to Mosman, Manly, the Northern Beaches (via Condamine Street/Pittwater Road) and the Forest District (via Condamine Street/Allambie Road)
- Sydney Road, which passes through Balgowlah and Seaforth and provides connections to Seaforth and Manly
- The Wakehurst Parkway, which passes through Frenchs Forest and Killarney Heights and provides access to Seaforth, the Northern Beaches, the Northern Beaches Hospital precinct and the Forest District
- Warringah Road, which passes through Frenchs Forest and provides access to Chatswood, the Northern Beaches, the Northern Beaches Hospital precinct and the Forest District.

The Spit Bridge is also located within the study area. The bridge provides vehicle access between the Eastern and Western Precincts.

At the 2016 Census, car travel was the predominant mode of travel to work for residents in the precinct areas, with about 46.6 per cent of people aged 15 years or over using a car for all or part of their journey to work.

Public transport

Public transport modes across the precinct areas include rail, bus and ferry services. At the 2016 Census, bus transportation was the second preferred mode of transport across the precinct areas, carrying about 15.6 per cent of residents, followed by rail with about 7.2 per cent.

Further details for public transport services in the precinct areas are included in Chapter 8 (Construction traffic and transport).

Active transport

In 2016, walking and cycling were both common forms of active transport for commuters across the precinct areas, with about 6.1 per cent of residents walking or cycling to work. A number of shared user paths are located in the precinct areas, including separated off-road dedicated cycleways and dedicated on-road cycling lanes.

The pedestrian and cycle network is varied within the precinct areas. The Western Precinct offers off-road shared user paths at the following locations:

- Along the southern side of the Gore Hill Freeway
- Near Flat Rock Creek between Weedon Road and Flat Rock Drive
- Around Artarmon Reserve, Naremburn Park, Bicentennial Reserve and the Willoughby Leisure Centre

- Within Spit West Reserve and across Spit Bridge, connecting to the Spit Bridge to Manly Walk.

The Eastern Precinct offers off-road shared user paths at the following locations:

- Near Burnt Bridge Creek between Baringa Avenue and Condamine Street
- White Street, Lauderdale Avenue, The Crescent, Commonwealth Parade and Fairlight Walk between Balgowlah and Manly
- Shared user bridge connecting Karingal Crescent Reserve and Forest Way
- Between Wakehurst Parkway north of Warringah Road and Frenchs Forest Road East, to the west of Inverness Avenue
- Shared user bridge across Warringah Road west of the intersection of Forest Way
- Shared user bridge across Warringah Road on the western side of the intersection with Hilmer Street
- Shared user bridge connecting Warringah Aquatic Centre and Bantry Bay Road
- Allambie Road between Aquatic Drive and Eaton Square
- Manly Dam Bike Track within Garigal National Park.

Maritime transport

Middle Harbour maritime transport, access, users and restrictions as well as marinas, boat ramps and mooring fields are discussed in Chapter 8 (Construction traffic and transport), Section 8.3.4.

21.4 Assessment of potential construction impacts

Construction of the project would have the potential to affect the social and economic environment of the precinct areas. These potential impacts are assessed in this section.

21.4.1 Property impacts and acquisition.

The project has been designed to minimise the need for surface property acquisition. This has been done by locating road infrastructure in tunnels and, where possible, using government owned land for construction and operation of the project. Nonetheless, some property acquisition would be required to facilitate construction of the project.

Property acquisition and temporary leases

The project would require the full and partial acquisition of 46 properties. This includes temporary leases of land required for temporary construction support sites and other construction works. The tunnel alignment would also pass under numerous residential and commercial properties and social infrastructure. The nature of direct property impacts, including details of property acquisitions, temporary occupation of land is discussed further in Chapter 20 (Land use and property).

Some residents and communities near the project may experience a level of stress and anxiety due to uncertainty about potential property impacts, property acquisition and proposed changes that may be associated with the project. These concerns were raised by community members during consultation for the project.

Twenty-eight residential properties would be fully acquired for the project, requiring affected households to relocate prior to construction. Some individuals impacted by acquisition of residential properties may also experience impacts on health and wellbeing associated with disruptions to social networks and personal relationships associated with their permanent or temporary relocation or relocation of neighbours. These impacts are likely to have the greatest effect on groups such as elderly, people with a disability, longer term residents and people on lower incomes, who are often more reliant on personal and community networks.

Properties required for the project would be acquired by Transport for NSW in accordance with the provisions of the (NSW) *Property Acquisition (Just Terms Compensation) Act 1991* and the Land Acquisition Reform 2016 process. The *Property Acquisition (Just Terms Compensation) Act 1991* provides the basis for assessing compensation. Transport for NSW has started consultation with affected property owners about the acquisition process and potential adjustments required to properties. Consultation will continue through the project development.

The sensitivity of affected individuals and households are considered to be high. However, the magnitude of the change is considered to be moderate given the number of affected residential properties relative to residential properties in the vicinity of the project. As a result, the overall significance of potential impacts from the acquisition of residential properties is considered high-moderate.

Other property impacts

The mainline and ramp tunnels would pass beneath numerous properties, including residential, commercial, industrial and social infrastructure properties. Potential impacts of relatively deep tunnels on the use of properties and future development potential was raised during community consultation for the project. Under the *Property Acquisition (Just Terms Compensation) Act 1991*, compensation is generally not payable for acquisition of land under the surface unless the surface of the overlying soil is disturbed or the support of that surface is destroyed or affected by construction of the tunnels.

Potential impacts on future development above tunnels generally only occurs in locations where the tunnel depth is shallow, for example close to portals. The location of the portals and tunnels beneath properties is not expected to impact on the future use of development of properties at the surface along the alignment. Subject to council regulations and approvals, landowners would generally be able to:

- Carry out improvements, such as installing a swimming pool
- Dig deeper foundations for a new building or second storey additions.

The overall significance of potential impacts on future development of properties directly above the tunnels is considered negligible, with the sensitivity of affected properties considered to be moderate, and the magnitude of the change considered to be negligible.

Concerns were raised during community and stakeholder consultation about potential for property damage, including to basement car parks, unit developments and pools, due to vibration from tunnelling activities. During construction, some properties located above or near the tunnel alignment may experience short term vibration and ground-borne noise impacts due to the use of equipment such as rock hammers and road headers. For most properties, vibration levels would generally be below levels that may cause potential risk to buildings or structures, including minor cracking. However, there is potential for cosmetic damage risks to a small number of properties, particularly more sensitive heritage buildings, closest to vibration intensive construction activities. Further discussion about potential vibration impacts on buildings and structures is provided in Chapter 10 (Construction noise and vibration).

The excavation of tunnels has potential to result in settlement at the ground surface, potentially impacting properties above or near the project. Some buildings near the project may experience very slight cosmetic damage due to settlement (for example, fine cracks that are easily treated during normal decoration), although this is not expected to impact on the serviceability or stability of buildings which is discussed in Chapter 16 (Geology, soils and groundwater). It is noted that the potential for settlement has been assessed without design measures such as tunnel linings, which would help to reduce settlement associated with groundwater drawdown. The overall significance of potential damage to properties above the tunnels (assessed conservatively without considering the installation of designed tunnel linings) during construction is considered moderate-low, with the sensitivity of affected properties being moderate and magnitude of change (that is, fine cracks that are easily treated during normal decoration) considered to be low.

The air quality impact assessment, provided in Appendix H (Technical working paper: Air quality), found that the operation of the ventilation outlets would have no adverse impacts predicted at any existing or future buildings up to a height of 30 metres in the vicinity of the ventilation outlet at the Gore Hill Freeway and 20 metres within the vicinity of the ventilation outlet at the Warringah Freeway. There are predicted impacts for potential future buildings above 30 metres in height within 300 metres of the Gore Hill Freeway ventilation outlet and for buildings above 20 metres within 300 metres of the Warringah Freeway ventilation outlet. This would not necessarily preclude such development, although consideration of the ventilation outlets would be required during the rezoning or development application stage for proposed future development.

Transport for NSW would assist North Sydney Council, Willoughby City Council, Northern Beaches Council and the Department of Planning, Industry and Environment (as appropriate) in determining relevant land use considerations, which may include requirements for consultation with Transport for NSW at the rezoning or development application stage.

The community raised concerns about potential impacts on property values for communities near the project. Changes to property values, both positive and negative, are driven by a range of economic, social and amenity factors, for example housing supply and demand, interest rates, economic growth, local amenity and accessibility to such things as employment and social infrastructure. The assessment concluded that it is likely that broader external factors would influence property values more than perceived or actual impacts resulting from a road upgrade, including the project.

21.4.2 Equity

Equity refers to a fair distribution of the resources that allow residents full participation in their community. Equity requires that the well-being of people with fewer resources is protected. Changes to conditions which may affect equity in the precinct areas include impacts to amenity, liveability, access and connectivity.

During construction, it is anticipated that impacts to equity would be more acutely experienced by those communities closest to surface works, temporary construction support sites, or occupants of properties above the tunnel alignment. Potential equity impacts would mainly relate to construction noise, dust and vibration affecting the amenity and liveability of the area, as well as changes in local access and connectivity. These impacts would be relatively short-term and localised to discrete locations as construction activities at each temporary construction support site would be comparatively less than the overall construction program. After construction, many of these communities would experience benefits relating to improved access and connectivity to destinations across the Greater Sydney region.

The overall significance of potential impacts on equity during construction is considered moderate, with the sensitivity of affected residents and the magnitude of change considered to be moderate.

21.4.3 Population and demography

The construction workforce would generally be sourced from across the Greater Sydney region and is not expected to result in an influx of workers at a scale that would impact population and demography in the precinct areas.

The relocation of residents associated with the acquisition of residential properties have potential to result in changes to population and demography at a local neighbourhood level, although potential changes in population and demography would represent a very small proportion of the study area's population and are not expected to impact on the population and demography of the study area as a whole. They are also likely to be very minor in the context of expected population and demography changes associated with planned development within the study area. The sensitivity of communities to changes in population is low and the magnitude of change is considered negligible given the existing population of the study area. As a result, the overall significance of potential impacts of the project's construction on population and demography is considered negligible.

Further information on property acquisition as a result of the project is provided in Chapter 20 (Land use and property) and discussed in Section 21.4.

21.4.4 Social infrastructure

During construction, potential impacts on social infrastructure in the precinct areas may result from:

- Loss of open space, parks and recreational facilities, due to use for temporary construction support sites and permanent project facilities
- Reduced visual amenity and increased air-borne construction noise, dust and visual environment, impacting on amenity for users of some social infrastructure
- Ground-borne noise and vibration from construction of the tunnels, impacting on amenity for users of social infrastructure above the tunnel alignment
- Changes in local access and traffic disruptions and delays due to construction activities and increased construction traffic
- Access restrictions to sections of Middle Harbour near proposed works.

Directly impacted social infrastructure

Social infrastructure would be directly impacted through the use of land for temporary construction support sites and project infrastructure. In particular, impacts would include:

- Temporary use of parks and open space areas for temporary construction support sites, resulting in the temporary loss of access to and use of land within the construction footprint
- Permanent loss of land at Cammeray Golf Course, Balgowlah Golf Course and Artarmon Park
- Direct impacts on land accommodating Ella Bache College and Duck and Dive Swim School at Artarmon, causing disruption to users of these facilities. It is likely that users of these facilities would be able to access similar services elsewhere
- Reduced amenity due to location of construction works and temporary construction support sites and changes in noise, dust and visual environment, potentially detracting from the use and enjoyment for people using the remaining parts of the social infrastructure.

Table 21-5 provides a summary of potential impacts on social infrastructure directly impacted by the construction of the project.

Table 21-5 Direct impacts on social infrastructure

Social infrastructure	Summary of potential impacts
Cammeray Golf Course	<p>Impact on land within Cammeray Golf Course would initially result from the establishment of infrastructure required to support the Western Harbour Tunnel and Warringah Freeway Upgrade project construction and operation. Part of the site would be later adjusted to support the establishment of the Cammeray Golf Course construction support site (BL1) and infrastructure required for the project.</p> <p>Impact on land within Cammeray Golf Course has been assessed as of high-moderate significance. The sensitivity of the golf course to change is considered moderate and the magnitude of the impact considered high given the project's construction would result in a permanent change to the existing golf course.</p> <p>The impacted section of the golf course adjoins the Warringah Freeway corridor and Ernest Street. Construction and longer term operation of the ventilation outlet at the Warringah Freeway and other project support infrastructure would require reconfiguration of the golf course before</p>

Social infrastructure	Summary of potential impacts
	<p>construction, including changes to some holes on the golf course (for example, reducing the length of fairways). These works would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, which has been designed and developed to minimise impacts to the golf course. Transport for NSW will continue its collaborative engagement with Cammeray Golf Club to allow the golf course to continue operating as a nine hole golf course during construction. Changes to the golf course during construction may impact on the use and enjoyment of the golf course for some members, potentially resulting in some members and golfers accessing alternative golf courses.</p> <p>During construction, increased noise, dust and construction traffic may impact on the amenity of the golf course for some users and may deter some people from using the golf course during the construction phase.</p> <p>Partial acquisition of Cammeray Golf Course for the Western Harbour Tunnel and Warringah Freeway Upgrade and the Beaches Link and Gore Hill Freeway Connection projects may also increase demand for golf membership of other clubs in the Northern Sydney region.</p> <p>After construction, areas of the golf course not required for permanent project infrastructure would be reinstated and rehabilitated, including replacement trees and landscaping.</p>
Flat Rock Reserve	<p>A small portion (about 10 per cent) of Flat Rock Reserve would be temporarily leased for use as the Flat Rock Drive construction support site (BL2). The construction support site would result in the temporary loss of access to and use of land within the construction footprint, temporarily disrupting the use of this land for informal recreation. Public access to areas of the reserve outside of the Flat Rock Drive construction support site (BL2) would be maintained during construction. The existing shared user path would be temporarily realigned along the western perimeter of the construction support site. Pedestrian pathways on the eastern perimeter of the site would be maintained with two minor temporary diversions required (refer to Chapter 8 (Construction traffic and transport) for further details).</p> <p>Clearing of trees would be required for the temporary construction support site establishment. However, Flat Rock Drive construction support site (BL2) is located in an area previously used as a landfill site comprising re-generated growth, and clearing of older, more established trees would be avoided where possible. The loss of trees would temporarily impact on the landscape and visual amenity of the reserve until new trees or landscaping or other recreation facilities becomes established. The clearing of trees in the reserve is also likely to be a concern for the local community. The amenity of other areas outside of the Flat Rock Drive construction support site (BL2) would be diminished during construction and may detract from the enjoyment of people visiting accessible parts of the parks or nearby facilities.</p> <p>Following construction, areas affected by construction and not required for the ongoing operation of the project would be rehabilitated and/or re-purposed, including with replacement trees and landscaping, with potential landscape and visual amenity impacts diminishing as the new trees or landscaping becomes established. Land affected by construction is therefore not expected to impact on the long-term use of Flat Rock Reserve. The rehabilitation of Flat Rock Reserve would be carried out through further consultation with Willoughby City Council and the community.</p>

Social infrastructure	Summary of potential impacts
	<p>Overall, the significance of potential impacts on Flat Rock Reserve during construction are assessed as moderate, with the sensitivity of the park and magnitude of the impact considered moderate.</p>
<p>Artarmon Park</p>	<p>Construction of the project would require the temporary lease of a portion (about 12 per cent) of land within Artarmon Park to allow for construction activities for the eastbound on-ramp from Lane Cove Tunnel/Longueville Road. Clearing of mature trees would be required for construction and operation of the on-ramp. The loss of these trees would temporarily impact on the landscape and visual amenity of the park until new trees or landscaping becomes established. Clearing of these trees is also likely to be a concern for the local community.</p> <p>Public access to the park from Parkes Road and Hampden Road would be maintained during construction. Works are unlikely to impact the recreational use of Artarmon Park, as the impacted area is steeply sloped and vegetated with dense scrub. The adjoining Artarmon Reserve (containing a playground, sports facilities and oval) would not be impacted.</p> <p>At the completion of construction, part of the land zoned for public recreation would be converted to permanent project infrastructure. The remainder of the land affected by construction would be reinstated after construction and is not expected to impact on the long-term use of Artarmon Park.</p> <p>Overall, the significance of potential impacts to Artarmon Park during construction of the project are assessed as moderate-low, given the sensitivity of the park to impacts is expected to be moderate and the magnitude of the impact is considered low.</p>
<p>Spit West Reserve</p>	<p>During construction, a portion of waterfront open space at Spit West Reserve would be temporarily leased for use as the Spit West Reserve construction support site (BL9). The sensitivity of the area affected by the project's construction and the magnitude of the impact are considered moderate. During construction, part of the reserve would be unavailable for public use for a period of about 48 months. The existing shared user path along the foreshore of Middle Harbour and Spit West Reserve would be temporarily diverted around the construction support site.</p> <p>The amenity of Spit West Reserve would also be diminished during construction and may detract from the enjoyment of people visiting accessible parts of the reserve or nearby facilities. These impacts would be temporary, with the affected areas of the reserve rehabilitated and landscaped following construction.</p>

Social infrastructure	Summary of potential impacts
<p>Balgowlah Golf Course and Balgowlah Golf Club</p>	<p>Land currently owned by the State of NSW and occupied by the Balgowlah Golf Course would be utilised for:</p> <ul style="list-style-type: none"> • The operation of the Balgowlah construction support site (BL10), which would be re-purposed at the end of the project as new and improved open space and recreation facilities. This portion of land would be leased by Transport for NSW for the construction support site • Construction of a new access road, motorway facility and ventilation outlet. This portion of land would be acquired by Transport for NSW for the permanent facilities • Construction of new and improved open space and recreation facilities which would be constructed on residual land immediately after the dedicated consultation process is completed. <p>The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities. Residual land not used for construction, primarily to the east and north of the new access road, would be progressively made available as new and improved open space and recreation facilities, subject to the completion of a dedicated consultation process led by Transport for NSW and Northern Beaches Council. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. Residual land not required for operation of the project is discussed in Section 21.5.3 and in Chapter 20 (Land use and property).</p> <p>The temporary construction support site would occupy part of the land (about 28 per cent) for a period of up to five years and the golf course would be permanently closed at the start of construction, which has been assessed as of high significance. Members of the golf club would be required to use alternative facilities, including Wakehurst Golf Course, Manly Golf Course and Warringah Golf Course, all of which are located within two kilometres of Balgowlah Golf Course.</p> <p>Construction of the project, including the new and improved open space and recreation facilities, would also require the select clearing of established trees within the golf course, including a small area of previously modified Burnt Bridge Creek riparian corridor. The loss of these trees may be a concern for some community members and impact on visual and landscape amenity of the surrounding area.</p> <p>The sensitivity of the golf course to change is considered high and the magnitude of the impact considered high, given the project's construction would result in the golf course not being available for public use.</p>

Indirectly impacted social infrastructure

During construction, impacts on amenity may be experienced by some users of social infrastructure near the project due to the presence of construction infrastructure, increased traffic (including increased heavy vehicle movements) and construction noise and dust. Changes in amenity can affect how users interact with or enjoy an environment or their ability to participate and concentrate. A reduction in the enjoyment or convenience of social infrastructure access may also deter users and potentially impact on community participation levels, which would have an impact on community values.

A number of schools and childcare facilities are located near the project (refer to Figure 21-3 to Figure 21-10). Students, teachers and visitors at the schools would potentially experience temporary amenity impacts due to increased noise and on occasion dust from construction activities at temporary construction support sites and surface road upgrades. Education and childcare facilities may also experience increased construction traffic and occasional dust impacts due to the use of Sydney Road by construction vehicles.

The Wakehurst Parkway north construction support site (BL14) is located near the Northern Beaches Hospital. Increased noise, occasional dust and construction traffic, has the potential to impact on the amenity for patients and workers of the hospital, although any potential impacts from the associated adjacent minor surface roadworks would be for a very short period only and are generally expected to be negligible.

Construction at Artarmon associated with the Gore Hill Freeway Connection component of the project, including the Dickson Avenue construction support site (BL4), would be near the Artarmon NSW Ambulance Superstation on Reserve Road. Access for emergency services would be maintained during construction. Consultation would be carried out with emergency services prior to and during construction of the project regarding potential impacts.

During construction of the project, Spit Road would be used for heavy vehicle access to the Spit West Reserve construction support site (BL9). Spit Road provides access to a number of recreation and leisure facilities and is the starting point for the Spit to Manly Walk. Increased construction traffic along Spit Road may impact on the perceptions of safety for people accessing social infrastructure at this location.

Middle Harbour also provides for informal and formal recreational opportunities, such as boating, fishing, sailing, rowing and kayaking. During construction of the project, there would be a requirement for four partial and two full planned closures of up to 48 hours each of Middle Harbour between Northbridge and Seaforth Bluff, to facilitate immersion of the immersed tube tunnel units. These closures would occur on weekdays to limit the disturbance to harbour recreational users, community groups and clubs. During full closure of Middle Harbour, no boating traffic would be able to pass the location of the Middle Harbour crossing. During partial closure of Middle Harbour, navigational restrictions would prohibit larger vessels from crossing the harbour between Northbridge and Seaforth Bluff. Smaller vessels passing through may require escort vessels to be provided. This would result in periods of traffic disruptions, potentially affecting recreational movements and access and connectivity for sporting clubs associated with Middle Harbour.

During all other days of the construction phase, partial restrictions of Middle Harbour with maritime speed restrictions and controlled access through the site would be required. Recreational users, such as boating, sailing, rowing and kayaking would be allowed to travel through the site in a controlled manner ensuring the safety of both the waterway user and the project team. Ongoing consultation and communication with users of Middle Harbour, such as with the local community, Mosman Rowing Club, Northbridge Sailing Club (located in Clive Park), Seaforth Moth Sailing Club (part of the Northbridge Sailing Club), Middle Harbour Yacht Club and users of D'Albora Marinas The Spit, would assist in managing potential impacts.

Users of other social infrastructure near construction activities, such as recreational facilities (including Balgowlah Scout Hall, Balgowlah Oval, and basketball and netball courts at Willoughby) and places of worship, may also experience potential impacts on amenity due to the presence of nearby construction infrastructure and associated construction noise.

The sensitivity of social infrastructure to amenity impacts is considered moderate with some ability of social infrastructure to adapt to change. The magnitude of the impact is also considered moderate given the duration of potential construction impacts, resulting in the overall significance of amenity impacts at social infrastructure being assessed as moderate.

Short-term low impacts on amenity may also be experienced for users of some social infrastructure located above or near the tunnel alignment due to vibration and ground-borne noise impacts from tunnelling. Those facilities that may be more sensitive to the effects of ground-borne noise and vibration include:

- Places of worship, such as Armenian Evangelical Brethren Church at Sailors Bay Road, Northbridge and St Mark's Anglican Church at Tunks Street, Northbridge
- Childcare facilities such as Sue's Childcare Castlevale at Artarmon Road, Willoughby; Naremburn Early Learning Centre at Donnelly Road, Naremburn; Northside Baptist Preschool at Sailors Bay Road, Northbridge; St Mark's Northbridge Preschool at Malacoota Road, Northbridge; and Jacaranda Creative Play Centre at Fromelles Avenue, Seaforth
- Educational uses such as Seaforth Public School at Kempbridge Avenue, Seaforth.

Some users may notice ground-borne noise and vibration for a short period as works occur beneath or near the property. Potential impacts would be managed through ongoing consultation with managers and users of these facilities. Further information about potential noise and vibration impacts are discussed in Chapter 10 (Construction noise and vibration). Overall, the sensitivity of social infrastructure located along the tunnels and magnitude of potential amenity impacts from tunnelling are considered low, resulting in the significance of potential impacts from tunnelling on the amenity of social infrastructure being assessed as low.

Temporary changes to local access and connectivity for motorists, pedestrians, cyclists and public transport users, may impact on access to social infrastructure near the project. A number of schools are located near surface works and temporary construction support sites at Cammeray and Balgowlah. Increased construction traffic may impact on perceptions of safety for children and students (refer to Section 21.4.5). The implementation of safeguards and management measures would assist in managing potential impacts.

Although controlled navigation routes would be provided through the site, increased marine construction traffic and activities could impact upon the perceptions of safety for water craft and other recreational users of the Middle Harbour. Measures would be implemented to manage potential safety risks associated with road and maritime construction traffic. Further details are provided in Appendix F (Technical working paper: Traffic and transport).

21.4.5 Community values

Potential impacts on community values during construction may be experienced by communities within the precinct areas due to:

- Temporary adverse changes in local amenity for residents, businesses, facilities and public open space areas near temporary construction support sites and surface works due to noise and dust generated from construction activities
- Temporary adverse changes in local amenity for occupants of properties located above the tunnel alignment due to ground-borne noise and vibration from construction activities
- Light spill from night time construction activities at temporary construction support sites and construction works in road reserve areas at the Warringah Freeway, the Gore Hill Freeway and Burnt Bridge Creek Deviation/Sydney Road
- Temporary changes in local access and connectivity, including for motorists, public transport users, pedestrians and cyclists, resulting in delays and disruptions
- Adverse changes in visual amenity and local character due to the presence of temporary construction support sites and surface works, infrastructure, and clearing of vegetation within the construction footprint.

Local amenity and character

Noise, dust, vibration, traffic, and visual impacts from construction activities may temporarily impact on the amenity for some residents and social infrastructure closest to surface works. Impacts on night time amenity due to construction noise and vibration and light spill may also be experienced should works need to be carried out outside of standard daytime hours. This may impact on night time amenity or sleeping patterns for some residents. These impacts would be short-term and may

potentially impact on the use and enjoyment of some homes, businesses, facilities and natural areas, particularly of outdoor areas.

As discussed in Section 21.3.3, Middle Harbour influences the local amenity and character of the precinct areas and is important to the local community. Middle Harbour provides a range of formal and informal recreational opportunities to both local and regional communities (including tourists). As described in Chapter 6 (Construction work), during construction, cofferdams would be located in Middle Harbour and used as temporary construction support sites. Visual and noise impacts during construction may have a negative impact on the use and enjoyment of Middle Harbour for some people, including formal and informal recreational users of land and water based facilities.

The project would require the clearing of vegetation in road reserve areas along the Wakehurst Parkway. Loss of vegetation may impact on community values relating to landscape and visual amenity of this area and the natural environment.

The project would also require the clearing of vegetation within Artarmon Park, Balgowlah Golf Course and areas of re-generated growth within Flat Rock Reserve. Loss of vegetation may also impact on community values relating to landscape and visual amenity of these areas and the natural environment. The extent of clearing on residual Balgowlah Golf Course land will be confirmed after a dedicated consultation process to determine the final form of the new and improved open space and recreation facilities to be constructed in the area.

Following construction, areas affected by construction and not required for the ongoing operation of the project would be rehabilitated and/or repurposed in accordance with the urban design and landscape plan. This would include replacement trees and landscaping, with potential landscape and visual amenity impacts diminishing as the new trees or landscaping become established.

Overall, the sensitivity of communities near the project to changes in amenity and magnitude of potential amenity impacts is considered moderate, resulting in the significance of potential impacts on local amenity assessed as moderate. The implementation of safeguards and management measures, in conjunction with ongoing consultation and communication with local communities, would assist in managing potential impacts on local character and amenity.

Community cohesion

The project construction phase has the potential to result in impacts on community cohesion by restricting access to some existing social infrastructure and meeting places, such as Cammeray Golf Course, and the removal of golfing facilities at Balgowlah Golf Course. This may reduce opportunities for social and community interaction, temporarily impacting on community cohesion.

Potential increased construction noise, dust and traffic may impact on the amenity of the Cammeray Golf Course for some users and may deter some people from using the golf course during the construction phase. This has potential to disrupt some social networks associated with the club. The amenity of other community facilities and meeting places near the project may also be disturbed, such as Balgowlah Scout Hall, Mosman Rowing Club and public facilities at Spit West Reserve. This may impact on people's use and enjoyment of these facilities.

Overall, potential impacts to community cohesion as a result of construction of the project have been assessed to have a moderate significance, with the sensitivity of meeting places to changes and the magnitude of impacts considered moderate.

Community health and wellbeing

Some areas near temporary construction support sites and along the Warringah Freeway and surface connections such as to the Gore Hill Freeway have potential to experience impacts from construction activities that create extended periods of noise potentially above the relevant assessment thresholds including for sleep disturbance. This has the potential to result in sleep disturbance for some residents and occupants of buildings nearest to these works, potentially impacting health and wellbeing for some individuals. Underwater noise and vibration from some construction activities within Middle Harbour (for example, installation of piles and dredging) has potential to cause sound pressure levels that may affect people diving or swimming (refer to Chapter 13 (Human health)). Mitigation measures proposed include communication to ensure the

community are aware of the timing of impact piling in Middle Harbour for cofferdam works. Impact piling works would be similar to works carried out recently for Sydney Harbour wharf upgrades by Transport for NSW.

The potential for construction dust to impact on health and wellbeing of groups in the community who may be more sensitive to changes in air quality (such as children, elderly people or people who suffer from asthma or similar conditions), is likely to be of concern for some community members near construction activities.

Increased construction traffic could impact upon the perceptions of road safety. This would be particularly relevant in areas that attract higher numbers of pedestrians, such as near local centres or social infrastructure.

The presence of a large construction workforce has potential to disrupt amenity and impact on perceptions of safety for surrounding neighbours and users of nearby social infrastructure. Workers on the project would be subject to the *Transport for NSW Code of Conduct* which outlines expectations for staff in and outside the workplace. The expectations within the *Code of Conduct* would be reinforced through construction worker inductions prior to commencement of construction and toolbox talks which focus on appropriate behaviours when working within the community.

The sensitivity of the general community to perceived health and safety impacts is moderate and the magnitude of possible impacts is considered low, resulting in the overall significance of potential impacts to community health and safety as a result of the project's construction being assessed as moderate-low.

21.4.6 Economics

Employment

During construction, the project would benefit employment through direct employment opportunities on the project and indirect employment opportunities in businesses and industries that support this construction.

A project of this scale is expected to support up to 7500 full time equivalent job years (direct employment) during the five years of construction, including construction workers and professional and administration staff. About 2350 full time equivalent jobs (2000 for Beaches Link and 350 for the Gore Hill Freeway Connection) would be expected to be supported during peak construction. Indirect employment opportunities would be generated across local, regional and national businesses in industries that support construction such as manufacturing and services.

The project's construction phase is likely to provide benefits for groups such as Aboriginal people, women, young people and the unemployed. This would support the NSW Government's *Infrastructure Skills Legacy Program* (Training Services NSW, 2020), which seeks to increase the representation of young people, Aboriginal people and women in the construction industry.

In particular, construction would provide opportunities to boost the number of skilled women construction workers and the number of women in trade-related work as outlined in the *NSW Women's Strategy 2018-2022, Advancing economic and social equality in NSW* (NSW Government, 2020) and *Infrastructure Skills Legacy Program*. To meet the targets within the *Infrastructure Skills Legacy Program*, the contractor would be required to employ women in two percent or more of trade-related roles, doubling the number of women in trade related work. The implementation of the NSW Government's Aboriginal Participation in Construction policy would also provide employment and training opportunities for Aboriginal people.

Training opportunities and apprenticeships provided by construction would support skills development and enhance opportunities for future employment for individuals. Income from employment on the project would also support improved social and economic outcomes for individuals. A workforce strategy for the project, that includes strategies to increase employment and training opportunities for the groups discussed above, would be developed and implemented and would help to maximise employment benefits of the project.

The construction workforce would generally be sourced from across the Greater Sydney region. It is expected that there would be capacity within the regional labour force for the project.

21.4.7 Business and industry

Businesses across the precinct areas may be affected during the construction phase by temporary changes in passing trade, access and travel time (for employees, customers, deliveries and/or servicing), parking, serving and deliveries and amenity. Depending on the nature of the business, the actual impact on business revenue may vary (positively or negatively). These impacts may be an inconvenience for businesses affected although they would be temporary in nature as construction activities at each temporary construction support site would be comparatively less than the overall construction program. There may also be benefits for businesses due to increased passing trade and business exposure.

Potential impacts have been assessed for those business centres identified as being most likely to experience direct and indirect construction impacts. Potential impacts at these locations are discussed below. Further information is provided in the business impact assessment in Annexure A of Appendix U (Technical working paper: Socio-economic assessment).

Passing trade

Passing trade refers to customers who choose to visit a business because they see it when walking, cycling or driving past, not because they planned to go there.

Construction of the project would result in changes to vehicle, pedestrian and cyclist flows that could influence the level of passing trade. Some businesses could benefit due to passing trade being re-directed to them or due to increases in construction workers in the area. Conversely some businesses might be disadvantaged as traffic is diverted away, or as they become less attractive to passing trade due to construction impacts (such as reduced visibility, amenity, ease of access or parking availability).

Increased passing trade from construction workers and construction vehicles is predicted for a number of business clusters located near the temporary construction support sites. Vehicle diversions are also expected to increase traffic along Sydney Road, leading to an increase in passing trade. Increased pedestrian and cyclist passing trade is expected at Francis Road, Lambs Road, Cleg Street and Reserve Road in Artarmon as a result of the diversion of the Gore Hill Freeway shared footpath. Overall, benefits to businesses as a result of passing trade are expected during construction.

Employee and customer access

The construction phase of the project would result in changes to road, public transport and active transport networks, which may affect employee and customer access. Increased journey times can affect staff recruitment and retention, which may in turn impact on business productivity and function. Similarly, customers may respond to access difficulties and delays by visiting alternative centres that offer similar goods or services, resulting in a loss of trade for affected businesses.

Businesses often rely on parking facilities for deliveries and/or services and parking convenience for workers and customers. Increased demand and competition for car parking could influence customers to drive to an alternative business providing similar goods or services in a more accessible location. A reduction in parking spaces may also impact on visitor numbers to the broader area and therefore reduce opportunities for passing trade. Limitations on business parking could also reduce productivity, employee attraction and retention. For example, competition for parking may increase in the Artarmon Industrial Centre precinct due to the additional construction workers in the area. Construction workers will be actively encouraged to use public transport rather than travelling to work by car. Where public transport availability to temporary construction support sites is limited, shuttle bus transfers may also be provided from public transport centres where required. This would be of moderate significance for the Artarmon industrial area, as the sensitivity and magnitude would be moderate.

The traffic and transport assessment (refer to Chapter 8 (Construction traffic and transport)) identified that road network performance would be affected during construction, with a number of temporary road closures and increased construction traffic resulting in increased travel times in some areas. The T2 transit lanes currently in operation along the Gore Hill Freeway would be permanently converted to general traffic lanes to allow for construction of the Gore Hill Freeway Connection and to improve lane utilisation. This is not expected to materially impact employee and customer travel times by bus (refer to Chapter 8 (Construction traffic and transport) for more information). Changes to road network performance would likely affect employee and customer travel time and the efficiency of services and deliveries. Impacts of moderate significance on employee and customer access would be experienced by businesses within Artarmon Industrial Centre, and impacts of moderate-low significance would be experienced at The Spit. Impacts on employee and customer access would be experienced by businesses within the Frenchs Forest Business Hub Centre, Manly Vale Business Centre, Balgowlah Centre, Seaforth Centre, and Miller Street Cammeray and would be of low to negligible significance as both sensitivity and magnitude would be low to negligible.

Construction vessels travelling from the Outer Harbour to Middle Harbour would complete their movement when the Spit Bridge is open. Given the length, limited speed and limited manoeuvrability of the immersed tube tunnel units, the construction contractor may be required to arrange several special bridge opening times outside of peak traffic periods to transport the units to their intended destination. If required by the construction contractor, the additional bridge opening times would have a limited impact on maritime businesses.

Servicing and deliveries

Businesses rely on deliveries and dispatch of goods to support the sale of products and/or services. Businesses also require services from other businesses such as refuse collection. These activities are often required to occur daily or multiple times per day. The construction phase of the project would result in changes to loading zones, road performance and road network configuration, which can affect the reliability and capacity of servicing and delivery. This may temporarily impact travel times and vehicle-related costs as well as revenue for businesses.

Reduced road performance is expected to lead to some delays in service and delivery times to businesses, however it is expected that impacts to business viability would be minor. The business surveys indicated that 60 per cent of businesses believed construction of the project would have a neutral effect on servicing and delivery, whereas 39 per cent of businesses believed it would have a negative effect.

The closure of Lambs Road between Punch Road and Cleg Street, and periodic closures of Reserve Road, Hampden Road, Dickson Avenue and Punch Street during construction are expected to have impacts of moderate significance on businesses in the Artarmon Industrial Centre because of disruption to servicing and deliveries, as the level of sensitivity and magnitude is moderate.

A key factor in receiving servicing and deliveries is access at the business location itself, as this access is often reliant on dedicated loading zones. The construction of the project is, however, not anticipated to remove loading zones or parking that would affect the business clusters.

The significance of impacts on services and deliveries would be low at the Frenchs Forest Business Hub Centre, the Manly Vale Business Centre, the Balgowlah Centre and the Seaforth Centre.

Amenity

The construction phase of the project would affect the amenity of an environment, including for people visiting or working at local businesses in the precinct areas. This would be as a result of increased noise, vibration and dust, or reduced visual outlook and business visibility. Changes to amenity can affect business ambience, productivity, functionality, exposure and client patronage. Business clusters that have higher dependency on amenity to attract and retain customers would be more susceptible to changes in amenity as a result of construction activity.

During construction, visual amenity would be affected by the removal of vegetation and the introduction of temporary construction support sites, equipment and other visible elements such as hoardings and fencing. This is most likely to impact on those retail, personal service providers, cafes and restaurants that rely on the pleasantness and quality of an environment to attract customers. Important aspects of visual amenity which may be affected include access to natural daylight, clear sightlines and permeability to the surrounding landscapes. Businesses that rely on storefront exposure to attract customers may be affected by reduced visibility or safety concerns of customers as a result of the presence of construction machinery and materials. The significance of impacts on amenity at the Balgowlah Centre would be low, and moderate-low at the Artarmon Industrial Centre, the Seaforth Centre and The Spit.

Increased noise and vibration levels from construction activities and traffic could also impact on customer amenity, and on the amenity and productivity levels of employees. Potential exposure to dust and air pollutants could impact on cleanliness and attraction in particular for sensitive business receive such as education, accommodation and food services that rely on outdoor dining.

The establishment of construction infrastructure and increased construction traffic at Spit West Reserve would have an impact on the views, character and identity of maritime businesses at The Spit. Although cafes, restaurants and the function rooms/event spaces at The Spit have a high dependency on visual amenity, the orientation of view corridors from these businesses would be in a direction away from the construction footprint, and the significance of amenity impacts are expected to be moderate-low.

Employee productivity and communication

During construction, there would be a temporary increase in noise levels due to the use of construction plant, equipment and vehicles that may affect employee productivity and communication. The significance of impacts on employee productivity and communication for businesses at the Artarmon Industrial Centre, along Punch Street, Cleg Street, Waltham Street and the Gore Hill Freeway, would be low as the sensitivity and the magnitude of change for this business centre would be low. Impacts on employee productivity and communication would be negligible at the Balgowlah Centre and are not anticipated at businesses at the Frenchs Forest Business Hub, Miller Street (Camberay), The Spit and Seaforth Centre.

Business visibility

The construction phase of the project would result in changes to vehicle, pedestrian and cyclist flows that could influence the level of business exposure and visibility. Some businesses could benefit as they might be exposed to more potential customers (ie through pedestrian or traffic diversions) while others might not, as traffic is diverted away or construction hoardings reduce the ease of access to/visibility of their business, which could result in a loss of trade. During construction, site hoardings may impact business visibility along Punch Street and Dickson Avenue, resulting in a low significance of impact on business visibility at the Artarmon Industrial Centre. However, overall, benefits are anticipated for the business centres assessed.

Demand for services

The construction phase of large infrastructure projects can affect demand for local and regional goods and services. This can result in both negative and positive impacts with some businesses experiencing a loss of customers avoiding particular areas due to construction activities while other businesses experiencing increased trade from construction workers in the area. Demand for services, such as construction recruitment agencies, construction companies and resource suppliers, can also be generated from infrastructure projects, creating employment opportunities both within and outside local business centres.

Construction of the project would benefit short-term local employment opportunities through the creation of direct construction related employment on the project and indirect employment opportunities in businesses and industries that support the construction works. An increase in construction workers in an area often provides an economic injection into the local economy due to increased demand for local services. As a consequence of the increase in workers associated with

construction of the project, the largest benefits from increased trade are anticipated for convenience retail and the food and beverage industry.

Demand for services at business centres along the project are generally assessed as being benefited during construction of the project.

Displacement of businesses

The acquisition of properties, including cessation of leases, and subsequent relocation or closure of businesses has the potential to result in:

- Disruptions to business operation
- Loss of revenue
- Relocation and re-establishment costs
- Training expenses for new employees and cost of productivity loss until new workers are at the same skill productivity level as the old workers
- Trade catchment alterations
- Business closure.

Businesses required to close or relocate due to the project are predominantly commercial, light industrial or speciality services, including a media and production company, swim school and beauty college, and are located in the Artarmon Industrial Centre. These businesses would service a wider area and would likely employ a small number of workers. Due to the nature of these businesses and the supply of alternative industrial zoned land in the surrounding area, it is likely that these businesses would relocate to another trade catchment. This would result in relocation and establishment costs with potential loss in trade and revenue during this time.

The project would also result in permanent land use impacts at the Balgowlah Golf Course. Land currently occupied by the Balgowlah Golf Course would be utilised by the Balgowlah construction support site (BL10) and the construction of a new access road, motorway facility and ventilation outlet. The temporary construction support site would occupy part of the land for a period of up to five years and the golf course would be permanently closed at the start of construction. The closure of the golf course would result in a loss of employment. Residual land would be progressively become available through the construction period which would facilitate re-purposing it as part of the new and improved open space and recreation facilities, subject to completion of a dedicated consultation process led by Transport for NSW and Northern Beaches Council as described in Chapter 6 (Construction work). As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.

Of the businesses affected by property acquisitions, there are limited co-dependencies or synergies between those that would be acquired and those that would remain operational in the surrounding catchment. Therefore, the operation of remaining businesses is not expected to be substantially affected by these changes. The significance of property acquisitions on individual businesses is expected to be high-moderate, with level of sensitivity considered to be high and magnitude of change considered to be moderate.

Overall, the number of acquisitions and businesses required to cease operation to facilitate the project is relatively low for an infrastructure project of this scale. Although the impact on individual businesses may be significant, the compensation process is generally designed to reduce this impact. Refer to the business impact assessment in Annexure A of Appendix U (Technical working paper: Socio-economic assessment) for further details.

Maritime businesses

Construction activities have the potential to impact maritime businesses as follows:

- Middle Harbour access:
 - Generally, access through Middle Harbour between Northbridge and Seaforth Bluff would be restricted via a controlled navigation route for all business related water craft. Recreational users, such as boating, sailing, rowing and kayaking would be allowed to travel through the site in a controlled manner ensuring the safety of both waterway users and the project team. These controlled restrictions would occur during the whole of the construction period. This would result in the slowing of maritime traffic potentially affecting recreational movements and resulting in potential access and connectivity impacts for Mosman Rowing Club, Northbridge Sailing Club, Seaforth Moth Sailing Club (part of the Northbridge Sailing Club), Middle Harbour Yacht Club and maritime businesses located at The Spit local centre (low significance)
 - Construction of the project would require up to six closures, including two full and four partial closures, of Middle Harbour between Northbridge and Seaforth Bluff for periods of up to 48 hours each to install the immersed tube tunnel units. These closures would normally occur on weekdays to limit the disturbance to maritime and tourism businesses. During full closure of Middle Harbour, no boating traffic would be able to pass the location of the Middle Harbour crossing. During partial closure of Middle Harbour, navigational restrictions would prohibit larger vessels from crossing the harbour between Northbridge and Seaforth Bluff, while smaller vessels passing through may require escort vessels to be provided. This would result in periods of maritime traffic disruptions potentially affecting recreational movements and resulting in potential access and connectivity impacts for Mosman Rowing Club, Northbridge Sailing Club, Seaforth Moth Sailing Club, Middle Harbour Yacht Club and maritime businesses located at The Spit local centre (low significance)
- Employee and customer access: Construction works may require several additional bridge opening times of the Spit Bridge outside of peak traffic periods to transport immersed tube tunnel segments, which may have a limited impact on maritime businesses. The project would also require some commercial moorings to be temporarily relocated during the construction phase (negligible significance)
- Amenity: Construction activities are expected to impact on local amenity and alter the views, character and identity of Mosman Rowing Club, Northbridge Sailing Club, Seaforth Moth Sailing Club (part of the Northbridge Sailing Club), Middle Harbour Yacht Club and businesses within The Spit local centre (low significance)
- Travel time delays: Business harbour users such as boat hire businesses and commercial boats would experience a minor increase in travel time resulting from imposed speed restrictions during construction (negligible significance)
- Business operation impacts: Interference with training routes used by members of the Mosman Rowing Club, course layouts for Northbridge Sailing Club, Seaforth Moth Sailing Club or kayak routes have the potential to result in existing members joining an alternative club. Any impacts on these clubs may also have indirect impacts on cafes in The Spit which are often visited by club members after training. Increased wash from barge and work vessel movements may also disrupt boating and kayak users, although the duration of peak works would be relatively short (low significance).

During construction, maritime businesses and waterway users would also experience temporary changes to access and temporary impacts on amenity during construction. Impacts to waterway users have been reduced by minimising movement of moorings, limiting closure, ensuring right of way for recreational craft over construction maritime vessels and maintaining access to the foreshore where feasible (as discussed in Section 21.4.8). Businesses and users would be able to adapt to the change with minimal disruptions to the way they operate or use the waterway.

While there may be temporary impacts on some maritime businesses during construction, there is not expected to be a lasting impact on these businesses. Any effects would be experienced at an individual business level, with no discernible changes to overall performance of the broader maritime industry. Measures would be defined that outline how marine works would be carried out and mitigate potential business impacts as far as practical.

Refer to Chapter 8 (Construction traffic and transport) for safeguards to manage impacts from maritime construction activities.

21.4.8 Access and connectivity

Potential short-term impacts on access and connectivity are identified below.

Roads and private access

The following potential access impacts are anticipated:

- Temporary changes to road conditions near construction activities, including several partial and full road closures, temporary diversions and access changes, removal of some on-street parking, and reductions in speed limits, resulting in possible delays and disruptions for motorists and other road users
- Increased construction traffic on roads within the precinct areas, including heavy vehicles used to deliver materials and equipment and construction worker vehicles, potentially impacting on road safety for motorists, pedestrians and cyclists. However, most construction traffic would access temporary construction support sites from the arterial road network or water
- The permanent removal of 10 parking spaces along Ernest Street and the temporary removal of parking spaces on other local roads such as Punch Street, Dickson Avenue, Barton Road, Cleg Street and Hampden Road, resulting in a reduction of available parking. Some car parking for the construction workforce would be provided at the temporary construction support sites. Where on-site parking is not provided or where provision of on-site parking cannot accommodate the full construction workforce, feasible and reasonable management measures that minimise parking impacts on the surrounding road network will be implemented, such as encouraging the use of public transport and provision of workforce shuttle buses
- Access to private properties near proposed works is generally expected to be maintained during construction. Where temporary changes are required, suitable access arrangements would be implemented in consultation with affected property owners.

The sensitivity of road users to changes in construction traffic and the magnitude of impacts are considered moderate. As such, the overall significance of impacts on road users are assessed as moderate. The significance of potential impacts to parking as a result of the project's construction have been assessed as moderate-low, with the sensitivity being moderate and magnitude of impacts considered low. The sensitivity of individuals to changes in private property access would be low and magnitude of impact are considered negligible, resulting in an overall significance of impacts on property access being assessed as negligible.

Public and active transport

The following potential public transport impacts are anticipated:

- Potential disruptions to bus services, including from changes to road conditions and the temporary relocation of some bus stops near construction works for safety, resulting in possible delays and disruptions for bus users and changes in bus access for some people
- Delays or short-term changes in local routes and bus priority infrastructure may be required due to temporary road adjustments and could result in minor travel time increases.

Changes to local bus routes and bus stops would be determined prior to the start of works in consultation with relevant stakeholders, including other divisions of Transport for NSW and bus operators. Advanced notification would be provided to affected bus customers and bus stops would

be relocated within walking distance of their existing position, to minimise disruption where reasonable and feasible. The sensitivity of commuters to changes in public transport services are considered moderate, with the magnitude of impacts considered low. As such, potential impacts to public transport as a result of construction of the project have been assessed to have a moderate-low significance.

Active transport impacts would be anticipated due to temporary closures or changes to pedestrian and cycle paths would be required near construction works for safety of pedestrians and cyclists. Existing connectivity for users of these facilities would be maintained and temporary access arrangements would result in a small increase in travel distances. Temporary closures and adjustment of pedestrian and cycle paths would include:

- Temporary detour of the Warringah Freeway shared user path and provision of signalised pedestrian and cyclist crossing at the access for the Cammeray Golf Course construction support site (BL1)
- Temporary detour of the shared user path within Flat Rock Reserve (parallel to Flat Rock Drive, on the western side of the Flat Rock Drive construction support site (BL2)), and provision of signalised pedestrian crossing at the access to the Flat Rock Drive construction support site (BL2) (the existing walking tracks along the eastern perimeter of the site would be largely maintained with two minor temporary diversions required)
- Temporary adjustments to Reserve Road, Dickson Avenue and Punch Road footpaths at Artarmon and to Hampden Road footpaths and cycle path near to works at Artarmon Park
- Temporary detour to the Gore Hill Freeway shared user path near to the Dickson Avenue construction support site (BL4)
- Closure of Lambs Road due to Punch Street construction support site (BL3)
- Temporary detour of the Figtree Lane shared user path around the Spit West Reserve construction support site (BL9)
- Provision of signalised pedestrian crossing at the Sydney Road and Burnt Bridge Creek Deviation site accesses for the Balgowlah Golf Course construction support site (BL10)
- Temporary adjustment to Manly Dam mountain bike track at Wakehurst Parkway
- Demolition and replacement of the Wakehurst Parkway pedestrian bridge. The existing bridge will remain operational while the replacement works are carried out
- Temporary adjustments to Wakehurst Parkway shared user path near the Wakehurst Parkway north construction support site (BL14).

Overall, the significance of potential impacts to active transport as a result of construction of the project have been assessed as low, with the sensitivity and magnitude of impacts considered low.

Maritime transport

The following potential maritime transport impacts are anticipated:

- Generally, access through the site between Northbridge and Seaforth Bluff would be restricted via a controlled navigation route for all business related water craft. These controlled restrictions would occur during the whole of the construction period. This would result in the slowing of maritime traffic potentially affecting recreational movements and resulting in potential access and connectivity impacts for Mosman Rowing Club, Northbridge Sailing Club, Seaforth Moth Sailing Club, Middle Harbour Yacht Club and maritime businesses located at The Spit local centre
- Temporary closures of Middle Harbour between Northbridge and Seaforth Bluff, which would occur on weekdays to limit the disturbance to harbour recreational users, community groups and clubs. During the two proposed 24 to 48 hour full closures of Middle Harbour, all marine traffic would be restricted from moving through the site for the period. During the four proposed 24 to 48 hour partial closures of Middle Harbour, navigational restrictions would prohibit larger

vessels from crossing the harbour between Northbridge and Seaforth Bluff. Smaller vessels passing through may require escort vessels to be provided. This would result in periods of traffic disruptions, potentially affecting recreational movements and access and connectivity for sporting clubs associated with Middle Harbour

- The six steel shell immersed tube tunnel units and heavy marine construction plant would need to access the Spit West Reserve construction support site (BL9) via the Outer Harbour and then via Middle Harbour between Grotto Point and the Spit Bridge. Navigation impacts in these areas are not expected to be substantial due to the lower frequency of construction vessel movements and the increased space the Outer Harbour provides for maneuverability
- Business harbour users such as boat hire businesses and commercial boats would experience a minor increase in travel time resulting from imposed speed restrictions during construction, however the significance of impacts is considered to be negligible
- The establishment and operation of the Spit West Reserve construction support site (BL9) would require temporary relocation of around 45 swing moorings. The establishment of the Middle Harbour north cofferdam (BL8) would require the temporary relocation of about 10 swing moorings below Seaforth Bluff and would prevent access to three private marina berths in Seaforth Bluff. Temporary alternative marina berths would be provided at D'Albora Marinas at The Spit or other marinas nearby. Relocated moorings would be relocated elsewhere in Middle Harbour in consultation with the lease holder(s) during construction and would be restored to their original position on completion of the project. A number of moorings would also require very short term temporary relocation on the eastern side of the channel, west of Bradys Point to allow safe passage of the immersed tube tunnel units.

Ongoing engagement and communication with users of Middle Harbour, such as with the local community, Mosman Rowing Club, Northbridge Sailing Club, Seaforth Moth Sailing Club, Middle Harbour Yacht Club and users of D'Albora Marinas The Spit, would assist in managing potential impacts. Rowers and sailing craft would have right of way over maritime construction vessels in the vicinity of the project. Overall, the significance of potential impacts on maritime transport during construction have been assessed as low, with the sensitivity of maritime users considered moderate and the magnitude of potential impacts low.

21.5 Assessment of potential operational impacts

The operation of the project has the potential to positively and negatively affect residents, businesses, road users, users of social infrastructure and the wider community. This section provides an assessment of potential social and economic impacts within the precinct areas during operation of the project.

21.5.1 Equity

The operation of the project would provide improved access and connectivity which would benefit the wider community and people living and working in or near the precinct areas. In particular, reduced congestion and improved journey times provided by the project would help to reduce travel time for individuals, families and the wider community, increase time available to individuals and families for leisure, and increase access to employment opportunities within convenient commuting times. Reduced traffic congestion, upgrades to bus infrastructure and opportunities for new express bus services delivered by the project would also have benefits that would be shared by local and regional communities.

In conjunction with the Western Harbour Tunnel and Warringah Freeway Upgrade project, the project would help to reduce traffic on major roads in the precinct areas, including Military Road/Spit Road/Manly Road, Warringah Road, Eastern Valley Way, Pacific Highway and Western Distributor, Frenchs Forest Road, the Ourimbah Road corridor and local roads such as Brook Street (Naremburn). It would also support local environment and amenity improvements in the precinct areas and surrounding region and improve access and connectivity for residents, business

and industry in the precinct areas, northern suburbs, north western suburbs, south western suburbs and the Greater Sydney region.

21.5.2 Population and demography

Travel time savings and improved accessibility provided by the project are likely to make some areas within or near to the precinct areas more attractive for people looking to relocate. While this change has been occurring and is expected to continue, the project is likely to contribute to the acceleration of development locally and regionally, particularly when considered in conjunction with the Western Harbour Tunnel and Warringah Freeway Upgrade project.

21.5.3 Social infrastructure

As discussed in Section 21.4.4, a number of open spaces would be used during construction of the project. At completion, land not required for operation of the project would be rehabilitated and reinstated. However, some land would be retained for operational purposes as follows:

- A portion of land at Cammeray Golf Course would be acquired and/or leased as part of the Warringah Freeway Upgrade component of the Western Harbour Tunnel and Warringah Freeway Upgrade project. Part of the site would be later adjusted to support the establishment of the Cammeray Golf Course construction support site (BL1) and operational facilities and other utilities for the project. This would require the reconfiguration of the golf course to allow its ongoing use. As discussed above, Transport for NSW will continue its collaborative engagement with Cammeray Golf Club to allow the golf course to continue operating as a nine hole golf course during construction. The establishment of the motorway facilities would change the visual setting of this location. Landscaping would be provided to reduce the visual impacts of these facilities. Further discussion about the project's impacts on visual and landscape impacts are provided in Chapter 22 (Urban design and visual amenity). The sensitivity of the golf course to change is considered moderate and the magnitude of the impact considered high given that the project would result in a permanent change to the existing golf course. As a result, the overall significance of potential impacts to Cammeray Golf Course during operation of the project are assessed as high-moderate
- A portion of land currently occupied by the Balgowlah Golf Course would be acquired by Transport for NSW for the construction of permanent facilities, including a new access road, motorway facility and ventilation outlet, leading to the closure of the golf course. This would require members and visitors of the golf club to access golf courses elsewhere, impacting on social networks associated with the club. The sensitivity of the golf course to change is considered high and the magnitude of the impact considered high given the permanent closure of the golf club. As a result, the overall significance of potential impacts to Balgowlah Golf Course during operation have been assessed as high.

The project would progressively return an area, equivalent to around 90 per cent of the current open space at Balgowlah Golf Course, to the community as new and improved public open space and recreation facilities. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council will take place to give the community an opportunity to provide comment on the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link and Gore Hill Freeway Connection environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting.

As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new and improved open space and recreation facilities. This would allow it to be handed over progressively for

use by the community. The new and improved open space and recreation facilities to the west of the proposed access road, between the access road and the widened Burnt Bridge Creek Deviation, would be constructed and handed over to Northern Beaches Council after completion of the project. Further information regarding the new and improved open space and recreation facilities at Balgowlah is provided in Chapter 20 (Land use and property)

- The project would require the permanent acquisition of a portion of land at Artarmon Park to accommodate road infrastructure associated with the Gore Hill Freeway Connection. This is not expected to impact on the ongoing use or functioning of the park and its facilities, which mainly include seating and dog off lease area within a vegetated open space. Overall, the significance of potential impacts on the permanent strip acquisition of Artarmon Park during operation of the project have been assessed as moderate-low, with the sensitivity of the park to impacts considered moderate and the magnitude of the impact low.

During operation, the project would contribute to improved access and connectivity through improved travel time and improved travel time reliability, including to local and regional infrastructure within and near the precinct areas including major hospitals, tertiary education facilities, regional and state sport and recreation facilities, and major retail, commercial uses, cultural and community support facilities (refer to Section 21.3.2). However, operation of the project may also result in impacts to some social infrastructure due to changes in local road access.

Overall, the significance of impacts on social infrastructure from the project's operation is considered low, with the sensitivity of social infrastructure to changes and the magnitude of potential impacts considered low.

21.5.4 Community values

Local amenity and character

Operation of the project may result in changes to traffic noise levels for communities near the tunnel connections and the Warringah Freeway. In particular, increased traffic noise may be experienced by some receivers near the surface connections at the Gore Hill Freeway, Balgowlah and the Wakehurst Parkway due to forecast increases in traffic volumes and realignment or widening of roads closer to receivers. Conversely, decreased traffic noise impacts may be experienced by some communities near the surface connections at Balgowlah, the Gore Hill Freeway and the Warringah Freeway due to the forecast reduction in traffic volumes along existing surface roads with traffic being moved into tunnels. This may have beneficial impacts on local amenity at some properties.

The early development of the new and improved open space and recreational facilities in Balgowlah would improve access to sport and recreational facilities for surrounding communities. Increased availability of public open space and passive and active recreation facilities would impact positively on local amenity in this area. Use of the residual land for such facilities would address the current under supply of sporting grounds available for public use in the local area.

The sensitivity of communities near the entry and exit ramp tunnels to connections at the surface to adverse changes in local amenity and character and the magnitude of potential changes are considered low. As such, the overall significance of potential impacts on local character and amenity from the project's operation are assessed as low.

Community cohesion

Community cohesion is encouraged by connectivity or discouraged by barriers to movement. During operation, the project would support improved travel and access to work, business and leisure activities in the precinct areas and the Greater Sydney region. Regionally, improved accessibility and connectivity is likely to provide long-term benefits for community cohesion. In particular, travel facilitates social interactions and where access on major routes is constrained, some people may avoid making trips. Reduced travel times and improved travel time reliability may encourage some people to make trips they otherwise wouldn't, helping to facilitate community cohesion.

Locally, residential property acquisition has the potential to impact on community cohesion through the disruption to social networks and community relationships. As discussed in Chapter 20 (Land use and property), 28 residential lots would be wholly impacted by the project's construction and operation, requiring affected households to relocate before construction. This has potential to disrupt personal networks and local social connections associated with residents of these properties, particularly if the households are not able to find suitable alternative accommodation in the local area. Residents of Dudley Street at Balgowlah are likely to experience the greatest disruption to local social connections. Elsewhere, while any impact is likely to be important to affected individuals and their local networks, the impact in the context of the project as a whole is expected to be minor given the relatively small number of properties acquired.

Increased traffic volumes on roads such as the Wakehurst Parkway leading to and from connections may reinforce existing perceived barriers to local movements for pedestrians and cyclists, potentially influencing some people's ability to access services and meeting places. Conversely, improvements to pedestrian and cycle facilities with upgraded infrastructure (for example, along and under the Wakehurst Parkway) would support increased connectivity and enhanced safety, helping to encourage greater pedestrian and cycle movements.

Changes to Cammeray Golf Course and the closure of Balgowlah Golf Course and associated golf club may also impact on community cohesion. The permanent impact on the continued operation of Balgowlah Golf Course would require members and visitors to access golf courses elsewhere, impacting on social networks associated with the club. Potential impacts on individual members is likely to depend on individual circumstances such as the length of membership and the ability to access membership at an appropriate alternative club. The closure of the club may result in some members no longer participating in the sport. This is most likely to be long-term members or older golfers, potentially impacting individuals' general levels of physical activity, and overall wellbeing associated with the possible loss of social networks and personal relationships. The progressive establishment of new and improved public open space and recreation facilities in Balgowlah would provide opportunities for community members to meet and connect, helping to support community interaction and cohesion within the broader local community.

Changes to the Cammeray Golf Course may impact on the use of the golf course for some members. While works carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project would allow the Cammeray Golf Course to continue operating as a nine hole golf course, this may potentially result in some members and golfers accessing alternative golf courses, particularly following possible disruptions associated with changes to amenity during construction. These changes may impact on some social networks associated with the clubs.

The sensitivity of affected individuals and the magnitude of impact on community cohesion is considered moderate. As such, the overall significance of potential impacts on community cohesion due to the closure of Balgowlah Golf Club and permanent changes to Cammeray Golf Course are assessed as moderate.

Community health and wellbeing

Some residents and communities near the project may experience a level of stress and anxiety (refer to Chapter 13 (Human health)) due to uncertainty about potential property impacts and proposed changes. This may impact on the health and wellbeing of some individuals. Some residents impacted by acquisition of residential properties may also experience impacts on health and wellbeing associated with disruptions to social networks and personal relationships associated with the relocation of residents.

The operation of motorway facilities and ventilation outlets at the Warringah Freeway, the Gore Hill Freeway, Burnt Bridge Creek Deviation and the Wakehurst Parkway may influence people's perceptions of air quality in surrounding areas. This is likely to be of particular concern for surrounding residents and users of social infrastructure near ventilation outlets (for example, ANZAC Park Public School, Balgowlah Boys High, Seaforth Public School, ANZAC Park, Cammeray Park, Cammeray-Neutral Bay Skate Park, Cammeray Tennis Club and Seaforth Oval). Concerns about potential impacts on the health of students of schools near ventilation outlets were raised during consultation for the project.

The project tunnel ventilation outlets contribution to air pollutant concentrations would be negligible and any predicted changes in air quality mainly due to changes in traffic volumes on surface roads. At a regional level, potential impacts on air quality would be negligible and generally undetectable. Refer to Chapter 12 (Air quality) for an assessment of air quality impacts from the project. The overall significance of this impact is assessed as negligible, with the sensitivity of affected communities considered moderate and the magnitude of the impact considered negligible.

The project would support improvements in road safety, with reduced traffic demands along key surface road transport corridors including heavy vehicles transferring into the tunnels resulting in a forecast reduction in crashes across the network and consequent delays and disruptions during major incidents. Specifically, the project would result in substantial reductions in traffic volumes on the existing crossings into and out of the Northern Beaches peninsula, with the largest reductions in traffic volumes being on the Spit Road and Military Road corridor (refer to Chapter 9 (Operational traffic)).

The establishment of new and improved public open space and recreation facilities at Balgowlah Golf Course site would provide greater access to active and passive recreation facilities for surrounding communities, helping to encourage increased participation in recreation activities and overall levels of physical activity. The project would also include new and upgraded active transport infrastructure along the Burnt Bridge Creek Deviation and new access road at Balgowlah, and a new shared user path along Wakehurst Parkway from Seaforth to Frenchs Forest. This would support safer and easier access for pedestrians and cyclists, further helping to encourage increased walking and cycling and overall levels of physical activity.

21.5.5 Economic

Employment

The project would support improved access and connectivity to employment areas in the study area and the wider Sydney region. Changes to the business environment or the acquisition of properties accommodating businesses as part of the project may cause some loss of local employment, which may result in loss of income for affected employees and business owners. Potential impacts on employment due to the relocation of businesses to alternate sites are likely to be dependent on the businesses' new location (that is whether alternate premises are found locally) and individual circumstances of employees, for example increased commuting distances and times and ability of individual employees to travel to the new business location. While this would be a concern for employees and owners of affected businesses, given the small number of commercial properties affected, this is not expected to impact on the overall levels of employment in the precinct areas.

Freight and efficiency costs

Operation of the project would deliver significant long-term improvements to freight and efficiency costs for a large number of businesses and business centres within the region. Operation of the project would have benefits for businesses and business centres across the Northern Beaches by reducing travel times for light commercial and freight trips, which would in turn reduce transportation costs and increase efficiency. It is noted that Spit Road and Military Road have access restrictions for large articulated trucks (ie B-doubles and other higher mass limit vehicles). As such, access to the Northern Beaches for B-doubles is currently limited to Mona Vale Road and Warringah Road. Notwithstanding, the project would result in the majority of heavy vehicle trips on existing roads travelling through the Northern Beaches peninsula transferring to the tunnels. Peak period heavy vehicle volumes on Spit Road, Warringah Road and Mona Vale Road would decrease as a result of the project.

The movement of freight and commercial trips from surface arterial corridors to motorways would also increase the amenity of businesses and business centres located along the main arterial corridors into and out of the Northern Beaches peninsula. Amenity improvements are most likely to be experienced at The Spit, Spit Junction, Forestville, Seaforth, Neutral Bay and Cremorne.

Employment and customer access

The project would increase the accessibility of the Northern Beaches and reduce travel time from Manly to Chatswood, Chatswood to Dee Why-Brookvale and St Leonards, North Sydney to Chatswood, St Leonards, Artarmon and Macquarie Park.

The introduction of an additional transport connection, which increases the efficiency of a network and connectivity across a broader geographic area, can lead to expanded trade catchment and employment opportunities due to improved accessibility. The project has the capacity to increase the secondary trade catchment (the area from which the business attracts or services 20 to 30 per cent of customers). With the project, travel time from Artarmon to Manly, Frenchs Forest to North Sydney and North Sydney to Balgowlah would be between 10-15 minutes faster in both directions, compared to an alternative 'Do minimum' (without the project) scenario in 2027 and 2037. These travel time savings expand the catchment areas benefiting businesses in the suburb and further afield.

There would be a reduction in traffic demand on the Spit Road and Military Road corridor with improved travel times due to reduced congestion. Customers and employees accessing the centres of Military Road Mosman, Military Road Cremorne, Spit Junction and Neutral Bay would benefit from improved travel times.

Existing local and B-Line bus services would also benefit from reduced congestion on surface routes resulting in efficiency improvements in journey-to-work time. Additional significant improvements would result from the addition of further express bus routes using the tunnels to access employment centres and connecting to transport hubs like North Sydney and new transport services like the new Sydney Metro stations at Crows Nest and North Sydney.

Overall, any negative impacts associated with road alterations are localised and are offset by network wide improvements in travel time and accessibility. The significance of impacts on employee and customer access would be negligible.

Tolling

Tolling infrastructure has been included as part of this environmental assessment to provide the NSW Government with the option to apply tolls to traffic using the Beaches Link tunnels. While no decision on final toll costs has been made, if tolls were introduced, the additional tolling expense may deter some customers from driving to a business centre (that induces a toll charge) if there is another centre offering similar services in a location without the toll charge. This would cause a redistribution of customer expenditure, potentially benefiting some locations while others are disadvantaged. Although customer behaviour may alter, the trade catchments of businesses would generally remain consistent as customer expenditure is redistributed equally on either end of the connection. Alternate untolled routes would be available for motorists using existing surface roads.

The assessed significance of impacts associated with tolling are expected to be low, with the sensitivity of affected businesses to tolling changes and magnitude of impacts considered to be low. Overall, although the potential introduction of tolling would be a direct cost to businesses and persons, this would be offset by the reductions in congestion, vehicle running costs and travel time savings.

21.5.6 Business and industry

During operation, potential impacts on businesses located near the project may result from:

- Increased passing trade due to increased traffic volumes
- Improved travel times for employees and customers accessing the centres due to increased travel speeds
- Changes to access for employees and customers
- Potential increase to the trade catchment for some businesses, due to improved accessibility.

Potential impacts on business and industry have been assessed for those business centres identified as being most likely to experience direct and indirect operational impacts as discussed below. Business centres which are not anticipated to experience operational impacts include the Warringah Mall, Austlink Business Park, Manly Vale Business Centre, Seaforth Centre, Miller Street Cammeray and The Spit. These centres have not been included in the discussion below.

Passing trade

Operation of the project may result in changes to vehicle, pedestrian and cyclist flows that could influence the level of passing trade.

The operation of the project would result in additional passing trade for businesses within the Balgowlah Centre and the Frenchs Forest Business Hub due to increased traffic demand. In addition, pedestrian and bicycle facilities to be provided as part of the project would improve the active transport network and benefit passing trade. Overall, benefits to businesses within the Balgowlah Centre are expected due to increased passing trade as a result of the project.

The conversion of Dickson Avenue east of Reserve Road to a cul-de-sac and the removal of property access to Reserve Road (replaced with access via Hesky Lane) would potentially reduce passing traffic on Reserve Road, and increase on Hesky Lane and the surrounding road network (such as Taylor Lane, Cleg Street, Herbert Street and Waltham Street). Overall, the Artarmon Industrial Centre has a negligible sensitivity to passing trade and low magnitude of change, making the significance of any negative impacts as a result of the project considered to be negligible.

Employee and customer access

Operation of the project would result in changes to road, public transport and active transport networks, which would affect employee and customer access.

Customers and employees at the Artarmon Industrial Centre may experience minor inconvenience due to disruptions in the local road network and the conversion of Dickson Avenue and Punch Street to cul-de-sacs. However, impacts are considered minimal to businesses as there would be minimal impact on travel times. The centre has a low sensitivity to customer and employee access and negligible magnitude of change, resulting in a negligible significance of impacts.

The project would result in isolated, minor localised increases in travel times and minor reduced travel speeds in the southbound direction on Wakehurst Parkway, north of Warringah Road, and reduced local access from Wakehurst Parkway northbound into Frenchs Forest Road East. This may affect employee and customer access to the Frenchs Forest Business Hub. However, impacts are considered to be negligible to businesses as there would be a negligible magnitude of change. The substantial increase in connectivity would counter negative impacts and enhance accessibility for the broader catchment.

Existing local and B-Line bus services would benefit from reduced congestion on surface routes resulting in efficiency improvements in journey-to-work time. Substantial improvements would also result from the addition of new express bus routes using the tunnels to access employment centres and connecting to transport hubs like North Sydney and new transport services like the new Sydney Metro stations at Crows Nest and North Sydney.

Overall, the project would have long term positive effects on the business environment through improved connectivity and road network efficiency, expanded trade catchments, reduced passenger travel time and improved safety and active transport network infrastructure.

Servicing and deliveries

Changes in the road network performance may lead to some minor localised impacts to delivery times in Frenchs Forest north of Warringah Road, which may result in impacts of low significance on servicing and deliveries for businesses within the Frenchs Forest Business Hub Centre. The level of sensitivity of the centre is moderate and the magnitude of change is low.

Generally, the project is expected to result in benefits to servicing and deliveries due to increased transport efficiencies and road capacity. The additional, faster and more direct road connections

would improve connectivity to the broader network and enhance the efficiency of supply chain movements, allowing deliveries to reach their destinations more quickly.

Amenity

Businesses within the Balgowlah Centre may experience a very minor increase in noise due to an increase of vehicles along Sydney Road. This is unlikely to noticeably alter local amenity as the existing acoustic environment is already subject to higher vehicle noise, and therefore the impact would be negligible.

Businesses within the Artarmon Industrial Centre may experience impacts on amenity and character due to views of the motorway facilities and ventilation outlet, motorway control centre and portals, and due to the removal of vegetation. However, industrial land use generally has a lower dependency on character and amenity than commercial or mixed use centres. The level of sensitivity of the centre is negligible and the magnitude of change is considered to be low. As a result, the significance of potential impacts is considered to be negligible.

Employee productivity and communication

Businesses within the Artarmon Industrial Centre along Punch Street, Cleg Street, Waltham Street and the Gore Hill Freeway may experience slightly higher noise levels due to additional vehicles on the road. The significance of these impacts is considered negligible, with a negligible sensitivity and low magnitude of change.

Business visibility

The operation of the project may result in benefits for businesses within the Balgowlah Centre and Artarmon Industrial Centre due to improved business visibility as a result of increased traffic at these locations.

Demand for services

During operation of the project, businesses are generally expected to experience benefits to demand for services due to improved access and connectivity, and increased trade catchments. No negative impacts on demand for services are anticipated due to the project.

Maritime businesses

The top of the immersed tube tunnels would be up to 9.2 metres above the existing elevation of the harbour bed at the centre of the crossing. The water depth above the immersed tube tunnels would vary between 16 metres and 22 metres, depending on the distance from the shore (due to the profile of the bed of the harbour). Such reduction in water depth is considered inconsequential as the draught of vessels in this part of the Harbour is constrained by shallow water depths downstream. Refer to the navigational impact assessment in Annexure A of Appendix F (Technical working paper: Traffic and transport).

Commercial moorings relocated during construction would be restored at or near their original position upon operation of the project.

Once in operation, the project would have no impacts on business reliant on the Middle Harbour for operation.

21.5.7 Access and connectivity

Road and private access

The project would improve regional access and connectivity for motorists and other road users by providing an alternative crossing of Middle Harbour. The project would relieve congestion on the Military Road/Spit Road and Warringah Road/Eastern Valley Way corridors, and enable faster, more reliable journeys for bus customers, freight and private vehicles on all road corridors crossing Middle Harbour. The project would improve access to key commercial and employment centres including the Sydney CBD, North Sydney, Artarmon, St Leonards, Macquarie Park and other strategic centres. This would have positive long-term impacts for motorists.

Locally, the project would provide an alternative to existing arterial connections including Warringah Road, Military Road/Spit Road and the Spit Bridge, which currently experience high levels of traffic congestion and constrained freight access. The project would also enhance the resilience of the road network by providing additional road network capacity and alternate north-south and east-west linkages to reduce congestion and potential gridlock in the event of incidents on the road network.

The project has potential to change traffic movements on local roads near to the tunnel connections. Reduced traffic congestion on arterial roads would reduce 'rat running' through local neighbourhoods, impacting positively on local access and connectivity for motorists, pedestrians and cyclists. Surface connections at Balgowlah have potential to increase the incidence of 'rat running' on some local roads. Traffic calming measures would be implemented where required and agreed in consultation with Northern Beaches Council, which would help to minimise potential for 'rat running' on local roads.

Public and active transport

The project would provide opportunity for improved access to public transport for local and regional communities. The new tunnels would allow the opportunity for new public transport routes including express buses within the tunnel to be developed in response to diverse travel demands and support new social and economic development such as the Northern Beaches Hospital precinct in Frenchs Forest. The new tunnels would reduce congestion on key arterial routes like Warringah Road, Eastern Valley Way and Military Road thereby improving travel times and reliability of buses in peak periods between the Northern Beaches, North Sydney, north western Sydney and the Sydney CBD. The new tunnels would also make buses a more attractive surface route transport option by relieving existing congestion and removing stop start conflict to improve existing travel times thereby supporting further mode shift to public transport. In particular, the project would allow new express bus connections between major centres on the Northern Beaches and Frenchs Forest and those in the lower North Shore, Sydney CBD, the north-west and beyond and opportunity for efficient access and interchange with the Sydney Trains and Sydney Metro stations at North Sydney.

The majority of cycling and pedestrian infrastructure along the project corridor provides links to recreational areas such as parks and open space. Cycle routes on the road network within and surrounding the project corridor are predominantly located within the road corridor. The project would improve cyclist and pedestrian connectivity along the project corridor through increased provision of dedicated cyclist and pedestrian links. This includes the provision of a new and upgraded pedestrian and cyclist infrastructure around surface connections and along the upgraded Wakehurst Parkway. It is anticipated that these improvements in connectivity would encourage greater use of existing infrastructure by pedestrians and cyclists.

The project would contribute to improved access and connectivity to social infrastructure within Middle Harbour and the Northern Beaches, which would increase access to recreational opportunities such as kayaking, boating and swimming.

Reinstatement of moorings impacted during construction near the Middle Harbour immersed tube tunnels would be as close as possible to their current locations.

A detailed assessment of potential operational traffic impacts of the project is included in Chapter 9 (Operational traffic and transport).

21.6 Environmental management measures

Measures to avoid, minimise or manage social and economic impacts as a result of the project are detailed in Table 21-6. Additional measures relevant to the management of socio-economic impacts are also outlined in other chapters of the environmental impact statement, including:

- Chapter 8 (Construction traffic and transport)
- Chapter 9 (Operational traffic and transport)
- Chapter 10 (Construction noise and vibration)
- Chapter 11 (Operational noise and vibration)
- Chapter 12 (Air quality)
- Chapter 13 (Human health)
- Chapter 20 (Land use and property)
- Chapter 22 (Urban design and visual amenity).

Table 21-6 Environmental management measures – socio-economics

Ref	Phase	Impact	Environmental management measure	Location
SE1	Design	Social infrastructure	Where feasible and reasonable, the extent of permanent impact on public open space areas (for example, Artarmon Park) will be minimised in further design development.	BL/GHF
SE2	Construction	Social infrastructure	Ongoing engagement will be carried out with representatives of user groups and managers of social infrastructure located near surface construction works/construction support sites and sensitive social infrastructure above the tunnel alignment (for example, schools, places of worship, aged care, child care, health and medical facilities) about the timing and duration of construction works and management of potential impacts.	BL/GHF
SE3	Pre-construction and construction	Stakeholders, community and business	Consultation for the project will be carried out in accordance with the Community Consultation Framework provided as Appendix E of the environmental impact statement.	BL/GHF
SE4	Pre-construction and construction	Employment benefits	A workforce strategy for the project that includes strategies to increase employment and training opportunities for groups such as Aboriginal people, women, young people and the unemployed will be developed and implemented to help maximise employment benefits of the project.	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
BU1	Pre-construction and construction	Businesses	Where businesses are affected by property acquisition, or lease cessation, the acquisition and compensation process will be implemented in line with the <i>Determination of compensation following the acquisition of a business guideline</i> . Compensation for a business conducted on land that is acquired should be determined in accordance with the <i>Land Acquisition (Just Terms Compensation) Act 1991</i> as relevant.	BL/GHF
BU2	Construction	Businesses	Specific consultation will be carried out with businesses potentially impacted during construction. Consultation will aim to identify specific potential construction impacts for individual businesses.	BL/GHF
BU3	Construction	Businesses	Based on consultation with businesses, specific feasible and reasonable measures to maintain business access, visibility, parking and address other potential impacts as they arise through the construction phase will be identified and implemented. A phone hotline that enables businesses to find out about the project or register any issues will be maintained.	BL/GHF

Beaches Link = BL, Gore Hill Freeway = GHF



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 22

Urban design and visual amenity

22 Urban design and visual amenity

This chapter provides an assessment of the urban design, landscape character and visual amenity impacts of the project and identifies measures to address these impacts. A detailed urban design, landscape character and visual impact assessment has been prepared for the project and is provided in Appendix V (Technical working paper: Urban design, landscape character and visual impact).

The Secretary's environmental assessment requirements as they relate to urban design, visual amenity and landscape, and where in the environmental impact statement these have been addressed, are detailed in Table 22-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to urban design, visual amenity and landscape are included in Section 22.8.

Table 22-1 Secretary's environmental assessment requirements – Urban design, visual amenity and landscape

Secretary's requirement	Where addressed in the EIS
Placemaking and urban design (visual amenity requirements)	
<p>1. The Proponent must identify how functional 'place' outcomes of public benefit will be achieved, including design principles and strategies that:</p> <ul style="list-style-type: none"> a. consider areas identified for future urban renewal; b. capitalise on reduced traffic volumes and the reduction of traffic permeation, particularly in and around commercial and community centres; c. avoid locating infrastructure, including ancillary facilities adjoining residential areas and other sensitive receivers, and justify where this cannot be achieved; d. achieve high quality landscaping, streetscapes, architecture and design; e. identify urban design strategies and opportunities that would enhance healthy, cohesive and inclusive communities, including in relation to accessibility and connectivity; f. consider resulting residual land treatments, and demonstrate how the elements of the proposal would be consistent with the 	<p>Chapter 22 (Urban design and visual amenity) provides the principles that identify how functional 'place' outcomes of public benefit would be achieved (in respect to points a – h) and are outlined in Section 22.2 and Section 22.8 and Table 1.2 of Appendix V (Technical working paper: Urban design, landscape character and visual impact).</p> <p>Justification for the location of ancillary facilities is provided in Chapter 4 (Project development and alternatives) and Chapter 5 (Project description).</p>

Secretary's requirement	Where addressed in the EIS
<p>existing and desired future character of the area traversed or affected by the proposal;</p> <p>g. identify opportunities to utilise surplus or residual land, particularly for the provision of community space (passive and recreational) and utilise key structures (such as ventilation outlets) for multiple uses (i.e. integration with other structures; and</p> <p>h. explore the use of Crime Prevention Through Environmental Design (CPTED) principles during the design development process, including natural surveillance, lighting, walkways, signage and landscape</p>	
<p>2. The Proponent must describe the accessibility elements of the proposal including relevant accessibility legislation and guidelines, including:</p> <p>a. impacts on public transport infrastructure and services;</p> <p>b. impacts on pedestrian and cyclist access and safety across and adjoining the proposal; and</p> <p>c. opportunities to integrate and enhance accessibility including the provisions public and active transport infrastructure as a result of the proposal.</p>	<p>A high-level outline of the legislation and guidelines relevant to the project and its possible visual amenity and landscape impacts is presented in Section 22.1.</p> <p>Accessibility and transport related issues are outlined in Chapter 8 (Construction traffic and transport) and Chapter 9 (Operational traffic and transport).</p>
<p>3. The Proponent must assess the visual and landscape impacts of the proposal, including ancillary infrastructure on:</p> <p>a. views and vistas;</p> <p>b. streetscapes, key sites and buildings;</p> <p>c. landscaping, green spaces and existing tree canopy including an assessment of likely magnitude of impacts to trees and need for removal to be undertaken by an arborist including the provision of measures to minimise and offset impacts;</p> <p>d. heritage items Aboriginal places, environmental heritage and areas of heritage sensitivity; and</p> <p>e. the local community.</p>	<p>The visual and landscape impacts of the proposal including ancillary infrastructure (in respect to points a, b, d, and e), associated with construction and operation are outlined in Section 22.6 and Section 22.7 respectively and Table 1.1 of Appendix V (Technical working paper: Urban design, landscape character and visual impact).</p> <p>The potential removal and likely magnitude of impacts to trees is assessed in Appendix W (Technical working paper: Arboricultural impact assessment) and is subject to further design development and construction planning.</p>
<p>4. The Proponent must provide artist impressions and perspective drawings of the proposal from</p>	<p>Appropriate impressions and perspective drawings of the proposal from key receiver locations are provided in Section 22.7.</p>

Secretary's requirement	Where addressed in the EIS
key receiver locations to illustrate the proposal and its visual impacts.	

22.1 Legislative and policy framework

An urban design framework (refer to Appendix V (Technical working paper: Urban design, landscape character and visual impact)) has been prepared with reference to the urban design principles in *Beyond the Pavement* (Transport for NSW, 2020g). A design review panel has been established for the project to provide independent review and advice throughout the design development. *Better Placed* (NSW Government Architect, 2017), other Transport for NSW design and biodiversity guidelines and local government planning documents, such as local environmental plans and development control plans, have also been considered in the preparation of the urban design framework.

The landscape character and visual impact assessment has also considered relevant local environment plans, development control plans, and regional planning documents. A complete list of the local environment plans, development control plans, regional planning documents, as well as guidelines relating to landscape character and visual impact assessment, is provided in Appendix V (Technical working paper: Urban design, landscape character and visual impact).

22.2 Urban design framework

Transport for NSW has developed a strategic urban design framework for the Beaches Link and Gore Hill Freeway Connection project to inform the urban design and establish benchmarks for achieving a well-planned and integrated road alignment through a high-quality urban design response. The urban design framework has been informed by the urban design policy, *Beyond the Pavement* (Transport for NSW, 2020g) and is provided in Appendix V (Technical working paper: Urban design, landscape character and visual impact).

22.2.1 Urban design vision and objectives

The urban design vision for the project is to provide “a distinctive motorway experience that, through a series of undulating subterranean journeys, provides a connection across Sydney Harbour from the urban centre of North Sydney, through residential suburbs towards the landscape of the Northern Beaches. It also provides east/west connectivity, improving access to employment centres like Macquarie Park and Chatswood and improved traffic levels on Warringah Road through Roseville Bridge. It is a transition between tunnel and surface environments, a connection across the Harbour and a link from city to bushland. It will provide enhanced green connections, improved pedestrian and cyclist amenity and facilitate local places to return to local communities”. This vision is further outlined in Appendix V (Technical working paper: Urban design, landscape character and visual impact).

To help achieve this urban design vision, urban design objectives and the desired outcome for each objective have been established to guide the urban design process. These are discussed in Table 22-2.

Table 22-2 Urban design objectives

Objective	Desired outcome
Identity and user experience	Develop a theme that references Sydney's unique geography and place to provide a user experience that enhances the journey, encourages awareness of the living environment, enables orientation and enhances safety.

Objective	Desired outcome
Integrated design	Provide an integrated urban design approach that thoughtfully seams the Beaches Link and Gore Hill Freeway Connection to its surrounding urban and landscape interfaces.
Connectivity and legibility	Provide connectivity between areas beyond the boundaries of the motorway corridor and promote increased legibility of places, buildings, streets and landmarks.
Urban renewal and liveability	Unlock potential for urban regeneration, landscape improvements as well as active transport and public transport upgrades along the project corridor. These urban renewal opportunities would provide high levels of urban amenity and liveability.
Living environments	Ensure the design, planning, construction and management of the project responds to the living environment. Infrastructure interventions would reflect a natural system approach which is responsive to the environment and promotes the highest levels of sustainability.
Sustainability	Embed sustainability considerations into the design and delivery of the project in order to minimise environmental and social impacts whilst delivering positive economic outcomes for the people of NSW.

22.2.2 Urban design requirements

The urban design requirements of the project have been informed by the urban design vision and objectives and encompass the requirements for the spatial and functional design of the urban and public domain, and the built elements of the project. The architectural treatments for the tunnels, surface connections and other operational infrastructure would be guided by the urban design requirements and finalised during further design development of the project.

Experience and function

Good urban design has the ability to connect communities and provide a positive experience for users. Design principles for spatial and functional design of the project, and the relevant urban design objective that these would address, are provided in the urban design framework in Appendix V (Technical working paper: Urban design, landscape character and visual impact).

Urban elements

The built elements of the project would contribute to creating desirable public spaces by providing a high-quality experience for users and a balanced, contextually responsive approach. Table 22-3 outlines the principles for designing the urban elements of the project. Further detail, including the proposed approach to achieving these principles, is provided in the urban design framework in Appendix V (Technical working paper: Urban design, landscape character and visual impact). These principles, including CPTED principles, would be further developed during the further design development stage of the project.

Table 22-3 Principles for designing urban elements of the project

Urban elements	Design principle	Relevant urban design objective
Earthworks	Visually integrate earthworks into their landscape setting as much as possible, keeping engineered structures to a minimum.	<ul style="list-style-type: none"> Urban renewal and liveability Integrated design Living environments Sustainability.

Urban elements	Design principle	Relevant urban design objective
Noise walls	Visually integrate noise walls into the road corridor and urban/landscape setting as part of a coordinated whole-of-corridor design.	<ul style="list-style-type: none"> • Identity and user experience • Integrated design • Sustainability.
Retaining walls and flood walls	Visually integrate retaining walls and flood walls into the road corridor and urban/landscape setting as part of a coordinated whole-of-corridor design.	<ul style="list-style-type: none"> • Identity and user experience • Integrated design • Connectivity and legibility • Living environments.
Mainline tunnels and ramp tunnels	Deliver a tunnel that makes a positive contribution to the journey experience through intuitive wayfinding and a varied and stimulating driver environment.	<ul style="list-style-type: none"> • Identity and user experience • Integrated design • Connectivity and legibility.
Tunnel portals and trough structures	Deliver portals and trough structures that are visually appealing, sensitive to their context, reflect the above ground environment and provide a legible, self-explaining journey which enables awareness of location.	<ul style="list-style-type: none"> • Identity and user experience • Integrated design • Connectivity and legibility • Living environments.
Motorway facilities, ventilation outlets and motorway control centre	Minimise the physical footprint and visual impact of these structures whilst ensuring they are designed as high quality pieces of well integrated architecture.	<ul style="list-style-type: none"> • Identity and user experience • Integrated design • Connectivity and legibility • Sustainability.
Road bridges	Deliver elegant road bridges that integrate all architectural and engineering systems requirements while minimising visual impacts.	<ul style="list-style-type: none"> • Identity and user experience • Urban renewal and liveability • Integrated design • Connectivity and legibility • Sustainability.
Shared user bridges	Deliver well designed and attractive shared user bridges that provide safe access for all pedestrians and cyclists.	<ul style="list-style-type: none"> • Identity and user experience • Urban renewal and liveability • Integrated design • Connectivity and legibility • Sustainability.
Landscape treatments	Provide new and reinstated landscapes that are appropriate to the local conditions, consistent with the existing varied character of the project, provide opportunities to increase canopy cover wherever possible and provides improved public realm amenity.	<ul style="list-style-type: none"> • Identity and user experience • Urban renewal and liveability • Integrated design • Living environments • Sustainability.
Materials and finishes	Deliver a road corridor and associated infrastructure/public domain that presents a consistent palette of high-	<ul style="list-style-type: none"> • Identity and user experience • Urban renewal and liveability

Urban elements	Design principle	Relevant urban design objective
	quality materials representative of the project image and local context.	<ul style="list-style-type: none"> • Integrated design • Sustainability.
Safety in design and crime prevention through environmental design (CPTED)	Provide a corridor that allows all users, including motorists, pedestrians, cyclists and maintenance and management people to manage a safe and responsive journey.	<ul style="list-style-type: none"> • Urban renewal and liveability • Integrated design.
Aboriginal heritage	Deliver a corridor and public domain which provides Connection with Country and incorporates heritage and cultural contexts into the project.	<ul style="list-style-type: none"> • Connectivity and legibility • Integrated design • Living environments • Sustainability.

Illustrations of architectural treatments and urban design proposed for surface connections and other operational infrastructure associated with the project have been outlined within concept masterplans as presented below in Figure 22-1 to Figure 22-4 and in Appendix V (Technical working paper: Urban design, landscape character and visual impact).

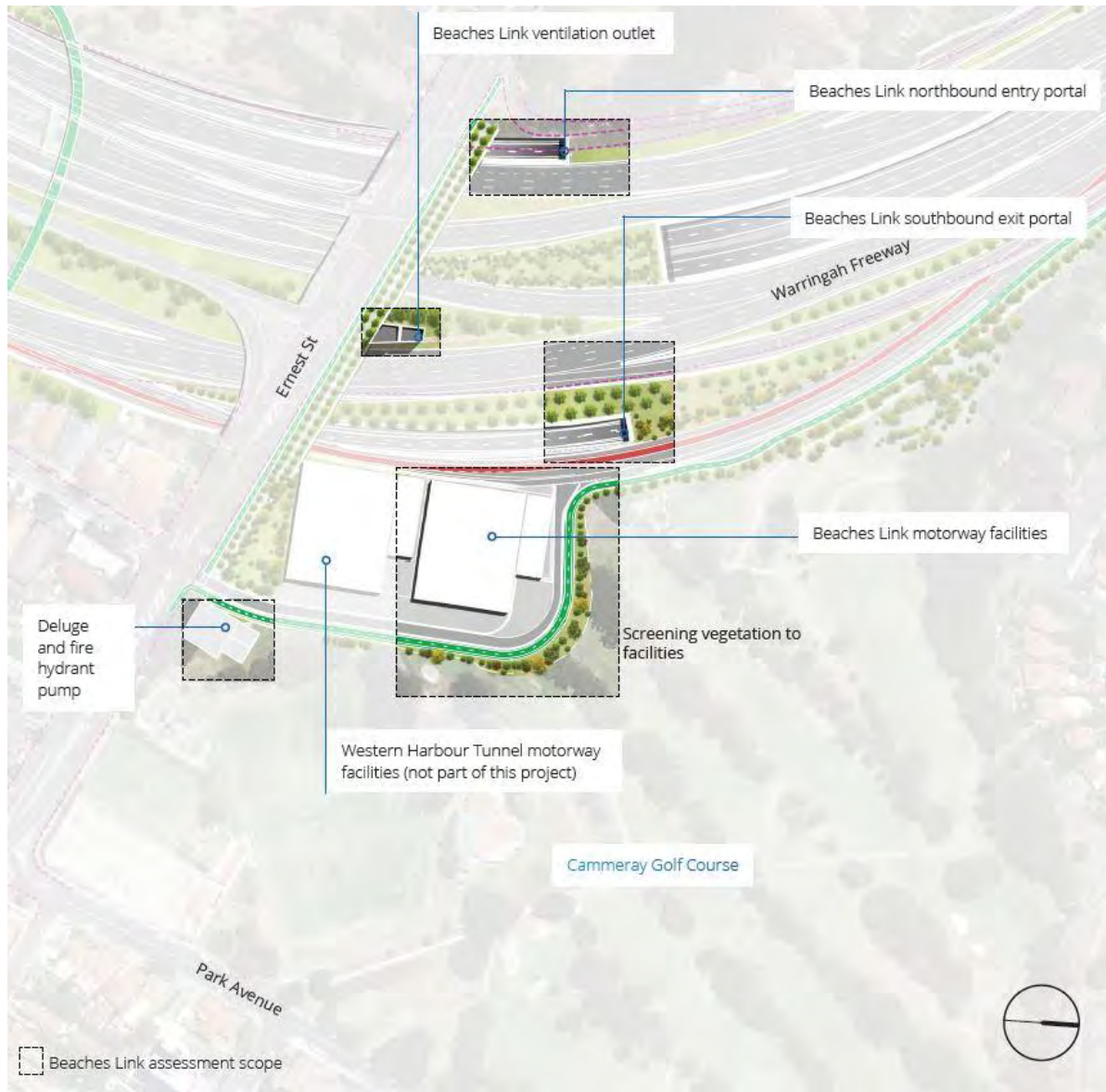


Figure 22-1 North Sydney precinct concept masterplan

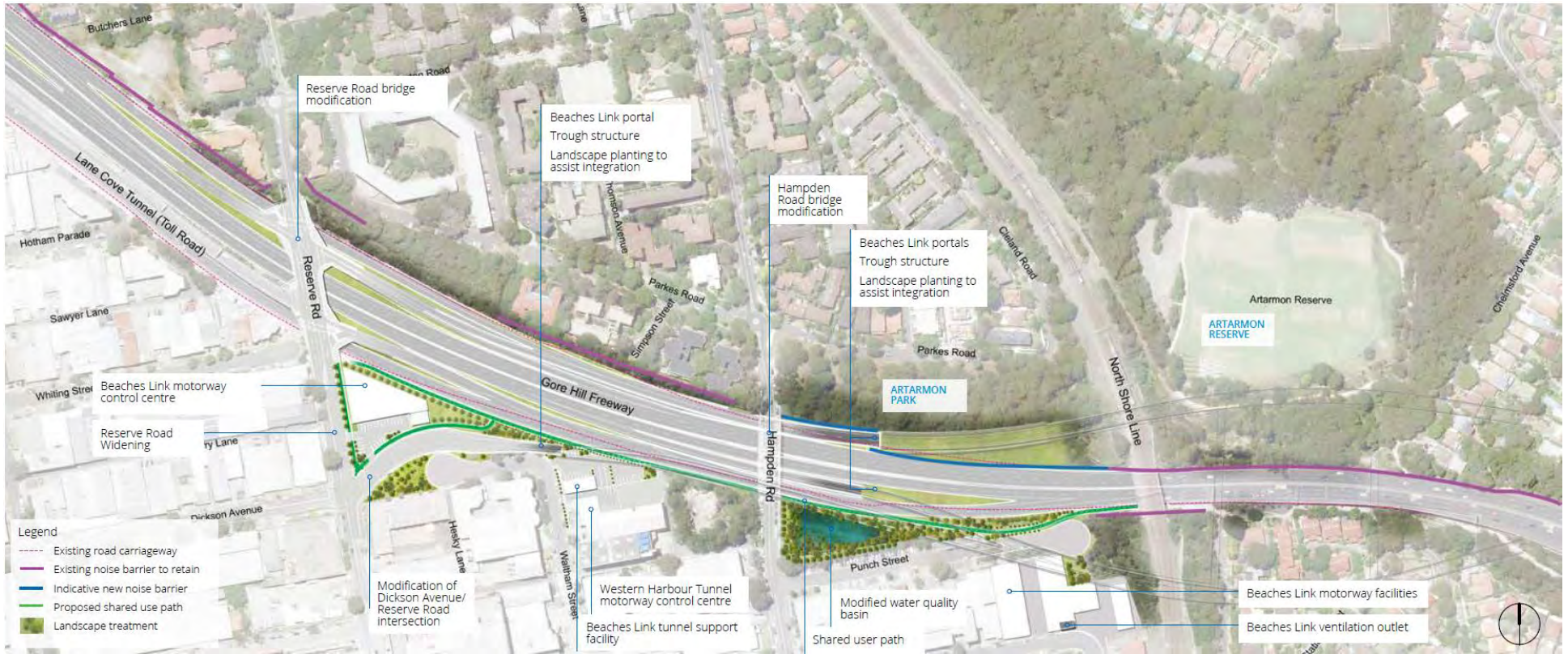


Figure 22-2 Artarmon precinct concept masterplan

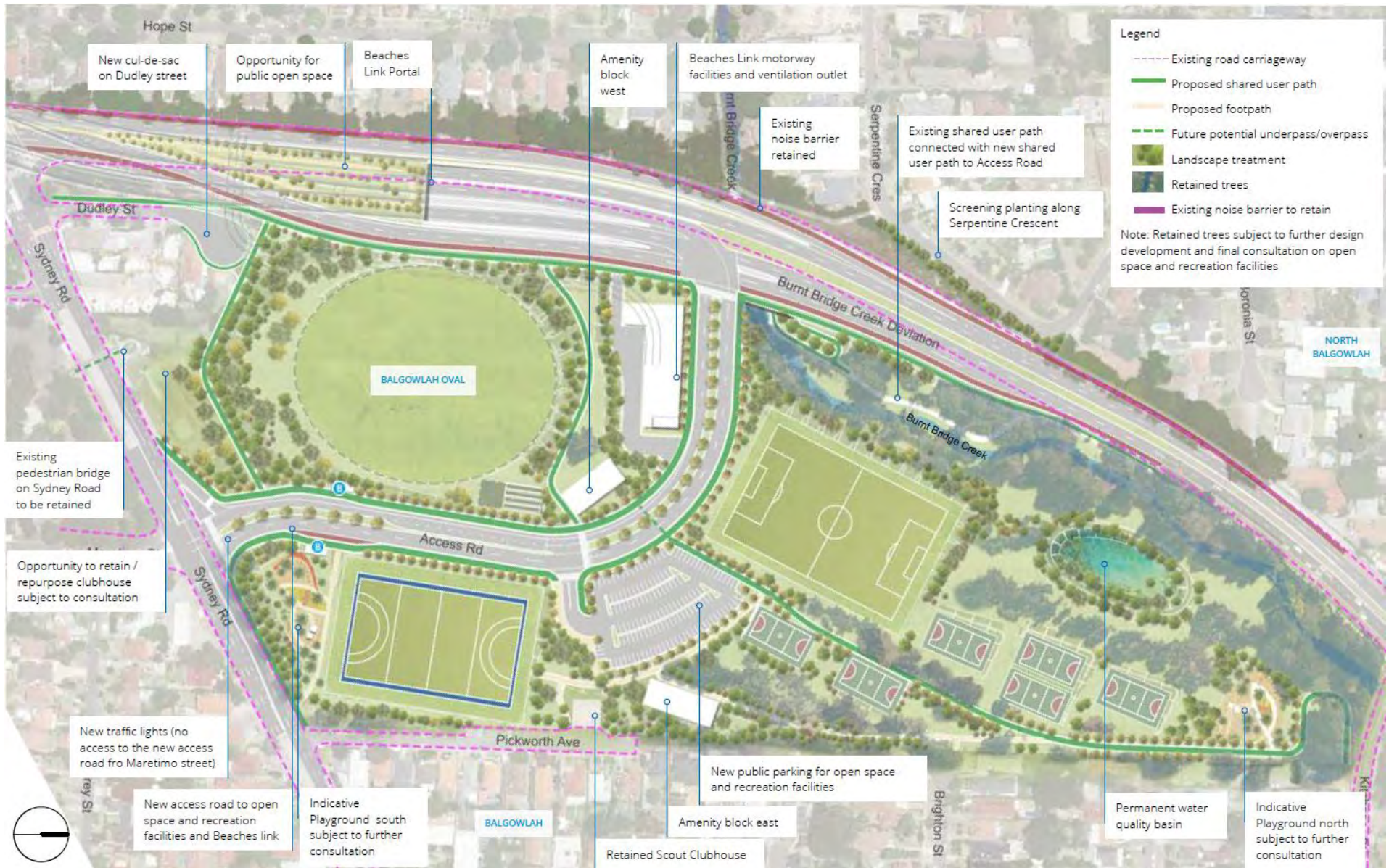


Figure 22-3 Balgowlah precinct concept masterplan

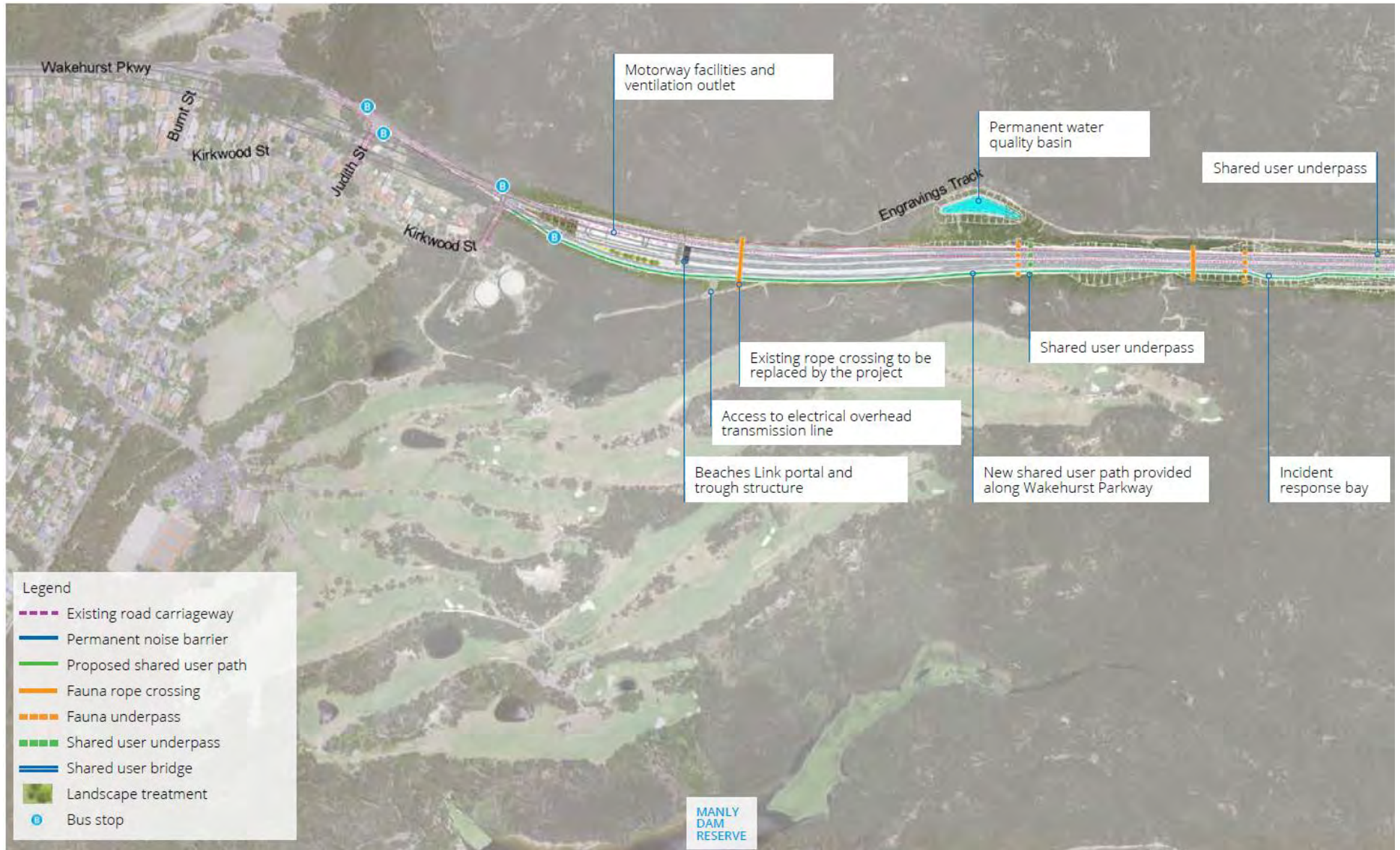


Figure 22-4a Wakehurst Parkway precinct concept masterplan

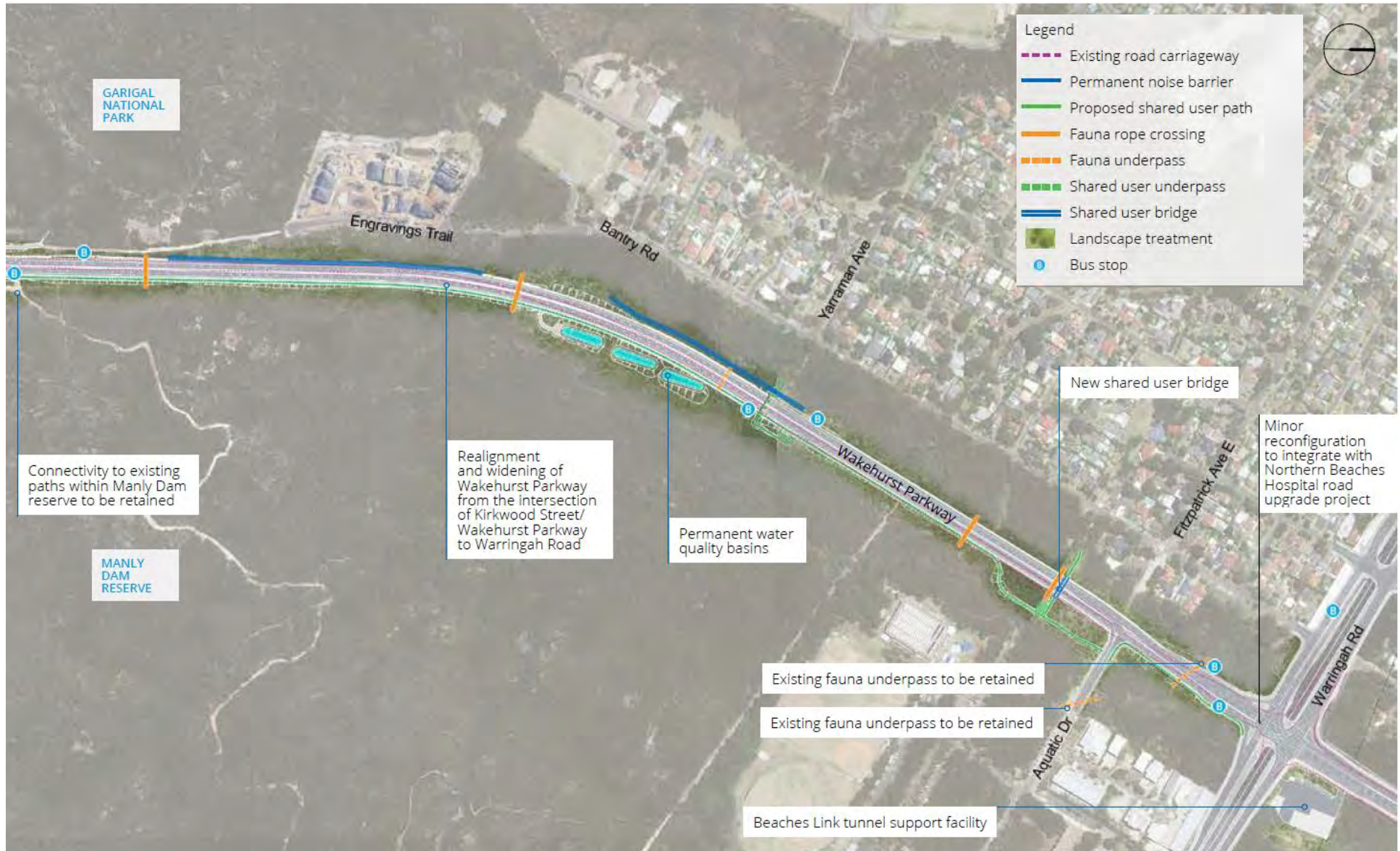


Figure 22 4b Wakehurst Parkway precinct concept masterplan

22.3 Assessment methodology

The landscape character and visual impact assessment presented in this chapter has been carried out in accordance with *Environmental Impact Assessment Practice Note – Guidelines for Landscape Character and Visual Impact Assessment* (Transport for NSW, 2020d).

Assessment of the impacts on landscape character involves an understanding of the built, natural and cultural character or sense of place. Assessment of visual impacts relates to the impacts of the project on public and private views and how people think and feel about the landscape on a day to day basis.

The assessment methodology involved:

- A desktop assessment including:
 - Consideration of relevant legislation and policy requirements
 - Review of the landscape context and study area
 - Determination of sensitive receiver locations and potential viewpoints
- Surveys of the study area to confirm significant landforms and potential viewpoints
- Assessment of potential landscape character and visual impacts (including cumulative impacts)
- Identification of environmental management measures to mitigate potential impacts.

The Western Harbour Tunnel and Warringah Freeway Upgrade project is subject to a separate environment assessment approval. For the purpose of assessing potential operational impacts of the project the Warringah Freeway Upgrade (without the Western Harbour Tunnel) is assumed to be delivered.

The civil construction of the Beaches Link ventilation outlet at the Warringah Freeway would be carried out as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project. As such, only fitout and commissioning works for this particular ventilation outlet would be carried out as part of this project. All other ventilation outlets for the project would be constructed as part of the Beaches Link project.

Any potential cumulative landscape character and visual impacts of both projects being operational together have been considered in this assessment.

22.3.1 Landscape character impact assessment

To assess the impacts on landscape character, landscape character zones (LCZ) were determined for the study area, particularly within the distinct precincts that have been identified within the study area (see Section 22.4.1 for more information). Landscape character zones are defined as areas having a distinct, recognisable and consistent pattern of elements, including natural elements (eg soil, vegetation, landform) and/or human built form, making one landscape different from another.

22.3.2 Visual impact assessment

Representative viewpoints with the potential to be visually impacted by elements of the project were identified for further analysis. Viewpoints were selected to show:

- A range of receiver types including public and private domain views (residents, motorists and users of public open space)
- A range of view types including elevated, panoramic and filtered views
- A range of viewing distance from the project
- Key or protected views identified in planning documents.

Viewpoints have been assessed for both the construction and operational stages of the project as well as potential night time impacts.

As part of the operational visual impact assessment, the zone of visual influence of new built form elements (including motorway facilities, ventilation outlets and operational infrastructure) has been assessed to identify areas from which these built form elements of the project would be potentially visible. This assessment takes into account topography and built form but excludes natural landscape features above ground level that would affect visibility such as trees, hedgerows or fences. Therefore, the zone of visual influence included as part of this assessment provides a worst-case scenario.

22.3.3 Landscape character and visual impact rating

Landscape character and visual impacts were measured by completing a sensitivity analysis of existing landscape character zones and views and assessing the magnitude of change on those zones and views.

Sensitivity and magnitude ratings are applied according to the landscape character and visual impact rating matrix specified in the *Environmental Impact Assessment Practice Note – Guidelines for Landscape Character and Visual Impact Assessment* (Transport for NSW, 2020d), shown in Table 22-4.

Table 22-4 Landscape character and visual impact rating matrix

Landscape character and visual impact	Magnitude of change				
		High	Moderate	Low	Negligible
Sensitivity of receivers	High	High	High-moderate	Moderate	Negligible
	Moderate	High – moderate	Moderate	Moderate – low	Negligible
	Low	Moderate	Moderate – low	Low	Negligible
	Negligible	Negligible	Negligible	Negligible	Negligible

Source: Transport for NSW (2020d)

Landscape character and visual impact ratings represent the potential impact of the project before the environmental management measures outlined in Section 22.8 have been applied. Potential landscape character and visual impact would be reduced by the application of environmental management measures.

22.3.4 Night lighting impact assessment

A broad assessment of the impacts of night lighting during both the construction and operation of the project was carried out by applying the methodology for assessment of visual impacts as described Section 22.3.2 above. Key visual receivers have been separately assessed and include neighbouring residential properties, users of recreational space and motorists in local streets.

The assessment of night lighting impacts is based on the following assumptions:

- Types and extent of lighting likely to be installed for both the construction and operation phases is consistent with applicable guidelines
- Lighting during construction is assumed to be in operation seven days a week and at levels sufficient to meet safety and security standards.

22.4 Existing environment

Visibility of the project would largely be determined by the surrounding topography, vegetation and the existing built environment. The project crosses areas with varied local context, differing built form elements, unique natural characteristics and various land use zones.

Four distinct precincts have been identified, which would have associated surface connections, operational facilities and several temporary construction support sites. These precincts are described further in Section 22.4.1 below. Details of works to occur in the precincts are provided in Section 22.5.1:

- North Sydney precinct
- Artarmon precinct
- Balgowlah precinct
- Wakehurst Parkway precinct.

Additionally, there are sites outside of these precincts which would be utilised temporarily for construction support sites:

- Flat Rock Drive (BL2)
- Middle Harbour Crossing (Middle Harbour south (BL7) and north (BL8) cofferdams) and Spit West Reserve (BL9).

The landscape character and visual amenity within each of the precincts and temporary construction support sites is discussed below.

22.4.1 Precincts

North Sydney precinct

Landscape character

The North Sydney precinct is centred around the North Sydney Central Business District (CBD) commercial hub, interspersed with a mix of residential land uses and areas of open space. It includes the residential neighbourhoods of Cammeray, Cremorne, Neutral Bay and North Sydney.

The precinct is located on the ridge of the Mosman peninsula, with steep slopes to the waterfront to the north and south respectively.

The Warringah Freeway forms a major human-made feature of the area, cutting through the landscape and creating east/west separation of the precinct both visually and physically.

The precinct also contains high quality but fragmented open space, including Cammeray Park (consisting of Cammeray Golf Course and Cammeray Oval), St Leonards Park with its heritage listed landscape and oval, Forsyth Park, ANZAC Park and Jeaffreson Jackson Reserve on the western edge of the Warringah Freeway.

Landscape character zones identified within the North Sydney precinct are shown in Figure 22-5 and comprise the following:

- LCZ 1 – St Leonards Park
- LCZ 2 – Warringah Freeway corridor
- LCZ 3 – Cammeray residential
- LCZ 4 – Cremorne and Neutral Bay residential
- LCZ 5 – Cammeray Park open space.

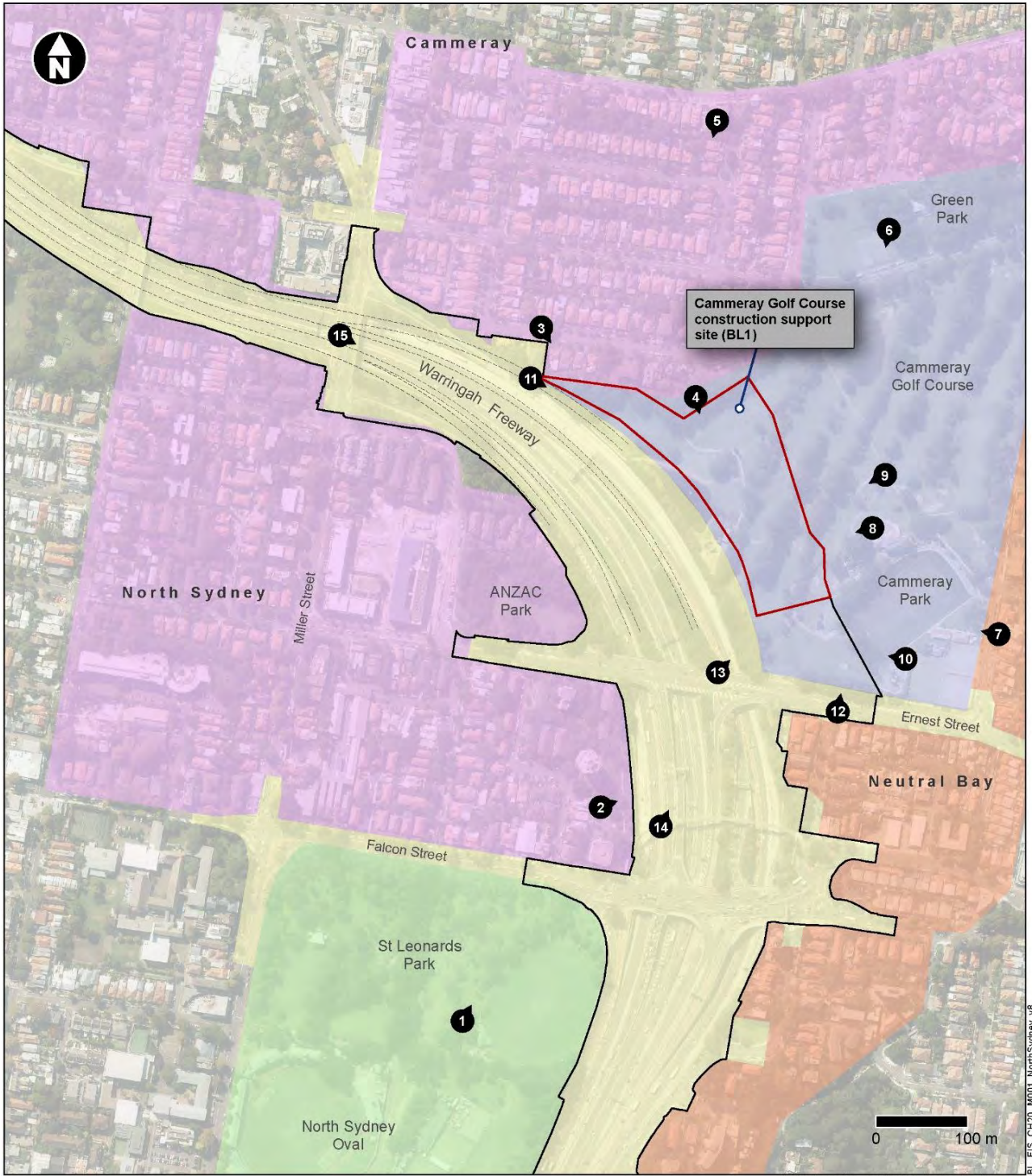
Visual environment

The visual character of the North Sydney precinct is defined by its elevated topography, major infrastructure and built form. North Sydney CBD forms a western edge to the precinct with large towers rising above the Warringah Freeway.

The Warringah Freeway sits within a depressed configuration within the landscape. Due to this position, the Warringah Freeway has limited visual connection to surrounding residential areas.

Viewpoints selected for the North Sydney precinct are also shown in Figure 22-5 and comprise the following:

- Viewpoint 1 – St Leonards Park – Bon Andrews Oval
- Viewpoint 2 – Jeaffreson Jackson Reserve and nearby residential
- Viewpoint 3 – Morden Street residential
- Viewpoint 4 – Warringa Road residential
- Viewpoint 5 – Carter Street lookout
- Viewpoint 6 – Green Park and Warwick Avenue residential
- Viewpoint 7 – Park Avenue residential
- Viewpoint 8 – Cammeray Golf Course club house
- Viewpoint 9 – Cammeray Golf Course footpath
- Viewpoint 10 – Cammeray Park sports facilities
- Viewpoint 11 – Warringah Freeway near Ernest Street
- Viewpoint 12 – Ernest Street residential
- Viewpoint 13 – Ernest Street bridge
- Viewpoint 14 – Falcon Street shared user bridge
- Viewpoint 15 – Miller Street bridge.



Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Landscape character zones

- Cammeray Park open space
- Cammeray residential
- Cremorne and Neutral Bay residential
- St Leonards Park
- Warringah Freeway corridor
- View point and direction

Indicative only - subject to design development

Figure 22-5 North Sydney precinct landscape character zones and viewpoints

Artarmon precinct

Landscape character

The Artarmon precinct is divided by the Gore Hill Freeway which cuts through the precinct in an east/west direction. Despite significant urban development surrounding the road, the Gore Hill Freeway has a noticeable green edge.

Northern sections of the precinct are comprised mostly of residential streetscapes with a well-vegetated character including numerous mature street trees.

The south of the precinct comprises large industrial lots with a mix of single and double storey warehouses, including a portion of the Artarmon/St Leonards industrial area.

The undulating topography of the precinct is a distinctive feature of the area. Densely vegetated valleys and gullies traverse the precinct, including Bicentennial Reserve (Flat Rock Creek) and Artarmon Reserve.

Landscape character zones identified within the Artarmon precinct are shown in Figure 22-6 and comprise the following:

- LCZ 1 – Artarmon industrial area
- LCZ 2 – Artarmon conservation area
- LCZ 3 – Gore Hill Freeway
- LCZ 4 – Artarmon residential
- LCZ 5 – Artarmon Reserve
- LCZ 6 – Artarmon Park.

Visual environment

The visual character of the precinct is defined by its undulating topography, major roads, mix of land uses, well vegetated streetscapes and dense bushland reserves.

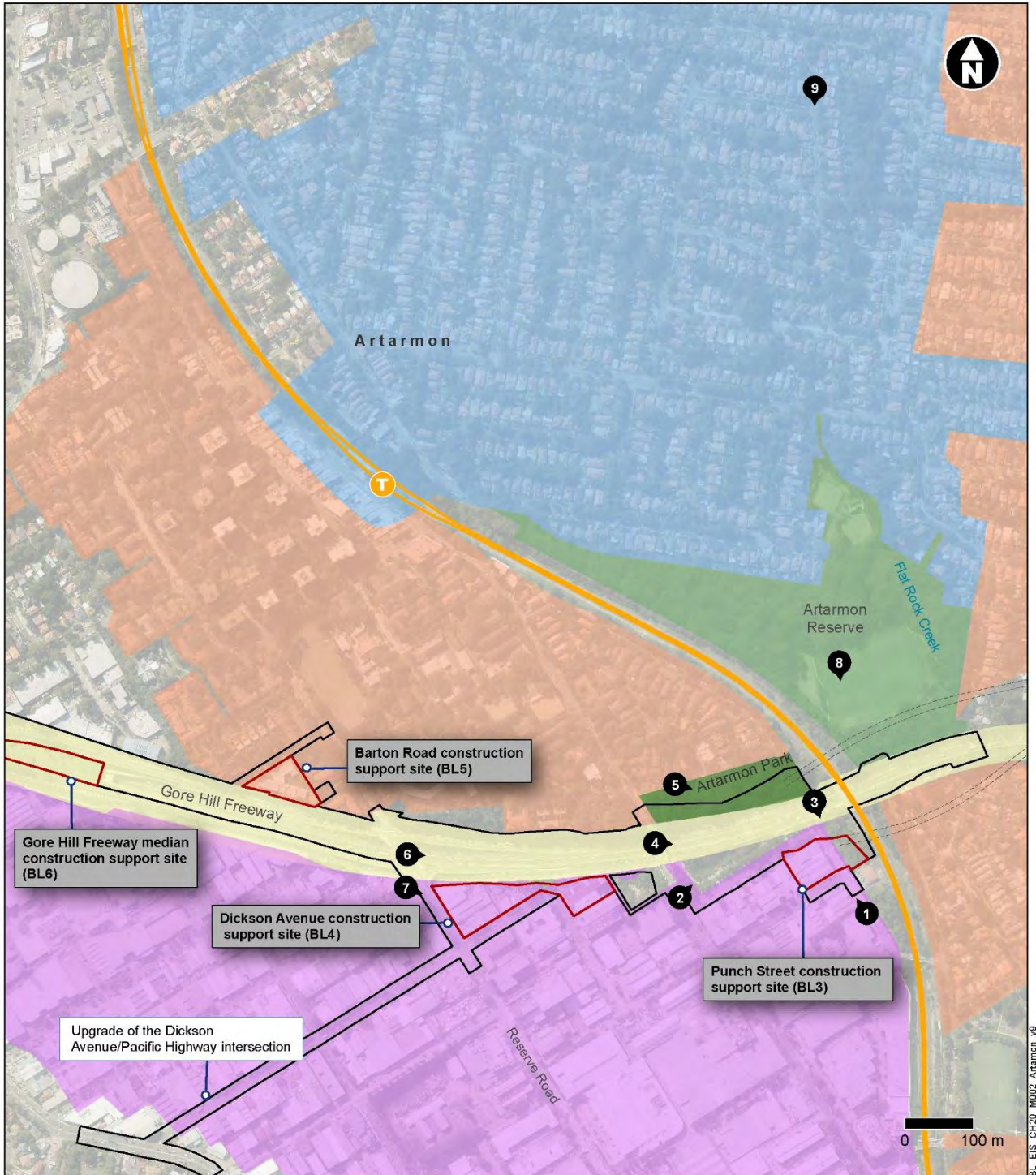
The elevated nature of the topography north of the Gore Hill Freeway offers this residential area some long distance views over the precinct, with some views filtered by tree planting.

Due to its position within the landscape, the Gore Hill Freeway allows visual connectivity across the road. Views within the Gore Hill Freeway are mostly constrained by the topography and dense vegetation either side of the road corridor.

Two transmission towers are located in the precinct, one to the east of Artarmon Reserve and another to the west of Artarmon Station. Where visible, these form strong vertical landmarks in the area.

Viewpoints selected for the Artarmon precinct are also shown in Figure 22-6 and comprise the following:

- Viewpoint 1 – Lambs Road
- Viewpoint 2 – Punch Street
- Viewpoint 3 – Gore Hill Freeway shared user path
- Viewpoint 4 – Hampden Road bridge
- Viewpoint 5 – Parkes Road/Artarmon Park
- Viewpoint 6 – Gore Hill Freeway
- Viewpoint 7 – Reserve Road
- Viewpoint 8 – Artarmon Reserve
- Viewpoint 9 – Godfrey Road residential.



Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Landscape character zones

- Artarmon conservation area
- Artarmon industrial area
- Artarmon Park
- Artarmon Reserve
- Artarmon residential
- Gore Hill Freeway
- Viewpoint and direction

- Sydney train rail
- T Artarmon train station

Indicative only - subject to design development

Figure 22-6 Artarmon precinct landscape character zones and viewpoints

Balgowlah precinct

Landscape character

The Balgowlah precinct contains the Burnt Bridge Creek Deviation and Sydney Road corridors. Despite the amount of road infrastructure in this precinct, it has a distinct leafy character including well vegetated streetscapes and a large area of open space in the form of the Balgowlah Golf Course.

The precinct generally slopes from south to north, towards Burnt Bridge Creek riparian corridor. Balgowlah Golf Course has a level change of approximately 20 metres across the site. The golf course forms a large area of open space in the centre of the precinct with stands of mature trees spread across the course and along the course boundaries adjoining residential developments. Dense vegetation also occurs along the Burnt Bridge Creek riparian corridor.

Landscape character zones identified within the Balgowlah precinct are shown in Figure 22-7 and comprise the following:

- LCZ 1 – Burnt Bridge Creek Deviation road corridor
- LCZ 2 – Burnt Bridge Creek riparian corridor
- LCZ 3 – Balgowlah Golf Course open space
- LCZ 4 – Balgowlah residential east
- LCZ 5 – Balgowlah residential west
- LCZ 6 – Balgowlah residential south
- LCZ 7 – Education campus.

Visual environment

The visual character of the precinct is defined by its sloping topography, major road corridors, leafy streetscapes and vegetated open spaces.

Burnt Bridge Creek Deviation provides a physical barrier across the precinct in an east/west direction. Local views into Balgowlah Golf Course from the road are generally filtered or blocked by dense vegetation along Burnt Bridge Creek riparian corridor.

Local views from the eastern residential edge of the golf course tend to be more open, with some expansive views across the open space of the golf course available. Elevated views of the western edge of the golf course are available from several residential properties along Serpentine Crescent and Dudley Street. Tree planting along sections of the eastern and southern golf course boundaries partially filters views west and north from adjacent residential properties.

Viewpoints selected for the Balgowlah precinct are also shown in Figure 22-7 and comprised of the following:

- Viewpoint 1 – Burnt Bridge Creek Deviation
- Viewpoint 2 – Hope Street
- Viewpoint 3 – Serpentine Crescent
- Viewpoint 4 – Burnt Bridge Creek Deviation existing shared user path
- Viewpoint 5 – Paris Street dwellings
- Viewpoint 6 – Pickworth Avenue dwellings
- Viewpoint 7 – Balgowlah Oval.



Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Landscape character zones

- Balgowlah Golf Course open space
- Balgowlah residential east
- Balgowlah residential south
- Balgowlah residential west
- Burnt Bridge Creek riparian corridor
- Education campus
- Burnt Bridge Creek Deviation road corridor
- Viewpoint and direction

Indicative only - subject to design development

Figure 22-7 Balgowlah precinct landscape character zones and viewpoints

Wakehurst Parkway precinct

Landscape character

The precinct is defined by its hilly, tree-lined streets and distinct bushland character which includes parts of Garigal National Park, Manly Dam Reserve and Bantry Bay Reserve.

Wakehurst Parkway is lined on both sides by dense bushland north of Seaforth Oval. Seaforth Oval is an area of level ground surrounded by bushland.

The precinct sits on a topographical ridge and Wakehurst Parkway has sections of exposed sandstone geology, which is a noticeable feature for road users.

Landscape character zones identified within the Wakehurst Parkway precinct are shown in Figure 22-8 and comprise the following:

- LCZ 1 – Seaforth Oval open space
- LCZ 2 – Seaforth residential
- LCZ 3 – Wakehurst Parkway road corridor
- LCZ 4 – Remnant bushland.

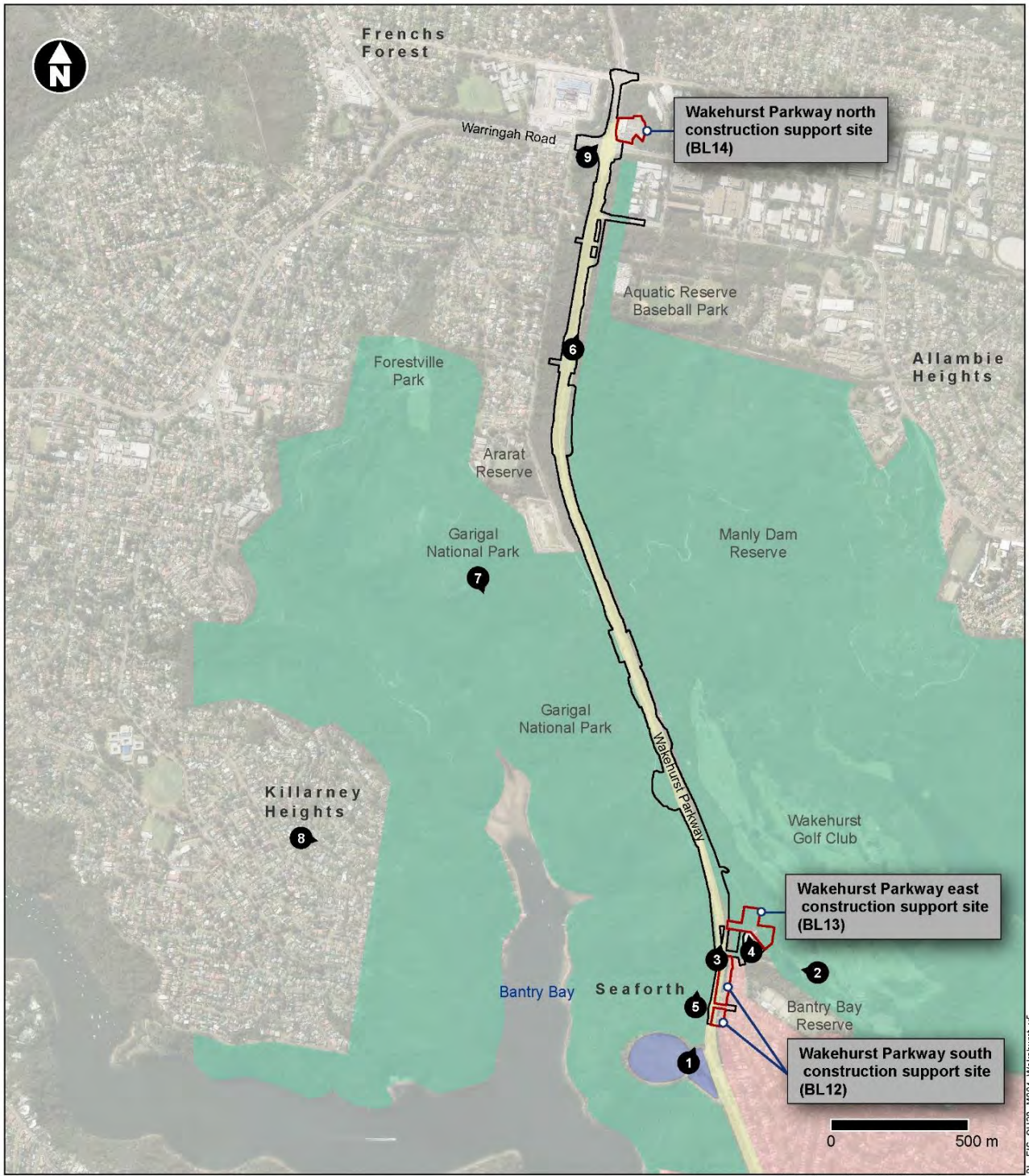
Visual environment

The visual character of the precinct is defined by its elevated topography, limited urban development and surrounding bushland. Views out from the Wakehurst Parkway road corridor are generally constrained by this dense vegetation. Filtered views are available towards Wakehurst Parkway from Seaforth Oval and residential properties to the east of the road corridor.

The elevated nature of the area allows some long distance views into the precinct from surrounding areas of bushland in the west. These include elevated lookouts within Garigal National Park and limited locations within the western residential areas overlooking Sugarloaf Bay such as Northbridge, Castlecrag and Castle Cove.

Viewpoints selected for the Wakehurst Parkway precinct are also shown in Figure 22-8 and comprise the following:

- Viewpoint 1 – Seaforth Oval
- Viewpoint 2 – Wakehurst Golf Course
- Viewpoint 3 – Wakehurst Parkway (south)
- Viewpoint 4 – Kirkwood Street residential
- Viewpoint 5 – Engravings Track
- Viewpoint 6 – Wakehurst Parkway (north)
- Viewpoint 7 – Garigal National Park lookout
- Viewpoint 8 – Killarney Heights residential
- Viewpoint 9 – Wakehurst Parkway/Warringah Road intersection.



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Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Landscape character zones

- Remnant bushland
- Seaforth Oval
- Seaforth residential
- Wakehurst Parkway road corridor

- Viewpoint and direction

Figure 22-8 Wakehurst Parkway precinct landscape character zones and viewpoints

22.4.2 Temporary construction support sites (outside precincts)

Flat Rock Drive

Landscape character

The land identified to facilitate the Flat Rock Drive construction support site (BL2) is currently a car park and bushland rehabilitation area within Flat Rock Reserve associated with a historic landfill site.

The site is bounded by Flat Rock Drive to the west and two creeks to the east and south. In this area, the original Flat Rock Creek passes approximately 30 metres below the site in a box culvert installed by the local council as part of the historic land filling operations. Residential development can be found on elevated topography to the east. The site connects to the adjacent Willoughby Leisure Centre and wider Bicentennial Reserve, approximately 11.5 hectares of open space which contains the Walter Burley Griffin designed incinerator, playing field, children's cycle track, Hallstrom Park Playground and shared user paths.

Landscape character zones close to Flat Rock Drive are shown in Figure 22-9 and comprise the following:

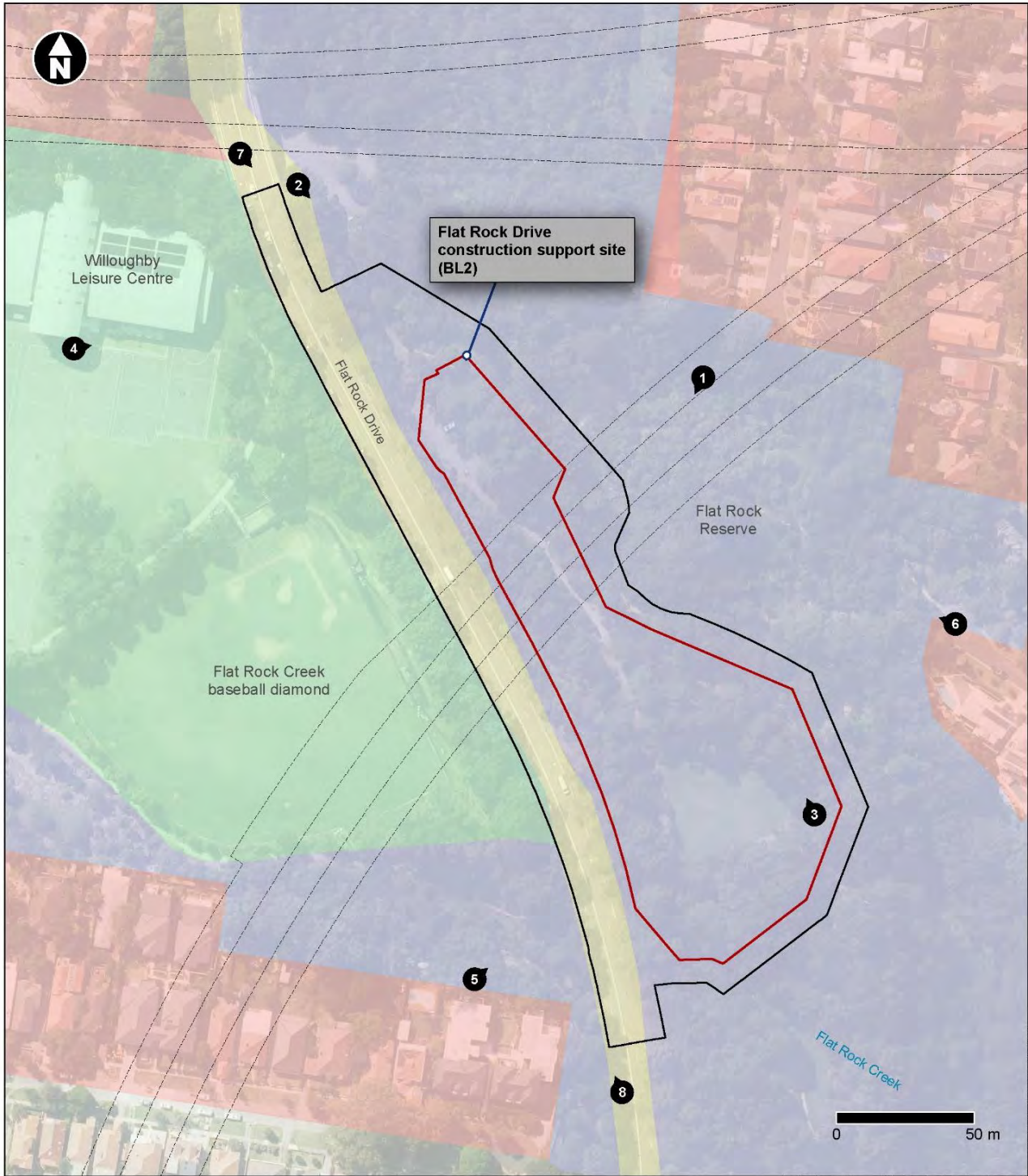
- LCZ 1 – Residential
- LCZ 2 – Flat Rock Reserve open space
- LCZ 3 – Sports precinct
- LCZ 4 – Road corridor.

Visual environment

The visual character of the study area is influenced by its undulating topography and vegetation. Dense bushland within Flat Rock Reserve mostly constrains and filters local views, although occasional breaks in the vegetation allowing sight lines across turfed open space. There are far reaching district views available from dwellings sitting on a ridgeline to the east of Flat Rock Reserve. Filtered views of the temporary construction support site are available from the Flat Rock Drive road corridor. Dense tree planting along the road boundary mostly obscures views of the site from Willoughby Leisure Centre.

Viewpoints for the Flat Rock Drive site are also shown in Figure 22-9 and comprise the following:

- Viewpoint 1 – Pyalla Street
- Viewpoint 2 – Flat Rock Drive
- Viewpoint 3 – Flat Rock Reserve walking/cycle paths
- Viewpoint 4 – Willoughby Leisure Centre
- Viewpoint 5 – Garland Road residential
- Viewpoint 6 – Calbina Road residential
- Viewpoint 7 – Flat Rock Drive southbound
- Viewpoint 8 – Flat Rock Drive northbound.



Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Landscape character zones

- Flat Rock Reserve open space
- Residential
- Road corridor
- Sports precinct
- Viewpoint and direction

Figure 22-9 Flat Rock Drive landscape character zones and viewpoints

Middle Harbour Crossing and Spit West Reserve

Landscape character

At the point between Clive Park in Northbridge and Seaforth Bluff in Seaforth, Middle Harbour is about 400 metres wide.

The character of Middle Harbour is heavily influenced by the mature tree canopies and steep topography along the adjacent foreshore. The extent of vegetation cover contributes to the sense of enclosure to the bay, beaches and inlets enhance the scenic value and visual dominance of the natural landscape features.

Spit West Reserve is located on the western side of the Spit peninsula in Mosman. It contains public parking and playing fields utilised by local schools. The reserve itself consists of a flat, open grassed area interspersed with mature plantings and a row of pines along Spit Road. It is located on an area of reclaimed land bounded by a sea wall. To the east and south of the site, yacht club facilities and rowing sheds provide for boating and water access.

Built elements on Spit West Reserve include Mosman Rowing Club, sporting fields, a children's playground and toilets. Currently there are sports pitches that support cricket and junior soccer, as well as a small oval.

Landscape character zones identified close to Middle Harbour Crossing and Spit West Reserve are shown in Figure 22-10 and comprise the following:

- LCZ 1 – Foreshore public open space and environmental
- LCZ 2 – Low density residential and environmental management
- LCZ 3 – Middle Harbour – open water.

Visual environment

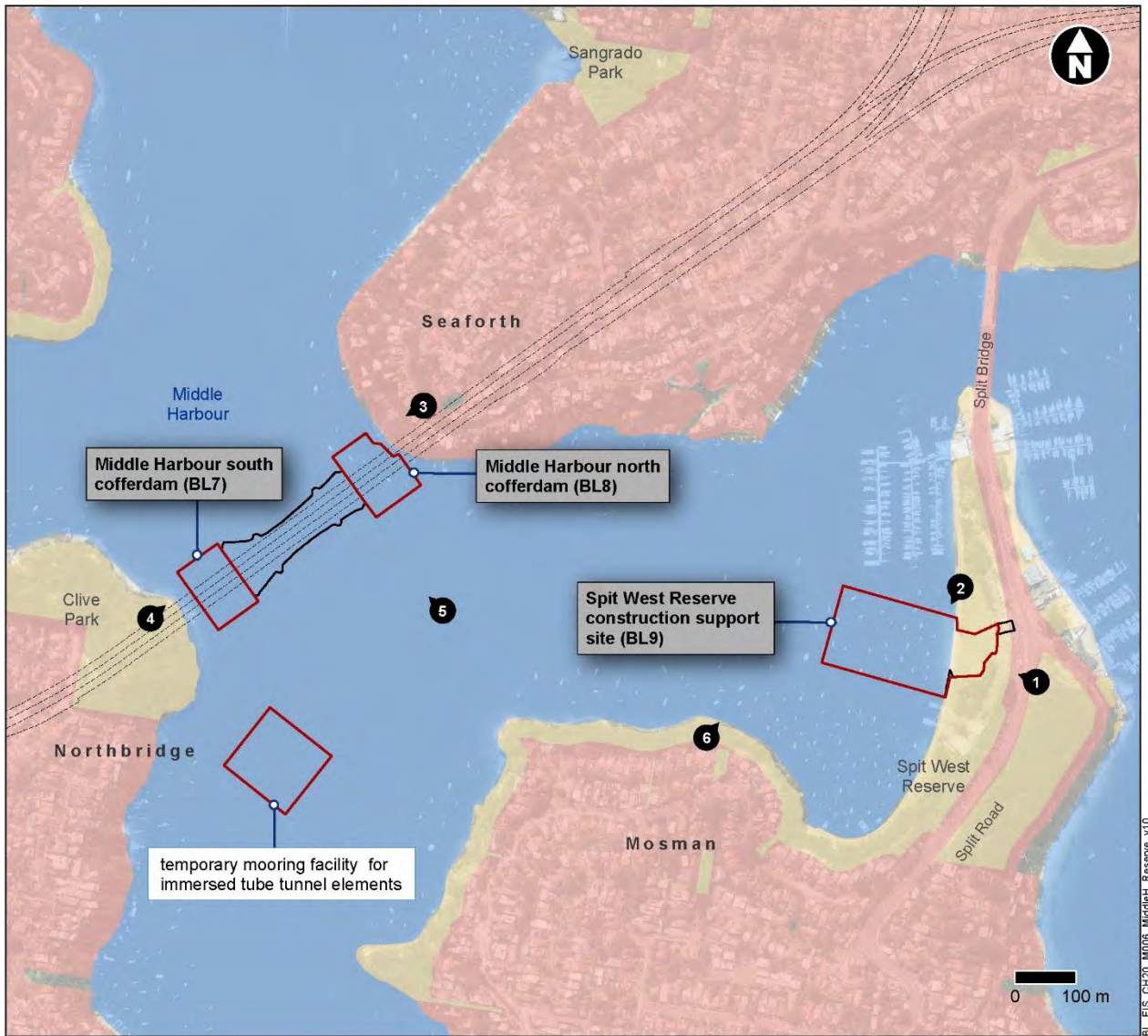
The section of Middle Harbour being assessed as part of the project is visually accessible from residential development bordering the water within the suburbs of Seaforth, Northbridge, Beauty Point and Castlecrag. It is also visible from areas of public open space along this section of the Harbour such as Clive Park and Spit West Reserve, as well as from the water itself.

The foreshore area of Spit West Reserve includes a promenade with water views to the west over Middle Harbour. The reserve is visually separated from Spit Road by mature tree planting and earth mounding. The nearby elevated sandstone bluff and bushland of Parriwi Park and foreshore paths have far reaching views west across Spit West Reserve and Middle Harbour.

Where not blocked by built form and vegetation, sections of residential development along the edge of Middle Harbour within the suburbs of Seaforth, Northbridge and Beauty Point have elevated views towards Spit West Reserve.

Viewpoints for Middle Harbour and Spit West Reserve are also shown in Figure 22-10 and comprise the following:

- Viewpoint 1 – Parriwi Park
- Viewpoint 2 – Spit West Reserve
- Viewpoint 3 – Seaforth Crescent dwellings
- Viewpoint 4 – Clive Park, Northbridge
- Viewpoint 5 – Middle Harbour – on water
- Viewpoint 6 – Beauty Point.



Indicative only - subject to design development

Legend

Construction features

- Construction footprint
- Construction support site
- Tunnel section

Landscape character zones

- Foreshore public open space & environmental
- Low density residential & environmental management
- Middle Harbour open water
- Viewpoint and direction

Figure 22-10 Middle Harbour and Spit West Reserve landscape character zones and viewpoints

22.5 Project elements

22.5.1 Precincts

North Sydney precinct

The project would connect to the Warringah Freeway and proposed Western Harbour Tunnel north of the Ernest Street overbridge at Cammeray. A motorway facility building would be constructed within the Cammeray Golf Course site, near the connection of the Beaches Link tunnels with the Warringah Freeway Upgrade and Western Harbour Tunnel.

Project elements within the North Sydney precinct would include:

- Motorway facility building
- A ventilation outlet next to Ernest Street within the Warringah Freeway corridor. The ventilation outlet at the Warringah Freeway would be constructed as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project, with fitout and the ventilation tunnel connection of this structure completed by the Beaches Link and Gore Hill Freeway Connection project
- Entry and exit portals for the Beaches Link tunnel within the Warringah Freeway road corridor
- Associated road widening, trough structures and retaining walls within the Warringah Freeway.

The construction footprint and temporary construction support sites of the project within the North Sydney precinct are shown in Figure 22-5. Further details of proposed construction work within the precinct are provided in Chapter 6 (Construction work).

Artarmon precinct

The project within the Artarmon precinct is focused on upgrading and reconfiguring the Gore Hill Freeway and providing direct connections to the Lane Cove Tunnel and Reserve Road.

Project elements within the Artarmon precinct would include:

- Two lane eastbound and westbound ramps to the Beaches Link mainline tunnel
- Separate cut and cover tunnels for both eastbound and westbound ramps
- Open trough structures on the Gore Hill Freeway ranging in depth up to ten metres
- Modifications to the Reserve Road and Hampden Road bridges
- A number of new retaining walls and modification to existing retaining walls for the Gore Hill Freeway to cater for the new traffic flow arrangements
- Conversion of Punch Street to a cul-de-sac, and removal of the existing connection between Punch Street and Lambs Road
- Motorway facilities and ventilation outlet located on the southern side of the Gore Hill Freeway, adjacent to Punch Street
- Motorway control centre adjacent to Reserve Road and the Gore Hill Freeway on a site currently occupied by commercial properties including the Freeway Hotel
- Tunnel support facility adjacent to Waltham Street
- The existing shared user path along the southern side of the Gore Hill Freeway would be replaced in areas directly disturbed by the project and connect with the existing active transport network.

The construction footprint and temporary construction support sites of the project within the Artarmon precinct are shown in Figure 22-6. Further details of proposed construction work within the precinct are provided in Chapter 6 (Construction work).

Balgowlah precinct

The project would connect to Burnt Bridge Creek Deviation between Kitchener Street and Sydney Road at Balgowlah. Connections to the local road network would be via a new access road through the existing Balgowlah Golf Course that connect to Sydney Road.

The connection would provide linkages to and from the project with the southern areas of the Northern Beaches, including Seaforth, Manly and Brookvale.

Portals would be located parallel to Burnt Bridge Creek Deviation, south of Burnt Bridge Creek. Burnt Bridge Creek Deviation would be realigned and widened to the east, adjacent to Burnt Bridge Creek and at Dudley Street, to accommodate the portals and ramps.

Project elements within the Balgowlah precinct would include:

- Minor changes to local road conditions including a revised cul-de-sac at the truncated southern end of Dudley Street
- Motorway facilities and a ventilation outlet located within Balgowlah Golf Course. Motorway facilities would be buried eight metres into the ground to assist integration
- A northbound and a southbound bus lane would be maintained along the Burnt Bridge Creek Deviation as part of the realignment and widening of that road
- A new access road between Burnt Bridge Deviation and Sydney Road, providing direct access to Beaches Link and providing connection to new and improved open space and recreation facilities.
- Extension of the existing pedestrian underpass beneath the Burnt Bridge Creek Deviation to the north of Dudley Street
- A new shared user path along the eastern side of the new access road between Burnt Bridge Creek Deviation and Sydney Road
- A new at-grade pedestrian crossing of the new access road at the intersection with Sydney Road.

Construction and operation of the project would require the closure of Balgowlah Golf Course. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities.

A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space.

Land not required for operation of the project to the east and north of the access road would be progressively converted to new open space and recreation facilities following its use for construction. This would allow it to be handed over progressively for use by the community. The land to the west of the proposed access road, between the access road and Burnt Bridge Creek Deviation, is required for the Balgowlah Golf Course construction support site (BL1) through to the completion of the project. The new open space and recreation facilities proposed for this land would be constructed after completion of the project and then handed over to Northern Beaches Council.

Outside the support site and operational footprint areas, the existing mature vegetation would be retained where appropriate to suit final open space and recreation facilities layout as determined by consultation. Disturbed landforms within the former Balgowlah Golf Course and outside the support site and operational footprint areas would be progressively re-vegetated with an appropriate mix of native trees, shrubs and groundcovers. Early re-vegetation works would occur along the project boundaries where feasible, ensuring an extended time period for planting establishment to provide visual screening and improve public amenity.

The construction footprint and temporary construction support sites of the project within the Balgowlah precinct are shown in Figure 22-7. Further details of proposed construction work within the precinct are provided in Chapter 6 (Construction work).

Wakehurst Parkway precinct

Wakehurst Parkway would be realigned and upgraded to two lanes each way, to provide north facing ramps that would connect the Beaches Link mainline tunnel with Wakehurst Parkway.

Project elements within the Wakehurst Parkway precinct would include:

- Two lane entry and exit ramps to the Beaches Link mainline tunnel
- Cut and cover tunnel within the Wakehurst Parkway road corridor likely to comprise a twin box structure (about 130 metres in length)
- Motorway facilities and ventilation outlet located directly above the portal
- Permanent tunnel support facilities on eastern side of Wakehurst Parkway at the Warringah Road/Wakehurst Parkway intersection
- Beaches Link maintenance facility south of Seaforth Oval
- Realignment and upgrade of Wakehurst Parkway in the vicinity of the portal
- New drainage network designed to minimise the amount of water approaching the tunnels
- Reinstatement of northbound and southbound bus stops
- Fauna rope crossings and fauna underpasses where appropriate along road corridor
- Widening of Wakehurst Parkway, facilitated mostly on the eastern side to avoid impacts on the Garigal National Park. The existing road would become the new northbound carriageway
- Water quality basins along the Wakehurst Parkway road corridor
- A new shared user path along the eastern side of the Wakehurst Parkway, from the northern end of Kirkwood Street at Seaforth to the intersection with Warringah Road at Frenchs Forest. The new shared user path includes a new bridge over a drainage culvert and fauna underpass (constructed as part of Northern Beaches Hospital road upgrade project), about 150 metres south of the intersection with Warringah Road
- A new shared user underpass beneath the Wakehurst Parkway about 700 metres north of Kirkwood Street to connect Garigal National Park and the Engravings Trail to the Manly Dam Reserve
- A new shared user underpass beneath the Wakehurst Parkway about 1150 metres north of Kirkwood Street to connect Garigal National Park to the Manly Dam Reserve
- A new shared user underpass beneath the Wakehurst Parkway about 750 metres south of the intersection with Warringah Road
- Reconstruction and lengthening of the existing shared user bridge across the Wakehurst Parkway opposite the Warringah Aquatic Centre.

The construction footprint and temporary construction support sites of the project within the Wakehurst Parkway precinct are shown in Figure 22-8. Further details of proposed construction work within the precinct are provided in Chapter 6 (Construction work).

22.5.2 Temporary construction support sites (outside precincts)

Flat Rock Drive

A small portion of Flat Rock Reserve to the east of Flat Rock Drive would be temporarily leased for use as the Flat Rock Drive construction support site (BL2).

Public access to areas of the reserve outside of the temporary construction support site would be maintained during construction. The existing shared user path would be temporarily realigned along the western perimeter of the temporary construction support site. Pedestrian pathways would be maintained with two minor temporary diversions required.

The site has been located to generally limit clearing impacts to areas of vegetation re-growth, which were established in 1998 on the historical land fill area east of Flat Rock Drive.

Land affected by construction would be rehabilitated following construction, as determined through consultation with Willoughby City Council and the community, and is not expected to impact on the long-term use of Flat Rock Reserve.

The Flat Rock Drive construction support site is shown in Figure 22-9.

Further details of proposed construction work within the support site are provided in Chapter 6 (Construction work).

Middle Harbour Crossing and Spit West Reserve

The Spit West Reserve construction support site (BL9) would be located primarily in the water west of Spit West Reserve, with a small adjoining land-based site in Spit West Reserve. The proposed support site works would include construction of a temporary floating immersed tube tunnel casting facility that would be connected to Spit West Reserve by two temporary fixed jetties. The floating facility and fixed jetties would require the installation of temporary piling and associated marine structures.

The Beaches Link tunnel would cross Middle Harbour between Clive Park and Seaforth Bluff where the harbour is approximately 400 metres wide. Temporary cofferdams would be constructed at each end of the Middle Harbour crossing and within the harbour off the shore at Northbridge to the south and Seaforth to the north. Access would be from the Spit West Reserve construction support site (BL9). A ferry barge would be used to transport materials from the casting facility adjacent to Spit West Reserve to the Middle Harbour cofferdam construction support sites. A work barge (flat top barge) would support the construction of the interface structure and would be permanently moored parallel to the cofferdam during the installation.

The Middle Harbour cofferdams and Spit West Reserve construction support sites are shown in Figure 22-10. Further details of proposed construction work within the support site are provided in Chapter 6 (Construction work).

22.6 Assessment of potential construction impacts

Landscape character and visual impacts during construction would result from the introduction of activities at construction sites and temporary construction support sites into the existing landscape. This would include night lighting at sites that involve tunnelling activities or support tunnelling activities and where surface roadworks are required to be carried out at night.

Receivers who are likely to be impacted include:

- Residents that adjoin and/or have views of the construction sites and/or temporary construction support sites
- Workers in commercial properties that adjoin and/or have views of the project
- Road users and pedestrians
- Users of recreation areas/reserves with views of the project.

Construction activities that would take place at the construction sites and temporary construction support sites are discussed in Chapter 6 (Construction work). In general, visible construction activities and equipment would include (where required):

- Surface roadworks and associated activities, such as vegetation removal, earthworks, bridgeworks, the construction of retaining walls, noise barriers, traffic barriers, flood walls and stormwater drainage, road pavement works, signage and linemarking works, installation and modification of new and existing lighting and lighting structures, construction of fauna connectivity structures, the construction/reconstruction of shared user paths and other pedestrian and cyclist transport facilities and surface finishing works
- The construction of permanent motorway facilities and ancillary infrastructure on land, including the construction of:
 - Driven tunnels, which would include the construction of access declines, on and off ramps, cross passages, cut and cover and trough structures
 - Motorway control centre and tunnel support facilities, which would include the demolition of existing structures, construction of buildings, car parking, hardstand areas and access to the public road network and security fencing
 - Tunnel ventilation systems including the excavation of ventilation tunnels, motorway facilities buildings, connections to utilities, car parking, hardstand areas, access to the public road network and the fitout of ventilation outlets
 - An operational wastewater treatment plant
 - Substations
- Immersed tube tunnel works, including the construction of the cofferdams, transportation and construction of immersed tube tunnel units, dredging, tunnel fitout and finishing works
- The construction of new and improved public open space and recreation facilities at Balgowlah
- Stockpile and laydown areas and storage containers
- The operation of plant and equipment, including cranes
- Heavy and/or light construction vehicle movements
- Temporary noise barriers, hoarding, fencing, staff offices and amenities, workshops, acoustic shed, wastewater treatment facility and car parking
- Lighting for night time works
- Water storage tanks.

In general, potential construction impacts would be temporary in nature and localised to the area subject to construction activities. Potential impacts would be managed through the implementation of appropriate environmental management measures, as outlined in Section 22.8.

22.6.1 Landscape character impacts at precincts during construction

North Sydney precinct

Construction activities within the North Sydney precinct would include surface roadworks (such as road widening and the construction of retaining walls), the installation of fencing and the construction of trough structures, motorway facilities and entry and exit portals for the Beaches Link tunnel within the Warringah Freeway road corridor. The Cammeray Golf Course construction support site (BL1) would be located in the Cammeray Park open space landscape character zone (LCZ 5), as shown in Figure 22-5.

Construction equipment, surface roadworks, site hoardings and increased vehicle movements would be visible within the landscape, leading to a greater exposure to built form and a potential reduction in landscape amenity.

Impacts on landscape character within the North Sydney precinct are likely to be high to moderate for Cammeray residential (LCZ 3), Cremorne and Neutral Bay residential (LCZ 4) and Cammeray Park open space (LCZ 5) landscape character zones due to altered traffic conditions, increased congestion, site hoardings and construction equipment within the landscape and high sensitivity to changes within the landscape.

The Warringah Freeway Corridor (LCZ 2) landscape character zone would be moderately impacted since, as a major road corridor, it is able to accommodate change without a major impact on its character.

While potential impacts of a high to moderate rating are anticipated for landscape character zones within the North Sydney precinct, such impacts are expected to be temporary in nature and localised to the specific areas in which they are likely to occur.

Since the St Leonards Park (LCZ 1) landscape character zone would only have very limited views of the proposed construction sites, impacts on landscape character would be negligible.

A summary of the landscape character impacts during construction for each landscape character zone within the North Sydney precinct is provided in Table 22-5.

Table 22-5 Landscape character impacts during construction – North Sydney precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – St Leonards Park	High	Negligible	Negligible
LCZ 2 – Warringah Freeway Corridor	Low	High	Moderate
LCZ 3 – Cammeray residential	High	Moderate	High – moderate
LCZ 4 – Cremorne and Neutral Bay residential	High	Moderate	High – moderate
LCZ 5 – Cammeray Park open space	Moderate	High	High – moderate

Artarmon precinct

Construction activities within the Artarmon precinct would include surface roadworks (such as earthworks, bridgeworks, installation of retaining walls and fencing) and the construction of cut and cover and trough structures, motorway facilities, ventilation outlet, motorway control centre and a tunnel support facility. The Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites would be located within the Artarmon industrial area (LCZ 1) landscape character zone, as shown in Figure 22-6.

Impacts on landscape character within the Artarmon precinct are likely to be high to moderate for the Artarmon Park (LCZ 6) landscape character zone due to the removal of vegetation, presence of construction equipment and site hoardings within the park during construction. For the Gore Hill Freeway (LCZ 3) and Artarmon residential (LCZ 4) landscape character zones, moderate impacts are expected due to altered traffic conditions, increased congestion and the presence of construction equipment.

While potential impacts of a high to moderate rating are anticipated for landscape character zones within the Artarmon precinct, such impacts are expected to be temporary in nature and localised to the specific areas in which they are likely to occur. Low and negligible impacts are anticipated for the remaining landscape character zones.

A summary of the landscape character impacts during construction for each landscape character zone within the Artarmon precinct is provided in Table 22-6.

Table 22-6 Landscape character impacts during construction – Artarmon precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – Artarmon industrial area	Low	Low	Low
LCZ 2 – Artarmon conservation area	High	Negligible	Negligible
LCZ 3 – Gore Hill Freeway	Low	High	Moderate
LCZ 4 – Artarmon residential	Moderate	Moderate	Moderate
LCZ 5 – Artarmon Reserve	High	Negligible	Negligible
LCZ 6 – Artarmon Park	Moderate	High	High – moderate

Balgowlah precinct

Construction activities within the Balgowlah precinct would include surface roadworks (such as earthworks, road widening and the construction of a new access road, new shared user path and pedestrian crossing), excavation of an access decline and the ramp tunnel alignment between Seaforth and Balgowlah and the construction of motorway facilities and a ventilation outlet adjacent to the new access road within Balgowlah Golf Course. The staged construction of the new and improved open space and recreation facilities within Balgowlah Golf Course, including a car park, would also be delivered progressively, subject to a dedicated consultation process as described in Section 22.5.1.

The Balgowlah Golf Course construction support site (BL10) would be located within the Balgowlah Golf Course open space landscape character zone (LCZ 3). The Kitchener Street construction support site (BL11) would be located within the Burnt Bridge Creek riparian corridor landscape character zone. The locations of the temporary construction support sites are shown in Figure 22-7.

Impacts on landscape character are expected for the majority of landscape character zones within the Balgowlah precinct. This is due to large scale construction activities, including vegetation removal, earthworks and surface roadworks, increased vehicle movements and the presence of construction equipment and temporary noise walls, which would temporarily increase the built form of the area.

There would be a high to moderate impact to the Balgowlah Golf Course open space (LCZ 3) landscape character zone, due to the construction of a new access road, motorway facilities, ventilation outlet and new and improved open space and recreation facilities within the landscape. Moderate impacts are expected for the Balgowlah residential east (LCZ 4), Balgowlah residential west (LCZ 5) and Balgowlah residential south (LCZ 6) landscape character zones due to vegetation removal, earthworks, temporary noise walls and the presence of construction equipment.

While potential impacts of a high to moderate rating are anticipated on landscape character zones within the Balgowlah precinct, such impacts are expected to be temporary in nature and localised to the specific areas in which they are likely to occur. Furthermore, these impact ratings may reduce as replacement planting matures over the duration of the construction period. Early re-vegetation works would occur along the construction footprint boundaries where feasible, ensuring an extended time period for planting establishment to provide visual screening and improve public amenity.

Moderate to low impacts are anticipated for the Burnt Bridge Creek Deviation road corridor (LCZ 1), Burnt Bridge Creek riparian corridor (LCZ 2) and Education campus (LCZ 7) landscape character zones.

A summary of the landscape character impacts during construction for each landscape character zone within the Balgowlah precinct is provided in Table 22-7.

Table 22-7 Landscape character impacts during construction – Balgowlah precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – Burnt Bridge Creek Deviation road corridor	Low	Moderate	Moderate – low
LCZ 2 – Burnt Bridge Creek riparian corridor	Moderate	Low	Moderate – low
LCZ 3 – Balgowlah Golf Course open space	Moderate	High	High – moderate
LCZ 4 – Balgowlah residential east	Moderate	Moderate	Moderate
LCZ 5 – Balgowlah residential west	Moderate	Moderate	Moderate
LCZ 6 – Balgowlah residential south	Moderate	Moderate	Moderate
LCZ 7 – Education campus	Moderate	Low	Moderate – low

Wakehurst Parkway precinct

Construction activities within the Wakehurst Parkway precinct would include surface roadworks and associated activities (such as earthworks, bridgeworks, installation of retaining walls, new shared user path and underpasses, fauna rope crossings and fauna underpasses) and the construction of a cut and cover tunnel, two entry and exit ramps to the tunnel, motorway facilities, ventilation outlet, maintenance facility and tunnel support facilities.

Three temporary construction support sites would be located within the precinct. The Wakehurst Parkway south construction support site (BL12) would be located at the interface of Seaforth residential (LCZ 2) and Wakehurst Parkway road corridor (LCZ 3) landscape character zones, on the eastern side of Wakehurst Parkway between Kirkwood Street and the area just south of Judith Street. The Wakehurst Parkway east construction support site (BL13) would be located further north to the rear of the existing Sydney Water Bantry Bay Reservoir site, within the Remnant bushland (LCZ 4) landscape character zone. The Wakehurst Parkway north construction support site (BL14) would be located on the eastern side of Wakehurst Parkway at the Warringah Road/Wakehurst Parkway intersection. The locations of the temporary construction support sites are shown in Figure 22-8.

High to moderate impacts are anticipated for the Seaforth residential (LCZ 2), Wakehurst Parkway road corridor (LCZ 3) and Remnant bushland (LCZ 4) landscape character zones during construction, due to the removal of vegetation, an increased visibility of construction activities, vehicle movements, earthworks, surface roadworks and exposure to built form in these landscapes.

Temporary construction support sites would be rehabilitated after construction and revegetated with appropriate native species. Landscape character impact ratings may therefore reduce as replacement planting matures over the duration of the construction period. The retention and re-establishment of vegetation along the road corridor would also assist in reducing landscape character impacts.

Landscape character impacts have been assessed as negligible for Seaforth Oval open space (LCZ 1) due to existing screen vegetation surrounding the oval.

While potential impacts of a high to moderate rating are anticipated for landscape character zones within the Warringah Parkway precinct, such impacts are expected to be temporary in nature and localised to the specific areas in which they are likely to occur.

A summary of the landscape character impacts during construction for each landscape character zone within the Wakehurst Parkway precinct is provided in Table 22-8.

Table 22-8 Landscape character impacts during construction – Wakehurst Parkway precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – Seaforth Oval open space	Moderate	Negligible	Negligible
LCZ 2 – Seaforth residential	Moderate	High	High – moderate
LCZ 3 – Wakehurst Parkway road corridor	Moderate	High	High – moderate
LCZ 4 – Remnant bushland	High	Moderate	High – moderate

22.6.2 Landscape character impacts at temporary construction support sites (outside precincts)

Flat Rock Drive

The Flat Rock Drive construction support site (BL2) would be located within Flat Rock Reserve.

High impacts are anticipated on the Flat Rock Reserve open space (LCZ 2), east of Flat Rock Drive, as a result of vegetation removal, the introduction of new built form and the diversion of existing walking and cycling trails.

Moderate impacts on landscape character are expected for the Residential (LCZ 1) landscape character zone, due to its physical separation from, but limited views of, the temporary construction support site.

Moderate to low impacts are anticipated for the Sports precinct (LCZ 3), due to the presence of screening vegetation along the western side of Flat Rock Drive, and for the Flat Rock Drive Road corridor landscape character zone (LCZ 4), as a result of the temporary reduction in vegetation along the eastern side of the road.

Following construction, the site would be re-vegetated or re-purposed subject to consultation with Willoughby City Council and other relevant stakeholders. Residual impacts may remain until planted vegetation has matured, however residual impacts are considered minor and following maturity, there would be no permanent impacts to the landscape character of the site.

A summary of the landscape character impacts during construction within the Flat Rock Drive construction support site is provided in Table 22-9.

Table 22-9 Landscape character impacts during construction – Flat Rock Drive

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 - Residential	High	Low	Moderate
LCZ 2 - Flat Rock Reserve open space	High	High	High
LCZ 3 - Sports precinct	Moderate	Low	Moderate – low
LCZ 4 - Road corridor	Moderate	Moderate	Moderate – low

Middle Harbour Crossing and Spit West Reserve

The Spit West Reserve construction support site (BL9) would be a combined land and water-based site and would make use of land within Spit West Reserve. Additionally, the Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8) would be located within Middle Harbour.

High to moderate impacts are expected for the Foreshore public open space and environmental (LCZ 1) and Low density residential and environmental management (LCZ 2) landscape character zones near the proposed temporary construction support sites, due to the increased exposure to built form.

Moderate impacts are expected on the Middle Harbour – open water landscape character zone (LCZ 3) surrounding the temporary construction support sites. There would be a temporary increase in built form on the waterways in the form of the cofferdam structure, dredging machinery, immersed tube tunnel piles/headstocks and immersion equipment (Middle Harbour) and casting facility (Spit West Reserve), which may lead to adverse impacts on the character of the waterway in close proximity to the works.

All construction plant and equipment would be removed following construction works, therefore the project is not expected to cause any permanent impacts to the landscape character post construction.

A summary of the landscape character impacts during construction within the Spit West Reserve and Middle Harbour is provided in Table 22-10.

Table 22-10 Landscape character impacts during construction – Middle Harbour and Spit West Reserve

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 - Foreshore public open space and environmental	High	Moderate	High – moderate
LCZ 2 - Low density residential and environmental management	High	Moderate	High – moderate
LCZ 3 - Middle Harbour – open water	Moderate	Moderate	Moderate

22.6.3 Visual impacts at precincts during construction

Visual impacts on representative receiver locations during construction are summarised below for each precinct. The location of viewpoints for each precinct is shown in Section 22.4. Visual impacts at temporary construction support sites not located in precincts are discussed in Section 22.6.4.

Appendix V (Technical working paper: Urban design, landscape character and visual impact) provides further detail on the sensitivity, magnitude of change and overall impact rating for each viewpoint.

North Sydney precinct

Construction activities within the North Sydney precinct would include surface roadworks (such as road widening and the construction of retaining walls), the installation of fencing and the construction of trough structures, motorway facilities and entry and exit portals for the Beaches Link tunnel within the Warringah Freeway road corridor. The Cammeray Golf Course construction support site (BL1) would be located within this precinct, as shown in Figure 22-5. Prior to the commencement of works at the site, it would initially be established as a temporary construction support site for the Western Harbour Tunnel and Warringah Freeway Upgrade project, supporting construction works in the precinct area.

High to moderate visual impacts are expected for six viewpoints during construction of the project. These would include users of Jeaffreson Jackson Reserve and nearby residential receivers (Viewpoint 2), residential receivers at Morden Street, Warringa Road and Ernest Street (Viewpoints 3, 4 and 12), and users of the Cammeray Golf Course club house and footpath (Viewpoints 8 and 9). This would be due to the temporary presence of site hoardings, stockpiles, construction equipment and increased vehicle movements during construction of the motorway facilities

While construction activities are likely to be most visible within the Warringah Freeway itself, major adverse visual impacts are not expected on road users due to the functional nature of the road and a lower level of receiver sensitivity. Moderate visual impacts are therefore expected for receivers at the Warringah Freeway near Ernest Street (Viewpoint 11) and users of the Ernest Street, Falcon Street shared use and Miller Street bridges (Viewpoints 13, 14 and 15).

Moderate visual impacts are also expected for users of the Carter Street lookout (Viewpoint 5), Green Park and Warwick Avenue residential receivers (Viewpoint 6), and users of the Cammeray Park sports facilities (Viewpoint 10) due to the potential visibility of equipment associated with the construction of the motorway facilities.

While potential impacts of a high to moderate rating are anticipated for landscape character zones within the North Sydney precinct, such impacts are expected to be temporary in nature and localised to the specific areas in which they are likely to occur.

Negligible visual impacts are anticipated for users of St Leonards Park Bon Andrews Oval (Viewpoint 1) and for residential receivers at Park Avenue (Viewpoint 7).

Table 22-11 Visual impacts during construction – North Sydney precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – St Leonards Park – Bon Andrews Oval	High	Negligible	Negligible
Viewpoint 2 – Jeaffreson Jackson Reserve and nearby residential	Moderate	High	High – moderate
Viewpoint 3 – Morden Street residential	High	Moderate	High – moderate
Viewpoint 4 – Warringa Road residential	Moderate	High	High – moderate
Viewpoint 5 – Carter Street lookout	High	Low	Moderate
Viewpoint 6 – Green Park and Warwick Avenue residential	Moderate	Moderate	Moderate
Viewpoint 7 – Park Avenue residential	High	Negligible	Negligible
Viewpoint 8 – Cammeray Golf Course club house	High	High	High – moderate
Viewpoint 9 – Cammeray Golf Course footpath	Moderate	High	High – moderate
Viewpoint 10 – Cammeray Park sports facilities	Moderate	Moderate	Moderate
Viewpoint 11 – Warringah Freeway near Ernest Street	Low	High	Moderate
Viewpoint 12 – Ernest Street residential	Moderate	High	High – moderate
Viewpoint 13 – Ernest Street bridge	Low	High	Moderate
Viewpoint 14 - Falcon Street shared user bridge	Low	High	Moderate
Viewpoint 15 – Miller Street bridge	Low	High	Moderate

Artarmon precinct

Construction activities within the Artarmon precinct would include surface roadworks (such as earthworks, bridgeworks, installation of retaining walls and fencing) and the construction of cut and cover and trough structures, motorway facilities, ventilation outlet, motorway control centre and a tunnel support facility. The Punch Street (BL3), Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites would be located within the precinct, as shown in Figure 22-6.

High to moderate impacts are expected for users of the shared user path along the Gore Hill Freeway (Viewpoint 3) which would be directly impacted during construction and may require rerouting. There would also be views of construction equipment, site hoardings, a temporary noise wall and increased vehicle movements from the shared user path. Receivers at Parkes Road/Artarmon Park (Viewpoint 5) would also experience temporary high to moderate impacts as vegetation is removed within Artarmon Park along the boundary of the Gore Hill Freeway and site hoardings, construction equipment, vegetation removal and increased vehicle movements become visible.

While construction activities are likely to be highly visible within the Gore Hill Freeway itself (Viewpoint 6), major visual impacts are not expected on road users due to the functional nature of the road and shorter duration of view. Moderate to low impacts are anticipated for receivers at Lambs Road (Viewpoint 1), Punch Street (Viewpoint 2), Hampden Road bridge (Viewpoint 4) and Reserve Road (Viewpoint 7), due to the likely visibility of temporary site hoardings, construction equipment and increased vehicle movements.

Negligible impacts are expected for receivers at Artarmon Reserve (Viewpoint 8) and Godfrey Road residential receivers (Viewpoint 9).

Table 22-12 Visual impacts during construction – Artarmon precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Lambs Road	Low	Moderate	Moderate – low
Viewpoint 2 – Punch Street	Low	Moderate	Moderate – low
Viewpoint 3 – Gore Hill Freeway shared user path	Moderate	High	High – moderate
Viewpoint 4 – Hampden Road bridge	Low	Moderate	Moderate – low
Viewpoint 5 – Parks Road/Artarmon Park	High	Moderate	High – moderate
Viewpoint 6 – Gore Hill Freeway	Low	Moderate	Moderate – low
Viewpoint 7 – Reserve Road	Moderate	Low	Moderate – low
Viewpoint 8 – Artarmon Reserve	High	Negligible	Negligible
Viewpoint 9 – Godfrey Road residential	High	Negligible	Negligible

Balgowlah precinct

Construction activities within the Balgowlah precinct would include surface roadworks (such as earthworks, road widening and the construction of a new access road, new shared user path and pedestrian crossing), excavation of an access decline and the ramp tunnel alignment between Seaforth and Balgowlah, and the construction of motorway facilities and a ventilation outlet adjacent to the new access road within Balgowlah Golf Course. The construction of the new and improved open space and recreation facilities within Balgowlah Golf Course, including a car park, would also be staged, subject to a dedicated consultation process as described in Section 22.5.1. The Balgowlah Golf Course construction support site (BL10) and Kitchener Street construction support site (BL11) would be located within the precinct, as shown in Figure 22-7.

Temporary high visual impacts are expected from residences on Pickworth Avenue (Viewpoint 6) due to the direct views of construction activities and the high sensitivity and magnitude of change at this location.

High to moderate visual impacts are expected at Balgowlah Oval (Viewpoint 7), due to potential direct views of temporary site hoardings, earthworks and construction equipment.

For receivers at Burnt Bridge Creek Deviation existing shared user path (Viewpoint 4) and residential receivers along Paris Street (Viewpoint 5), the visual impacts have been assessed as moderate. Receivers using the Burnt Bridge Creek Deviation existing shared user path (Viewpoint 4) would have direct views of temporary site hoardings, construction equipment and increased vehicle movements. Earthworks required for the open space and recreation facilities would be visible to receivers at Paris Street (Viewpoint 5) while turf and planting is being established.

Moderate to low visual impacts are expected for residential receivers at the Burnt Bridge Creek Deviation (Viewpoint 1), Hope Street (Viewpoint 2) and Serpentine Crescent (Viewpoint 3) due to potential views of temporary site hoardings, construction activities and equipment, and increased vehicle movements. However, views at Hope Street towards the road corridor and construction activities would be partially blocked by the existing noise wall and mature vegetation on the western side of the Burnt Bridge Creek Deviation.

Table 22-13 Visual impacts during construction – Balgowlah precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Burnt Bridge Creek Deviation	Low	Moderate	Moderate – low
Viewpoint 2 – Hope Street	Moderate	Low	Moderate – low
Viewpoint 3 – Serpentine Crescent	Moderate	Low	Moderate – low
Viewpoint 4 – Burnt Bridge Creek Deviation existing shared user path	Low	High	Moderate
Viewpoint 5 – Paris Street dwellings	High	Low	Moderate
Viewpoint 6 – Pickworth Avenue dwellings	High	High	High
Viewpoint 7 – Balgowlah Oval	Moderate	High	High – moderate

Wakehurst Parkway precinct

Construction activities within the Wakehurst Parkway precinct would include surface roadworks and associated activities (such as earthworks, bridgeworks, installation of retaining walls, new shared user path and underpasses, fauna rope crossings and fauna underpasses) and the construction of a cut and cover tunnel, two entry and exit ramps to the tunnel, motorway facilities, ventilation outlet, maintenance facility and tunnel support facilities. The Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites would be located within this precinct, as shown in Figure 22-8.

As shown in the table below (Table 22-14), temporary high to moderate visual impacts are expected along Wakehurst Parkway including Wakehurst Parkway south (Viewpoint 3) and Wakehurst Parkway north (Viewpoint 6) due to the removal of vegetation and direct views on temporary site hoardings, construction equipment, surface roadworks (including bridgeworks), construction of cut and cover and trough structures and increased vehicle movements within the Wakehurst Parkway road corridor.

High to moderate visual impacts are also expected for residential receivers at Kirkwood Street (Viewpoint 4) and users of the Engravings track (Viewpoint 5). Residential receivers at Kirkwood Street (Viewpoint 4) would have direct views of site hoardings, increased vehicle movements, road realignment and construction equipment associated with the Wakehurst Parkway south (BL12) and Wakehurst Parkway east (BL13) construction support sites. There would also be the discernible removal of vegetation across the two sites, increasing exposure to the Wakehurst Parkway road corridor. Users of the Engravings track (Viewpoint 5) are likely to have filtered views of temporary site hoardings and construction equipment and are considered to have high sensitivity to visual impacts.

Moderate visual impacts are anticipated for receivers at Wakehurst Golf Course (Viewpoint 2), due to the removal of vegetation along the golf course boundary at the Sydney Water Bantry Bay Reservoir site, exposing filtered views of project elements such as the acoustic shed. The site would be returned to its existing condition at the end of the construction phase.

Residential receivers at the western edge of Killarney Heights (Viewpoint 8) would experience moderate to low visual impacts due its large viewing distance from the construction footprint and panoramic nature of views at this location.

Negligible visual impacts are anticipated for receivers at Seaforth Oval (Viewpoint 1), Garigal National Park lookout (Viewpoint 7) and the Wakehurst Parkway/Warringah Road intersection (Viewpoint 9).

Table 22-14 Visual impacts during construction – Wakehurst Parkway precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Seaforth Oval	Moderate	Negligible	Negligible
Viewpoint 2 – Wakehurst Golf Course	Moderate	Moderate	Moderate
Viewpoint 3 – Wakehurst Parkway (south)	Moderate	High	High – moderate
Viewpoint 4 – Kirkwood Street residential	Moderate	High	High – moderate
Viewpoint 5 – Engravings Track	High	Moderate	High – moderate
Viewpoint 6 – Wakehurst Parkway (north)	Moderate	High	High – moderate
Viewpoint 7 – Garigal National Park lookout	High	Negligible	Negligible

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 8 – Killarney Heights residential	High	Low	Moderate – low
Viewpoint 9 – Wakehurst Parkway/Warringah Road Intersection	Low	Negligible	Negligible

22.6.4 Visual impacts at temporary construction support sites (outside precincts)

Visual impacts on representative receiver locations during construction are summarised below for temporary construction support sites that have not been considered as part of the broader precinct assessment. The location of viewpoints for each temporary construction support site is shown in Section 22.4. Appendix V (Technical working paper: Urban design, landscape character and visual impact) provides further detail on the sensitivity, magnitude of change and overall impact rating for each viewpoint.

Flat Rock Drive

The Flat Rock Drive construction support site (BL2) would be a tunnelling support site.

At Flat Rock Reserve shared user paths (Viewpoint 3) a temporary high visual impact is expected during construction as a result of an increase in the amount of built form in the area from the development and operation of the temporary construction support site but also the area of vegetation removal that is required to facilitate the site.

During construction at Pyalla Street (Viewpoint 1) and Calbina Road (Viewpoint 6) temporary high to moderate visual impacts are expected as both viewpoints are situated on elevated positions in respect to the temporary construction support site while receivers are also anticipated to have direct views of the site. The impacted portion of the reserve would be revegetated and rehabilitated as determined through further consultation by Willoughby City Council with the community.

Moderate to low visual impacts are anticipated for the rest of the selected viewpoints for the Flat Rock Drive construction support site (BL2), ie Flat Rock Drive (Viewpoint 2), Willoughby Leisure Centre (Viewpoint 4), Garland Road residential (Viewpoint 5), Flat Rock Drive southbound (Viewpoint 7) and Flat Rock Drive northbound (Viewpoint 8), since views of the temporary construction support site at these locations would be constrained by dense bushland vegetation during construction.

The temporary construction support site would be in use 24 hours a day with an associated increase in light emission that would result in some temporary impacts to surrounding receivers, including moderate night time impacts for receivers within residential properties on Pyalla Street (Viewpoint 1) and Calbina Road (Viewpoint 6), which are located above the Flat Rock Drive construction support site (BL2). The impacts of night time lighting would be low or negligible for all other viewpoints assessed.

The Flat Rock Drive construction support site (BL2) would be located primarily at road level with visual impacts largely contained to Flat Rock Drive itself. Existing vegetation would be retained surrounding the site, where possible, and would provide visual screening from other directions.

The site would be reinstated or re-purposed (subject to consultation) post construction. Depending on this outcome, varying levels of residual impact would be expected. Where reinstatement occurs, residual visual impacts would exist until vegetation has matured.

A summary of the anticipated visual impacts during construction at Flat Rock Drive construction support site (BL2) is provided in Table 22-15.

Table 22-15 Viewpoint impacts during construction – Flat Rock Drive construction support site

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Pyalla Street	High	Moderate	Daytime hours: High – moderate
			Night time hours: Moderate
Viewpoint 2 – Flat Rock Drive	Low	Moderate	Daytime hours: Moderate – low
			Night time hours: Negligible
Viewpoint 3 – Flat Rock Reserve shared user paths	High	High	Daytime hours: High
			Night time hours: Low
Viewpoint 4 – Willoughby Leisure Centre	Moderate	Low	Daytime hours: Moderate – low
			Night time hours: Negligible
Viewpoint 5 – Garland Road residential	High	Low	Daytime hours: Moderate – low
			Night time hours: Low
Viewpoint 6 – Calbina Road	High	Moderate	Daytime hours: High – moderate
			Night time hours: Moderate
Viewpoint 7 – Flat Rock Drive southbound	Low	Moderate	Daytime hours: Moderate – low
			Night time hours: Negligible
Viewpoint 8 – Flat Rock Drive northbound	Low	Moderate	Daytime hours: Moderate – low
			Night time hours: Negligible

Middle Harbour Crossing and Spit West Reserve

The Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve (BL9) construction sites would support the construction of the immersed tube tunnel units including a casting facility for the units at Spit West Reserve (BL9).

As outlined in Table 22-16 below, for this construction support site temporary high visual impacts are expected at Spit West Reserve (Viewpoint 2) and Clive Park, Northbridge (Viewpoint 4). At Spit West Reserve (Viewpoint 2), there would be direct views of both the Spit West Reserve and more distant Middle Harbour crossing construction sites, including site hoardings within the reserve. There would be a reduction in the amount of clear water visible within the foreshore area adjacent to the reserve and the foreshore shared user path would need to be temporarily relocated, reducing access to views over the water. Although views at Clive Park (Viewpoint 4) towards the Spit West Reserve construction site would be distant, there would likely be direct views of the Middle Harbour construction site including cranes, coffer dams, dredging equipment, immersed tube tunnel piles and headstock and barge movements.

Where direct views of the Middle Harbour crossing construction sites are available at Seaforth Crescent dwellings (Viewpoint 3), a temporary high to moderate visual impact is expected on these receivers during the construction period due to the visibility of the cranes, coffer dams, dredging equipment, immersed tube tunnel piles and headstock and barge movements.

Moderate visual impacts are expected for users of Parriwi Park (Viewpoint 1), due to the increase in built form and a temporary reduction in the extent of clear water visible. Moderate visual impacts are also expected for users of the waterway within Middle Harbour (Viewpoint 5) due to the visibility of cranes and cofferdams.

Moderate to low visual impacts are anticipated for receivers at Beauty Point (Viewpoint 6), due to the visibility of cranes and cofferdams. However, views north east to Spit West Reserve would be heavily filtered by existing vegetation.

Night time visual impacts would be low for receivers at Spit West Reserve (Viewpoint 2) and Seaforth Crescent dwellings (Viewpoint 3) and negligible for all other viewpoints assessed, since the level of night time lighting emittance is expected to be minimal.

No lasting visual impacts are expected post construction as the temporary construction support sites would be returned to their existing condition.

A summary of the anticipated visual impacts during construction at the Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve (BL9) construction sites is provided in Table 22-16.

Table 22-16 Viewpoint impacts during construction – Middle Harbour and Spit West Reserve construction support sites

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Parriwi Park	High	Moderate	Daytime hours: Moderate
			Night time hours: Negligible
Viewpoint 2 – Spit West Reserve	High	High	Daytime hours: High
			Night time hours: Low
Viewpoint 3 – Seaforth Crescent dwellings	High	Moderate	Daytime hours: High – moderate
			Night time hours: Low
Viewpoint 4 – Clive Park, Northbridge	High	High	Daytime hours: High
			Night time hours: Negligible
Viewpoint 5 – Middle Harbour – on water	Moderate	Moderate	Daytime hours: Moderate
			Night time hours: Negligible
Viewpoint 6 – Beauty Point	Moderate	Low	Daytime hours: Moderate – low
			Night time hours: Negligible

22.7 Assessment of potential operational impacts

The operational landscape character and visual impacts (including impacts on landscape character, views and night lighting) for the North Sydney, Artarmon, Balgowlah and Wakehurst Parkway precincts have been assessed and are outlined below.

The majority of the temporary construction support sites and other sites utilised during construction that are not required for operational infrastructure post construction would be rehabilitated following the completion of construction works. As such, there would be no permanent landscape character or visual impacts at the temporary construction support sites.

The mitigation of operational impacts would be considered through the strategic urban design framework (see Section 22.2 and Appendix V (Technical working paper: Urban design, landscape character and visual impact)) and the implementation of relevant environmental management measures (see Section 22.8 and Appendix V (Technical working paper: Urban design, landscape character and visual impact)). Based on this, it can be expected that the landscape character and visual impact assessment ratings derived below (considered to be day one of operation) would improve as project landscape works mature and buildings and other infrastructure associated with

the project (designed in accordance with the strategic urban design framework) blend into the surrounding environment over time.

Photomontages for each key project view impacted by operational infrastructure are provided in Section 22.7.2. Further photomontages are provided in Appendix V (Technical working paper: Urban design, landscape character and visual impact).

22.7.1 Landscape character impacts during operation

North Sydney precinct

The landscape character impact assessment for the North Sydney precinct identified the potential for a high to moderate landscape character impact for Cammeray Park open space (LCZ 5), in particular Cammeray Golf Course, due to the introduction of a large area of new built form (the Beaches Link motorway facilities) next to the Western Harbour Tunnel motorway facilities. The motorway facilities would be located near, but not encroaching, residential and public open space receivers. This impact is likely to reduce over time as replacement planting matures and partially screens the facilities.

The project would have moderate impacts on the landscape character of the Cammeray residential (LCZ 3) and Cremorne and Neutral Bay residential (LCZ 4) landscape character zones, due to the proposed motorway facilities and ventilation outlet at Warringah Freeway.

Impacts on the landscape character of the Cammeray residential (LCZ 3), Cremorne and Neutral Bay residential areas (LCZ 4) and Cammeray Park open space (LCZ 5) landscape character zones are likely to reduce over time as replacement planting matures and partially screens the motorway facilities and ventilation outlet.

The character of the St Leonards Park (LCZ 1) landscape character zone is unlikely to be adversely impacted by the project due to distance from the works and the presence of screening vegetation throughout the park that would block the majority of views to the proposed works.

The character of the Warringah Freeway corridor (LCZ 2) landscape character zone is unlikely to be considerably impacted by the project due to its low sensitivity to change and ability to absorb the proposed operational structural elements of the project.

A summary of the landscape character impacts during operation of the project within the North Sydney precinct are provided in Table 22-17.

Table 22-17 Landscape character impacts during operation – North Sydney precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – St Leonards Park	High	Negligible	Negligible
LCZ 2 – Warringah Freeway corridor	Low	Low	Low
LCZ 3 – Cammeray residential	High	Low	Moderate
LCZ 4 – Cremorne and Neutral Bay residential	High	Low	Moderate
LCZ 5 – Cammeray Park open space	Moderate	High	High – moderate

Artarmon precinct

The landscape character impact assessment for the Artarmon precinct identified the potential for a moderate landscape character impact for Artarmon Park (LCZ 6) landscape character zone adjacent to the Gore Hill Freeway, due to the reduction in vegetation in this area and the introduction of a noise wall along the road boundary.

There would likely be moderate to low impacts to the Artarmon residential area (LCZ 4) landscape character zone due to the introduction of new elements within the outlook of this landscape character zone, including potential views to the new motorway facilities and ventilation outlet along the Gore Hill Freeway, and the removal of adjacent vegetation (particularly along Parkes Road).

Since the proposed built form within the Artarmon industrial area (LCZ 1) and Gore Hill Freeway corridor (LCZ 3) landscape character zones would be similar to that of the existing environment, visual impacts within these landscape character zones would be low.

The Artarmon Reserve (LCZ 5) and Artarmon conservation area (LCZ 2) landscape character zones are spatially separated from the project works by dense tree planting and undulating landform and are not expected to be impacted by the project.

A summary of the landscape character impacts during operation of the project within the Artarmon precinct are provided in Table 22-18.

Table 22-18 Landscape character impacts during operation – Artarmon precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – Artarmon industrial area	Low	Low	Low
LCZ 2 – Artarmon conservation area	High	Negligible	Negligible
LCZ 3 – Gore Hill Freeway	Low	Low	Low
LCZ 4 – Artarmon residential	Moderate	Low	Moderate – low
LCZ 5 – Artarmon Reserve	High	Negligible	Negligible
LCZ 6 – Artarmon Park	Moderate	Moderate	Moderate

Balgowlah precinct

The landscape character impact assessment for the Balgowlah precinct identified the potential for a high to moderate landscape character impact for the Balgowlah Golf Course open space (LCZ 3) landscape character zone during the operation of the project. This would be due to the clearing of vegetation, remodelling of parts of the existing landform and introduction of new built form elements such as the access road and associated retaining walls which would alter the character of this open space.

The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities. Residual land, primarily to the east and north of the new access road, would progressively become available through the construction period, which would facilitate re-purposing it to the new and improved public open space and recreation facilities. This would allow it to be handed over progressively for use by the community. The new and improved open space and recreation facilities to the west of the proposed access road, between the access road and the widened Burnt Bridge Creek

Deviation, would be constructed and handed over to Northern Beaches Council after completion of the project.

A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. Assessments of landscape character impact have been undertaken using an indicative layout of the new and improved open space and recreation facilities. A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout.

There would be moderate impacts to the Balgowlah residential east (LCZ 4) and Balgowlah residential west (LCZ 5) landscape character zones due to the clearing of vegetation and the introduction of new built form elements. Impacts would be limited to residences that border the Balgowlah Golf Course (including residences on Dudley Street, Pickworth Avenue and Sydney Road), or are in close proximity to the golf course (including residences along Serpentine Crescent, Hope Street and Boronia Street). As replacement planting matures, the impact on landscape character is likely to reduce from that recorded. Due to the removal of vegetation and the introduction of new built form elements and road infrastructure, moderate to low landscape character impacts are expected in the Burnt Bridge Creek riparian corridor (LCZ 2) and the Balgowlah residential south (LCZ 6) landscape character zones. Burnt Bridge Creek would be re-aligned, potentially impacting its current scenic qualities. As before, the impact on landscape character is likely to reduce from that recorded as replacement planting matures.

The Educational campus (LCZ 7) landscape character zone, including Northern Beaches Secondary College, is likely to experience moderate to low impacts to its landscape character due to the removal of vegetation within Balgowlah Golf Course and the introduction of new built form elements, including the new and improved open space and recreation facilities within the golf course. The widening of the road corridor in proximity to the school (to facilitate the new access road intersection) would be on the northern side of Sydney Road but may, however, indirectly impact the northern college boundary. This section of the campus would be exposed to more extensive road infrastructure associated with a new traffic light intersection.

Low landscape character impacts are expected for the Burnt Bridge Creek Deviation road corridor (LCZ 1) landscape character zone. Despite the clearing of vegetation along its eastern boundary, the introduction of new built form elements within and adjacent to the corridor and realignment and widening of the road corridor, the road corridor is considered to have low sensitivity to change and the new built form elements would be mostly consistent with that of the existing road environment.

A summary of the outcomes of the landscape character impact assessment are provided in Table 22-19.

Table 22-19 Landscape character impacts during operation – Balgowlah precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – Burnt Bridge Creek Deviation road corridor	Low	Low	Low
LCZ 2 – Burnt Bridge Creek riparian corridor	Moderate	Low	Moderate – low
LCZ 3 – Balgowlah Golf Course open space	Moderate	High	High – moderate
LCZ 4 – Balgowlah residential east	Moderate	Moderate	Moderate
LCZ 5 – Balgowlah residential west	Moderate	Moderate	Moderate
LCZ 6 – Balgowlah residential south	Moderate	Low	Moderate – low
LCZ 7 – Education campus	Moderate	Low	Moderate – low

Wakehurst Parkway precinct

The landscape character impact assessment for the Wakehurst Parkway precinct identified the potential for a high to moderate landscape character impact for the Remnant bushland (LCZ 4) landscape character zone surrounding the Wakehurst Parkway road corridor, due to the widening of the road and removal of vegetation. There would likely be moderate impacts on the landscape character of the Wakehurst Parkway road corridor (LCZ 3), due to the reduced scenic nature of the corridor associated with the increased scale of the road corridor, and the addition of associated motorway facilities, ventilation outlet and tunnel support facilities as part of the project. The impact on these landscape character zones is likely to reduce from that recorded as replacement planting matures.

Moderate to low landscape character impacts are anticipated for the Seaforth residential (LCZ 2) landscape character zone. Despite the zones residential land use, retained dense vegetation is expected to screen the majority of views towards the project.

Negligible impacts on landscape character are anticipated for Seaforth Oval open space (LCZ 1) landscape character zone, primarily due to the physical separation of the oval from the project along with existing screening vegetation.

Despite the removal of vegetation either side of the road, the density of planting in this area would retain its bushland character, especially as replacement planting matures.

Although there would be some initial impacts as a result of the project due to vegetation removal along the residential boundary with Wakehurst Parkway, this is expected to be replaced following construction works which would reduce the operational impact of the project.

A summary of the outcomes of the landscape character impact assessment are provided in Table 22-20.

Table 22-20 Landscape character impact during operation – Wakehurst Parkway precinct

Landscape character zone	Sensitivity	Magnitude of change	Overall impact rating
LCZ 1 – Seaforth Oval open space	Moderate	Negligible	Negligible
LCZ 2 – Seaforth residential	Moderate	Low	Moderate – low
LCZ 3 – Wakehurst Parkway road corridor	Moderate	Moderate	Moderate
LCZ 4 – Remnant bushland	High	Moderate	High – moderate

22.7.2 Visual impacts during operation

Visual impacts on representative receiver locations during operation are summarised below. The location of viewpoints for each precinct is shown in Section 22.4. Appendix V (Technical working paper: Urban design, landscape character and visual impact) provides further detail on the sensitivity, magnitude of change and overall impact rating for each viewpoint.

North Sydney precinct

Visual impacts of the project within the North Sydney precinct would generally be moderate to low since much of the built form of the project (including portals, motorway facilities and ventilation outlet) would be congruous with the existing major infrastructure of the Warringah Freeway road corridor. The largest visual impacts would be experienced by residential and public open space receivers in close proximity to the motorway facilities within Cammeray Golf Course and elevated receivers that have clear views of the project. While the motorway facilities and ventilation outlet would be the most visible elements of the project, the presence of screening vegetation along the boundary of Cammeray Park would assist in filtering or blocking many views of the ventilation outlet and motorway facilities from street level. In addition, the impact on more distant, district views of the ventilation outlet would be somewhat reduced by the presence of existing vertical

elements within the view, including the North Sydney sewer outlet and the Neutral Bay/North Sydney CBD towers.

High to moderate visual impacts are expected for residential receivers at Jeaffreson Jackson Reserve (Viewpoint 2) and Ernest Street (Viewpoint 12) with clear views of the proposed built elements of the project, including the motorway facilities, substation and ventilation outlet. Users of the Cammeray Golf Course club house (Viewpoint 8) with clear views of the motorway facilities are also anticipated to experience high to moderate visual impacts. Impacts are likely to reduce as replacement planting matures and screens some parts of the motorway facilities. A comparison of the existing view north east over Warringah Freeway from Jeaffreson Jackson Reserve (Viewpoint 2) with the expected views of the project is provided in Figure 22-11 to Figure 22-13. Existing and proposed views from Ernest Street dwellings north to Cammeray Golf Course (Viewpoint 12) are shown in Figure 22-14 to Figure 22-16.

Moderate visual impacts are expected for residential properties along Morden Street (Viewpoint 3) and Carter Street (Viewpoint 5) that have elevated view corridors over Cammeray Park. Although the presence of retained foreground vegetation would likely assist in reducing the amount of proposed built form visible, views of the upper sections of the motorway facilities and ventilation outlet are still likely above the tree line. Users of the Cammeray Golf Course footpath (Viewpoint 9) with clear views of the motorway facilities are also anticipated to experience moderate visual impacts.

The removal of vegetation by the Western Harbour Tunnel and Warringah Freeway Upgrade project along the road corridor is likely to increase visibility of both existing and proposed infrastructure for receivers in proximity to the Warringah Freeway. Replacement screening vegetation would reduce these impacts over time as the vegetation matures. Moderate visual impacts are therefore also expected for Warringah Road residential receivers (Viewpoint 4) and users of the Cammeray Park sports facilities (Viewpoint 10), Warringah Freeway near Ernest Street (Viewpoint 11) and Ernest Street bridge (Viewpoint 13).

The retention of screening vegetation along the boundary of Cammeray Park would help to reduce visual impacts of new built form from street level viewpoints surrounding the park. Moderate to low visual impacts are therefore expected for residential receivers at Green Park and Warwick Avenue (Viewpoint 6). Moderate to low impacts are also anticipated for users of the Falcon Street shared user bridge (Viewpoint 14) and Miller Street bridge (Viewpoint 15), whereas impacts on views from St Leonards Park Bon Andrews Oval (Viewpoint 1) and Park Avenue (Viewpoint 7) are expected to be negligible.

While the project would likely lead to an increase in night time light emissions, the presence of numerous existing light sources within the mostly urbanised precinct would mostly reduce impacts to negligible or low. Exceptions to this would be receivers with local views into Cammeray Park and the golf course club house (Viewpoints 4, 8 and 9), where increased light emittance associated with the new infrastructure is likely to have moderate impacts to night time visual amenity.

A summary of the anticipated visual impacts during the operation of the project within the North Sydney precinct is provided in Table 22-21 below.

Table 22-21 Visual impacts during operation – North Sydney precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – St Leonards Park – Bon Andrews Oval	High	Negligible	Daytime: Negligible
			Night time: Negligible
Viewpoint 2 – Jeaffreson Jackson Reserve and nearby residential	Moderate	High	Daytime: High – moderate
			Night time: Low
Viewpoint 3 – Morden Street residential	High	Low	Daytime: Moderate
			Night time: Low
Viewpoint 4 – Warringa Road residential	Moderate	Moderate	Daytime: Moderate
			Night time: Moderate
Viewpoint 5 – Carter Street lookout	High	Low	Daytime: Moderate
			Night time: Low
Viewpoint 6 – Green Park/Warwick Avenue residential	Moderate	Low	Daytime: Moderate – low
			Night time: Low
Viewpoint 7 – Park Avenue residential	High	Negligible	Daytime: Negligible
			Night time: Low
Viewpoint 8 – Cammeray Golf Course club house	High	Moderate	Daytime: High – moderate
			Night time: Moderate
Viewpoint 9 – Cammeray Golf Course footpath	Moderate	Moderate	Daytime: Moderate
			Night time: Moderate
Viewpoint 10 – Cammeray Park sports facilities	Moderate	Moderate	Daytime: Moderate
			Night time: Low
Viewpoint 11 – Warringah Freeway near Ernest Street	Low	High	Daytime: Moderate
			Night time: Negligible
Viewpoint 12 – Ernest Street residential	Moderate	High	Daytime: High – moderate
			Night time: Low
Viewpoint 13 – Ernest Street bridge	Low	High	Daytime: Moderate
			Night time: Negligible
Viewpoint 14 - Falcon Street shared user bridge	Low	Moderate	Daytime: Moderate – low
			Night time: Negligible
Viewpoint 15 – Miller Street bridge	Low	Moderate	Daytime: Moderate – low
			Night time: Negligible



Figure 22-11 Existing view north east over Warringah Freeway from Jeaffreson Jackson Reserve



Figure 22-12 Proposed view (year 1 of operation) north east over Warringah Freeway from Jeaffreson Jackson Reserve



Figure 22-13 Proposed view (year 10 of operation) north east over Warringah Freeway from Jeaffreson Jackson Reserve



Figure 22-14 Existing view from Ernest Street dwellings north to Cammeray Golf Course



Figure 22-15 Proposed view (year 1 of operation) from Ernest Street dwellings north to Cammeray Golf Course



Figure 22-16 Proposed view (year 10 of operation) from Ernest Street dwellings north to Cammeray Golf Course

Artarmon precinct

Visual impacts of the project within the Artarmon precinct would generally be moderate to low since much of the built form of the project (including portals, trough structures, noise walls, motorway control centre and motorway facilities) would be congruous with the existing large scale road infrastructure of the Gore Hill Freeway road corridor and the industrial nature of the precinct. The ventilation outlet would be the most visible element of the project with visibility of the upper sections extending to elevated residential receivers in the north. However, the impact of the ventilation outlet on wider, district views would be reduced by the presence of existing vertical elements within the view, including the two transmission towers.

High to moderate visual impacts are expected for residential and public open space receivers along Parkes Road/Artarmon Park (Viewpoint 5), where vegetation is likely to be removed. This would reduce the current green buffer between these receivers and the Gore Hill Freeway.

Moderate visual impacts are likely for users of the shared user path alongside the Gore Hill Freeway (Viewpoint 3) due to a reduction in vegetation along the path, increasing exposure to the Gore Hill Freeway.

Moderate to low visual impacts are expected for users of Hampden Road Bridge (Viewpoint 4) as the project works would generally be congruous with the existing road infrastructure and nearby industrial development. Moderate to low impacts are also expected for users of the Gore Hill Freeway road corridor (Viewpoint 6) as vegetation removal reduces the green buffer currently present on either side of the road. A comparison of the existing view east over Gore Hill Freeway from Hampden Road Bridge with the expected views of the project is provided in Figure 22-17 to Figure 22-19.

Views from the south from Lambs Road (Viewpoint 1), Punch Street (Viewpoint 2) and Reserve Road (Viewpoint 7) are expected to have moderate to low impacts due to the built up nature of the existing environment. Landscape planting associated with the Freeway Hotel, a visually prominent built form element on the corner of the Gore Hill Freeway, contributes to the amenity value of the existing views from Reserve Road and would be replaced through mitigation planting.

While the motorway facilities and ventilation outlet may also be visible from some residential properties within the elevated areas of the northern part of the precinct, such as along Godfrey Road (Viewpoint 9), the presence of extensive screening vegetation and the reasonably large viewing distance would reduce the visual impact to negligible. Other views of the motorway facilities and ventilation outlet would be somewhat reduced by the presence of existing vertical elements within view, including two transmission towers. The motorway facilities and ventilation outlet are unlikely to be visible from Artarmon Reserve (Viewpoint 8) due to the presence of tall screening vegetation.

While the project would likely lead to a slight increase in night time light emissions associated with the motorway control centre and road upgrades, the majority of receivers' night time visual amenity is unlikely to be adversely affected. The presence of numerous existing light sources within the mostly urbanised precinct would generally reduce the impact to negligible. Exceptions to this would include receivers along Parkes Road and Artarmon Park (Viewpoint 5) which may be impacted by an increased light emittance associated with removal of vegetation along the road boundary (moderate visual impact).

A summary of the anticipated visual impacts during the operation of the project within the Artarmon precinct is provided in Table 22-22 below.

Table 22-22 Visual impacts during operation – Artarmon precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Lambs Road	Low	Moderate	Daytime: Moderate – low
			Night time: Negligible
Viewpoint 2 – Punch Street	Low	Moderate	Daytime: Moderate – low
			Night time: Negligible
Viewpoint 3 – Gore Hill Freeway shared user path	Moderate	Moderate	Daytime: Moderate
			Night time: Negligible
Viewpoint 4 – Hampden Road Bridge	Low	Moderate	Daytime: Moderate – low
			Night time: Negligible
Viewpoint 5 – Parkes Road/Artarmon Park	High	Moderate	Daytime: High – moderate
			Night time: Moderate
Viewpoint 6 – Gore Hill Freeway	Low	Moderate	Daytime: Moderate – low
			Night time: Negligible
Viewpoint 7 – Reserve Road	Moderate	Low	Daytime: Moderate – low
			Night time: Negligible
Viewpoint 8 – Artarmon Reserve	High	Negligible	Daytime: Negligible
			Night time: Negligible
Viewpoint 9 – Godfrey Road residential	High	Negligible	Daytime: Negligible
			Night time: Negligible



Figure 22-17 Existing view east over Gore Hill Freeway from Hampden Bridge towards the motorway facilities and ventilation outlet



Figure 22-18 Proposed view (year 1 of operation) east over Gore Hill Freeway from Hampden Bridge towards the motorway facilities and ventilation outlet



Figure 22-19 Proposed view (year 10 of operation) east over Gore Hill Freeway from Hampden Bridge towards the motorway facilities and ventilation outlet

Balgowlah precinct

Visual impacts of the project within the Balgowlah precinct would generally be moderate to low since much of the built form of the project (including the motorway facilities, ventilation outlet and access road) would be congruous with the road infrastructure of the Burnt Bridge Creek Deviation road corridor. The largest visual impacts would be experienced by residential receivers near the eastern boundary of the Balgowlah Golf Course, due to the removal of vegetation and introduction of new built form within the golf course. The project would return an area within Balgowlah Golf Course, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities.

A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities. Assessments of visual impact have been undertaken using an indicative layout of the new and improved open space and recreation facilities. Provided that the consultation process has been completed, portions of the land at Balgowlah Golf Course not required for construction (to the east and north of the new access road) would be re-purposed progressively from the commencement of the project construction phase, which would make facilities available for public use early on in the project program. The land to the west of the proposed access road, between the access road and the widened Burnt Bridge Creek Deviation, is required for the Balgowlah Golf Course construction support site (BL10). The new and improved open space and recreation facilities proposed for this land would be constructed after completion of the project and then handed over to the Northern Beaches Council.

Residential receivers at Pickworth Avenue (Viewpoint 6) are expected to experience high to moderate visual impacts, due to their close proximity and direct views to new built form of the project, including the new access road, motorway facilities, ventilation outlet and recreation facilities, and the reduction in the naturalistic setting of Balgowlah Golf Course. Screen planting along the golf course boundary would reduce these impacts over time. A comparison of the existing view west from Pickworth Avenue towards the motorway facilities and ventilation outlet at Burnt Bridge Creek Deviation with the expected views of the project is provided in Figure 22-20 to Figure 22-22.

Several receivers within the precinct are expected to experience moderate visual impacts as a result of project works. These include residential receivers in close proximity to the Balgowlah Golf Course along the eastern and western boundaries, including the southern end of Paris Street (Viewpoint 5) and users of Balgowlah Oval (Viewpoint 7). From these locations, the introduction of new built form within Balgowlah Golf Course and the removal of vegetation along Burnt Bridge Creek and within the golf course would be visible. However, impacts would be lessened as the overall parkland character of the golf course is retained. Existing and proposed views south from dwellings in Paris Street (Viewpoint 5) towards the motorway facilities and ventilation outlet at Burnt Bridge Creek Deviation is provided in Figure 22-23 to Figure 22-25.

Moderate visual impacts are also expected for residential receivers along Serpentine Crescent (Viewpoint 3) and users of the shared user path along Burnt Bridge Creek Deviation (Viewpoint 4) due to the removal of vegetation and the visibility of the new built form of the project. Replacement planting along the road corridor and Burnt Bridge Creek would likely assist in reducing these impacts over time and the new built form in these locations would generally be congruous with the existing road environment.

Moderate to low impacts are expected for users of Hope Street (Viewpoint 2) due to the presence of an existing noise wall and vegetation. Low visual impacts are expected for receivers at Burnt Bridge Creek Deviation (Viewpoint 1) as the project works would generally be congruous with the existing environment.

The precinct currently has relatively low night time light emissions with very few light sources located within the Balgowlah Golf Course area. During operation, the project would result in an increase in night time lighting, especially along the new access road proposed through the Balgowlah Golf Course open space. There would also be lighting associated with the new portal within the Burnt Bridge Creek Deviation road corridor, which currently has limited light sources.

The most impacted receivers would be residential receivers located along the eastern boundary of the Balgowlah Golf Course, such as receivers in Pickworth Avenue (Viewpoint 6) and Paris Street (Viewpoint 5). These properties would likely have increased visibility of street lighting and vehicle headlights along the new access road, resulting in high and moderate to high night time visual impacts. Low to negligible night time visual impacts are expected at the remaining viewpoints.

A summary of the anticipated visual impacts during the operation of the project within the Balgowlah precinct is provided in Table 22-23 below.

Table 22-23 Visual impacts during operation – Balgowlah precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Burnt Bridge Creek Deviation	Low	Low	Daytime: Low
			Night time: Negligible
Viewpoint 2 – Hope Street	Moderate	Low	Daytime: Moderate – low
			Night time: Low
Viewpoint 3 – Serpentine Crescent dwellings	Moderate	Moderate	Daytime: Moderate
			Night time: Low
Viewpoint 4 – Burnt Bridge Creek Deviation existing shared user path	Low	High	Daytime: Moderate
			Night time: Negligible
Viewpoint 5 – Paris Street dwellings	High	Moderate	Daytime: Moderate
			Night time: High – moderate
Viewpoint 6 – Pickworth Avenue dwellings	High	Moderate	Daytime: High – moderate
			Night time: High
Viewpoint 7 – Balgowlah Oval	Moderate	Moderate	Daytime: Moderate
			Night time: Negligible



Figure 22-20 Existing view west over Balgowlah Golf Course from dwellings in Pickworth Avenue Creek



Figure 22-21 Proposed view (year 1 of operation) west over Balgowlah Golf Course from dwellings in Pickworth Avenue



Figure 22-22 Proposed view (year 10 of operation) west over Balgowlah Golf Course from dwellings in Pickworth Avenue



Figure 22-23 Existing view south over Balgowlah Golf Course from dwellings in Paris Street



Figure 22-24 Proposed view (year 1 of operation) south over Balgowlah Golf Course from dwellings in Paris Street



Figure 22-25 Proposed view (year 10 of operation) south over Balgowlah Golf Course from dwellings in Paris Street

Wakehurst Parkway precinct

Visual impacts of the project within the Wakehurst Parkway precinct would generally be negligible or moderate to low since views of the new built form of the project (including the motorway facilities, ventilation outlet and portal) would be mostly screened by existing vegetation and replacement planting. The largest visual impacts are expected on residential development and bushland in close proximity to the realigned and upgraded Wakehurst Parkway. The retention and re-establishment of vegetation along the road corridor, where possible, would assist in reducing these impacts as the vegetation matures and provides a visual buffer to pedestrians, motorists and residential receivers.

Moderate impacts are expected for the Wakehurst Parkway road corridor (Viewpoints 3 and 6). This would be due to the widening of Wakehurst Parkway, the introduction of new built form (including the motorway facilities and ventilation outlet) within the road corridor and the removal of vegetation along the road corridor, which may increase visibility of the road and the proposed motorway facilities and ventilation outlet. The retention of foreground vegetation, where possible, to the south of the motorway facilities would help to screen views from the southern approach, including dwellings along Kirkwood Street. A comparison of the existing and proposed views to the south and north along Wakehurst Parkway is provided in Figure 22-26 to Figure 22-29.

Users of the Engravings walking track (Viewpoint 5) are expected to be moderately impacted by works associated with the proposed drainage basins and road widening, due to the associated vegetation removal near some areas of the track and increased exposure to the Wakehurst Parkway road corridor. Over time, replacement planting would assist in reducing visual impacts for the majority of receivers impacted.

Moderate impacts are also expected for residential receivers at Killarney Heights (Viewpoint 8), since the top of the ventilation outlet may be discernible above the treeline, forming a new built form element within the view. However, the large viewing distance and panoramic nature of the view ensures the ventilation outlet would form a relatively small part of the wider view frame.

Elsewhere, moderate to low visual impacts are expected for users of Wakehurst Golf Course (Viewpoint 2) and residential receivers at Kirkwood Street (Viewpoint 4). These impacts would result from removal of vegetation along Wakehurst Parkway, and potential filtered views to the top of the ventilation outlet from Wakehurst Golf Course.

Negligible visual impacts are anticipated for users of Seaforth Oval (Viewpoint 1) and the Garigal National Park lookout (Viewpoint 7), and receivers at the Wakehurst Parkway/Warringah Road intersection (Viewpoint 9). Additional landscape planting at the Wakehurst Parkway/Warringah Road intersection (Viewpoint 9) is expected to improve visual amenity of the site.

The precinct currently has low night time light emissions, with the greatest source being cars on Wakehurst Parkway. The widened road corridor and the removal of vegetation along the boundary of the road may expose residential receivers along Kirkwood Street (Viewpoint 4) to slightly increased light emittance resulting in a low impact, however these impacts would likely reduce as replacement screening vegetation matures. Low visual impacts are also expected along Wakehurst Parkway (south) (Viewpoint 3) due to the presence of lighting at the vent shaft. However, this view would only be experienced for a relatively short duration and in a localised position. Negligible night time visual impacts are expected for all other viewpoints.

A summary of the anticipated visual impacts during the operation of the project within the Wakehurst Parkway precinct is provided within the table below.

Table 22-24 Visual impacts during operation – Wakehurst Parkway precinct

Viewpoint	Sensitivity	Magnitude	Overall impact rating
Viewpoint 1 – Seaforth Oval	Moderate	Negligible	Daytime: Negligible
			Night time: Negligible
Viewpoint 2 – Wakehurst Golf Course	Moderate	Low	Daytime: Moderate – low
			Night time: Negligible
Viewpoint 3 – Wakehurst Parkway (south)	Moderate	Moderate	Daytime: Moderate
			Night time: Low
Viewpoint 4 – Kirkwood Street residential	Moderate	Low	Daytime: Moderate – low
			Night time: Low
Viewpoint 5 – Engravings Track	High	Low	Daytime: Moderate
			Night time: Negligible
Viewpoint 6 – Wakehurst Parkway (north)	Moderate	Moderate	Daytime: Moderate
			Night time: Negligible
Viewpoint 7 – Garigal National Park lookout	High	Negligible	Daytime: Negligible
			Night time: Negligible
Viewpoint 8 – Killarney Heights residential	High	Low	Daytime: Moderate
			Night time: Negligible
Viewpoint 9 – Wakehurst Parkway/Warringah Road Intersection	Low	Negligible	Daytime: Negligible
			Night time: Negligible



Figure 22-26 Existing view north along Wakehurst Parkway near Kirkwood Street



Figure 22-27 Proposed view (year 1 of operation) north with the project along Wakehurst Parkway near Kirkwood Street



Figure 22-28 Existing view south along Wakehurst Parkway near the Warringah Aquatic Centre



Figure 22-29 Proposed view (year 1 of operation) south with the project along Wakehurst Parkway near the Warringah Aquatic Centre

22.8 Environmental management measures

The project has aimed to limit its visual impact by situating project elements within or adjacent to major transport corridors and built-up urban areas. Project elements have been designed with consideration of the surrounding areas and landscape treatments have been proposed to reduce the visual impacts of new infrastructure.

Environmental management measures have been developed with the aim of avoiding significant visual impacts and, where impacts are unavoidable, to effectively reduce and alleviate impacts. Environmental management measures relating to urban design and visual amenity impacts during design and construction phases are outlined in Table 22-25 below.

As noted previously, no specific environmental management measures are outlined in this section in respect to potential operational impacts as the mitigation of such potential impacts would be considered through the strategic urban design framework (see environmental management measure V1, Section 22.2 and Appendix V (Technical working paper: Urban design, landscape character and visual impact)).

Table 22-25 Environmental management measures – Urban design and visual amenity

Ref	Phase	Impact	Environmental management measure	Location
V1	Design	Vegetation/ landscaping	The urban design and landscape plan will be further developed during further design development and implemented in line with the strategic urban design framework for the project and appropriate operational mitigation measures (Appendix V (Technical working paper: Urban design, landscape character and visual impact)). The urban design and landscape plan will detail built and landscape features to be implemented during construction and rehabilitation of disturbed areas during construction of the project. The urban design and landscape plan will be made available to the public for feedback.	BL/GHF
V2	Construction	Built form	Construction support sites will be developed to minimise visual impacts for adjacent receivers where feasible and reasonable.	BL/GHF
V3	Construction	Built form	Storage areas and associated works will be located in cleared or otherwise disturbed areas away from residential areas where feasible and reasonable.	BL/GHF
V4	Construction	Built form	Site hoardings will be in neutral colours and designs, in proximity to open space, to help them blend into surrounding environment.	BL/GHF
V5	Construction	Built form	Site hoarding and perimeter site areas will be maintained regularly to include the prompt removal of graffiti.	BL/GHF
V6	Construction	Built form	Site lighting will be designed to minimise glare issues and light spillage into adjoining properties and be generally consistent with the requirements of Australian Standard	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			4282-2019 <i>Control of the obtrusive effects of outdoor lighting.</i>	
V7	Construction	Built form	Hoardings and temporary noise walls will be erected as early as possible within the site establishment phase to provide visual screening.	BL/GHF
V8	Construction	Built form	High quality fencing suitable for parks and public spaces will be used where construction support sites are located in close proximity to sensitive residential receivers and users of recreational space.	BL/GHF
V9	Construction	Vegetation/ landscaping	Existing trees adjacent to the works will be retained and protected where possible to screen construction works.	BL/GHF
V10	Construction	Vegetation/ landscaping	Where possible, trees will be trimmed rather than removed. Works will be supervised by a qualified arborist.	BL/GHF
V11	Construction	Vegetation/ landscaping	All areas disturbed by construction and not required for operation of the project will be restored as soon as practicable to their existing condition or in accordance with the urban design and landscape plan where applicable (environmental management measure V1).	BL/GHF
V12	Construction	Vegetation/ landscaping	Early planting works will be considered to provide a screening buffer that has time to mature before the project is fully operational.	BL/GHF
V13	Construction	Vegetation/ landscaping	Where amenity trees are removed as a result of the establishment of construction support sites, they will be replaced at a ratio equal to or greater than 1:1. The replacement trees will consist of local native provenance species from the vegetation community that once occurred in the locality (rather than plant exotic or non-local native trees) where available and subject to the urban design and landscape plan. Where replacement trees cannot be accommodated within the operational footprint of the project, consultation will be carried out with the adjacent land owner and relevant local council (where appropriate) to determine if they can accommodate the replacement tree(s).	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 23

Hazards and risks

23 Hazards and risks

This chapter assesses potential hazards arising from possible incidents during project construction and operation that could pose a risk to public safety, the surrounding community or the environment, and summarises the approaches taken to manage these risks. Other potential environmental hazards resulting from construction and operation of the project, and measures to avoid, mitigate and manage these risks are addressed in Chapter 8 (Construction traffic and transport) to Chapter 27 (Cumulative impacts) of this environmental impact statement. The impacts associated with human health risks are detailed in Chapter 13 (Human health).

The Secretary's environmental assessment requirements as they relate to hazard and risk impacts, and where in the environmental impact statement these have been addressed, are detailed in Table 23-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to hazards and risks are included in Section 23.4.

Table 23-1 Secretary's environmental assessment requirements – hazards and risks

Secretary's requirement	Where addressed in EIS
Transport and traffic	
1. The Proponent must assess construction transport and traffic (vehicle, marine, pedestrian and cyclists) impacts, including, but not necessarily limited to: <ul style="list-style-type: none"> a. a considered approach to route identification and scheduling of marine and land transport movements, particularly outside standard construction hours j. impacts to water-based traffic on Middle Harbour. 	Within Chapter 6 (Construction work), Section 6.7 and Section 6.8 show the land and maritime construction traffic/vessel movements for each temporary construction support site, as well as the operating hours of each site. Construction traffic routes are discussed in Chapter 8 (Construction traffic and transport). Section 8.4 discusses the proposed marine and land transport movements. Section 23.2.4 outlines interactions between maritime traffic and tunnel infrastructure during construction.
Health and safety	

Secretary's requirement	Where addressed in EIS
<p>2. The assessment must:</p> <p>f. assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, bushfire risks and the handling and use of dangerous goods.</p>	<p>An assessment of bushfire risks relating to construction and operation is presented in Section 23.2.6 and Section 23.3.5 respectively. The handling, transport and use of dangerous goods is described in Section 23.2 and Section 23.3.</p> <p>An assessment of potential ground movement associated with the project is provided in Chapter 16 (Geology, soils and groundwater). Ground movement due to construction activities is also discussed in Section 23.2.3.</p> <p>Pedestrian safety is discussed in Chapter 8 (Construction traffic and transport). Section 23.3.3 provides an assessment of the impacts of potential traffic incidents during operation.</p>
Socio-economic, land use and property	
<p>4. The Proponent must assess potential impacts on utilities (including communications, electricity, gas, fuel and water and sewerage) and the relocation of these utilities.</p>	<p>Chapter 6 (Construction work) details utilities impacted during construction. Chapter 5 (Project description) outlines utilities and services management for the project.</p> <p>Appendix D (Utilities management strategy) provides a detailed description of utilities likely to be impacted and a framework for utility adjustment, relocation and protection. The framework is outlined in Section 23.2.5.</p>
Hazards	
<p>1. The Proponent must describe the process for assessing the risk of emissions from ventilation facilities on aircraft operations taking into consideration the requirements of the <i>Airports Act 1996</i> (Commonwealth) and the <i>Airports Regulations 1997</i>.</p>	<p>The process for the assessment of risk of emissions from ventilation facilities on aircraft operation is described in Chapter 2 (Assessment process). The findings of the assessment are summarised in Section 23.3.6.</p>

23.1 Assessment methodology

An assessment was carried out to identify environmental hazards and risks that could arise during construction and operation of the project, as well as appropriate risk management measures.

The assessment focused on those hazards with the potential to adversely affect the surrounding environment, and general public. It took into account the following guidelines:

- *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33* (Department of Planning, 2011)
- *Australian Code for the Transport of Dangerous Goods by Road and Rail* (7th edition) (National Transport Commission, 2007)
- *Storage and Handling of Dangerous Goods Code of Practice* (WorkCover, 2005)
- *Planning for Bushfire Protection* (Rural Fire Service (RFS), 2019)

- *Bush Fire Risk Management Planning Guidelines for Bush Fire Management Committees* (RFS, 2008)
- *Garigal National Park Fire Management Strategy* (Department of Environment and Conservation (DEC), 2006b)
- *Manly Warringah War Memorial Park Fire Regime Management Plan* (Eco Logical Australia, 2006)
- Bushfire prone land mapping developed and published by the relevant local councils
- Relevant Bush Fire Risk Management Plans including:
 - *Mosman North Sydney Willoughby Bush Fire Risk Management Plan 2017–2022* (Mosman North Sydney Willoughby Bush Fire Management Committee, 2017)
 - *Warringah Pittwater Bush Fire Risk Management Plan 2010–2015* (Warringah Pittwater Bush Fire Management Committee, 2010).

23.2 Assessment of potential construction impacts

During construction, potential hazards and risks to public safety, the surrounding community or the environment may be associated with:

- Storage and handling of dangerous goods and hazardous substances (Section 23.2.1)
- Transport of dangerous goods and hazardous substances (Section 23.2.2)
- Ground movement (settlement) or geotechnical uncertainty (Section 23.2.3)
- Interactions between maritime traffic and tunnel infrastructure (Section 23.2.4)
- Damage to, or disruption of, both underground and above ground utilities (Section 23.2.5)
- Bushfires (Section 23.2.6).

Other potential environmental hazards resulting from the construction of the project are considered and addressed in the relevant chapters of this environmental impact assessment.

23.2.1 Storage and handling of dangerous goods and hazardous substances

The anticipated types and quantities of dangerous goods and hazardous substances that would be stored and used at the temporary construction support sites are listed in Table 23-2. The types and quantities of dangerous goods and hazardous substances are indicative and would be confirmed during further design development and detailed construction planning, and if necessary, further screening of potential risks would be carried out at that time. The screening would be used to confirm that the project would not pose a substantial off-site risk.

State Environmental Planning Policy No 33 – Hazardous and Offensive Development (SEPP 33) presents a systematic approach to the assessment of development proposals for potentially hazardous and offensive industry or storage. SEPP 33 ensures that proposals can be built and operated with an adequate level of safety and pollution control. *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33* (Applying SEPP 33) (Department of Planning, 2011) includes a screening method, based on the quantities of dangerous goods on a site, to assist in determining if a proposed development is considered potentially hazardous and offensive under SEPP 33.

A screening comparison of the indicative quantities of dangerous goods to be stored at the temporary construction support sites against the threshold quantities listed in Applying SEPP 33 has been carried out. These thresholds represent the level at which dangerous goods may present a credible off-site risk requiring further, more detailed assessment. The comparison against the screening thresholds in Applying SEPP 33 is included in Table 23-2. Other potentially dangerous goods and hazardous substances to be used during construction of the project and not listed in Applying SEPP 33 have also been included in Table 23-2 for completeness.

Table 23-2 demonstrates that the Applying SEPP 33 inventory thresholds would not be exceeded for any material at any temporary construction support site. The storage and use of dangerous goods and hazardous materials at the temporary construction support sites would therefore not pose an unacceptable risk of harm beyond the temporary construction support site boundary.

Environmental hazards and risks associated with the on-site storage and use of chemicals, fuels and materials would be managed through standard mitigation measures (refer to Section 23.4). Storage of dangerous goods and hazardous substances would be in accordance with the supplier's instructions, and would comply with applicable legislation, guidelines and Australian Standards.

Table 23-2 Indicative dangerous goods and hazardous substances stored at temporary construction support sites

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
Explosives	1.1	No on site storage – delivery would be timed to avoid the need for on-site storage	Explosives would not be stored on site and would therefore not be subject to the Applying SEPP 33 thresholds.	N/A
Diesel	C1 ¹ , 3 PG III ²	Self-bunded fuel tank (up to 2.5 kilolitres) and 20 litre drums	Diesel would be less than five tonnes and would not be stored with Class 3 (flammable liquids) materials. It would therefore not be subject to the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Petrol	C1 ¹ , 3 PG III ²	Self-bunded fuel tank (up to 2.5 kilolitres) and 20 litre drums	Petrol would be less than five tonnes and would not be stored with Class 3 materials. It would therefore not be subject to the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Lubricating and hydraulic oils and grease	C2	20 litre drums	Lubricating and hydraulic oils and grease would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.	All temporary construction support sites.
Industrial grade acetylene	2.1	3.2 m ³ cylinders (13 kilograms)	Individual cylinders containing acetylene would not trigger the Applying SEPP 33 thresholds (100 kilograms). Maximum stored inventories (250 kilograms) would be located more than 25 metres away from the temporary construction support site boundary and would therefore also not trigger the Applying SEPP 33 thresholds if considered in aggregate.	All temporary construction support sites.

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
Industrial grade oxygen	2.2	8.9 m ³ cylinders	Industrial grade oxygen is a class 2.2 dangerous good and is therefore not subject to the Applying SEPP 33 thresholds.	All temporary construction support sites.
Accelerator for shotcrete	3.2	1000 litre intermediate bulk containers (IBC)	Individual IBCs containing accelerator fluid would not trigger the Applying SEPP 33 thresholds (five tonnes). Maximum stored inventories (20,000 litres) would be located more than eight metres away from the temporary construction support site boundary and would therefore also not trigger the Applying SEPP 33 thresholds if considered in aggregate.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13) • Wakehurst Parkway north (BL14).
Retardants for concrete	3 PGIII	205 litre drums	Retardants would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All land based temporary construction support sites.
Epoxies	3 PGIII	20 litre drums	Epoxies would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All temporary construction support sites.
Acids	8 PGIII	1000 litre IBC (and smaller containers)	Acids would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All temporary construction support sites.
Bases	8 PGIII	1000 litre IBC	Bases would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All temporary construction support sites.
Disinfectants	8 PGIII	500 litre IBC	Disinfectants would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.	All land based temporary construction support sites.

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
General purpose Portland cement	N/A	20 kilogram bags	Cement is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Road and joint sealants	N/A	12 litre boxes	Road and joint sealants are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites (except Spit West Reserve (BL9)).
Concrete curing compounds	N/A	1000 litre IBC	Concrete curing compounds are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Pavement layers curing compound	N/A	1000 litre IBC	Pavement layers and curing compounds are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Paint for tunnel roof	N/A	1000 litre IBCs	Paint is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).
Paints	N/A	50 litre drums	Paints are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Coagulants	N/A	1000 litre IBCs	Coagulants are not a dangerous good and therefore do not trigger the Applying SEPP 33 thresholds.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Material	Australian Dangerous Goods Code class	Storage method	Assessment against Applying SEPP 33 inventory thresholds	Temporary construction support site
Anti-scalent	N/A	100 litre drums	Anti-scalent is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Note 1: Classified as C1 if not stored with other Class 3 flammable liquids
Note 2: Classified as 3 PG III if stored with other Class 3 flammable liquids

23.2.2 Transport of dangerous goods and hazardous substances

Dangerous goods and hazardous materials that would be transported to each temporary construction support site are outlined in Table 23-3. Potential transportation hazards and risks have been considered through comparison of the likely type, quantity and frequency of dangerous goods and hazardous materials transportation with the thresholds presented in Applying SEPP 33. In all cases, the transportation of dangerous goods and hazardous materials to temporary construction support sites would be below the Applying SEPP 33 thresholds. This indicates that risks associated with transport of dangerous goods and hazardous materials would not be significant.

The proposed haulage routes outlined in Chapter 6 (Construction work) have been identified to avoid local roads where possible and would therefore minimise the risks associated with the transport of dangerous goods and hazardous materials.

Table 23-3 Indicative dangerous goods and hazardous substances transported to temporary construction support sites

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Explosives	1.1	As required, if blasting is carried out.	As required	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods.	<ul style="list-style-type: none"> Flat Rock Drive (BL2) Punch Street (BL3) Balgowlah Golf Course (BL10) Wakehurst Parkway east (BL13).
Diesel ¹	C1 ² , 3 PG III ³	Daily	1500 litres	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods. Refuelling at cofferdams would be carried out by fit for purpose refuelling barges.	All temporary construction support sites.
Petrol ¹	C1 ² , 3 PG III ³	Weekly	50 litres	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods. Refuelling at cofferdams would be carried out by fit for purpose refuelling barges.	All temporary construction support sites.
Lubricating and hydraulic oils and grease	C2	Weekly	40 litres	Not subject to the Applying SEPP 33 thresholds if not transported with Class 3 dangerous goods.	All temporary construction support sites.
Industrial grade acetylene	2.1	Monthly	410 litres ⁴	Transport quantities would not trigger the Applying SEPP 33 thresholds.	All temporary construction support sites.
Industrial grade oxygen	2.2	Monthly	410 litres ⁴	Not subject to Applying SEPP 33 transport thresholds	All temporary construction support sites.

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Accelerator for shotcrete	3PGII	Weekly	100 litres ⁴	Transport quantities would not trigger the Applying SEPP 33 thresholds.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13) • Wakehurst Parkway north (BL14).
Retardants for concrete	3PGIII	Monthly	205 litre drum	Transport quantities would not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Epoxies	3PGIII	Monthly	20 litres ⁴	Transport quantities would not trigger the Applying SEPP 33 thresholds.	All temporary construction support sites.
Acids	8 PGIII	Monthly	20 litres ⁴	Not subject to Applying SEPP 33 transport thresholds.	All temporary construction support sites.
Bases	8 PGIII	Monthly	20 litres ⁴	Not subject to Applying SEPP 33 transport thresholds.	All temporary construction support sites.
Disinfectants	8 PGIII	Monthly	20 litres ⁴	Not subject to Applying SEPP 33 transport thresholds.	All land based temporary construction support sites.
General purpose Portland cement	N/A	Monthly	72 bags ⁴	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Road and joint sealants	N/A	Monthly	Four 12 litre boxes	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites (except Spit West Reserve (BL9)).

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Concrete curing compounds	N/A	Monthly	50 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Pavement layers curing compound	N/A	Monthly	100 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Paint for tunnel roof	N/A	Five to six deliveries	50 litre drums	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Material	Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 transport thresholds	Temporary construction support site destination
Paints	N/A	Monthly (during the second half of construction program)	250 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	All land based temporary construction support sites.
Coagulants	N/A	Monthly	150 kilograms	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).
Anti-scalent	N/A	Monthly	1000 litres	This is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.	<ul style="list-style-type: none"> • Cammeray Golf Course (BL1) • Flat Rock Drive (BL2) • Punch Street (BL3) • Balgowlah Golf Course (BL10) • Wakehurst Parkway east (BL13).

Note 1: For some temporary construction support sites, the quantity of diesel and unleaded petrol delivered to site would be greater than the quantity stored within the facility at any time, because the delivery volume takes into the account fuel which is brought to the facility by mini-tanker and used to directly refuel plant. As this fuel is 'in use' in the plant it is not classified as 'stored'.

Note 2: Classified as C1 if not stored with other Class 3 flammable liquids.

Note 3: Classified as 3 PG III if stored with other Class 3 flammable liquids.

Note 4: Per temporary construction support site.

23.2.3 Ground movement and geological uncertainty

Ground movement (or settlement) refers to a localised lowering of the ground level due to construction activities involving excavation or disturbance below ground. If unmanaged, ground movement can present a risk to the stability of nearby buildings and other structures, including building basements and ground support structures.

Ground movement may occur as a result of:

- Tunnel induced movement caused by the relief of stress from the removal of intact rock during tunnelling
- Settlement induced by groundwater drawdown.

The construction of tunnels, even using the most modern machinery and control methods, results in some volume loss and corresponding ground movement. Geotechnical investigations have confirmed that high quality Hawkesbury Sandstone would be encountered for the majority of the proposed tunnel alignment. Furthermore, the alignment of the proposed tunnels means that they would be very deep for the majority of their length, with a substantial amount of sandstone between the tunnels and surface. Most of the induced settlement along the alignment due to tunnel excavation would therefore likely be as a result of stress redistribution within the rock mass.

An assessment of potential ground movement associated with the project is provided in Chapter 16 (Geology, soils and groundwater). Preliminary ground movement predictions indicate that there may be potential settlement of up to 40 millimetres around the Burnt Bridge Creek Deviation and Wakehurst Parkway portals. This would be considered 'slight' severity under relevant guidelines. Potential settlement at Flat Rock Creek Reserve could reach 85 millimetres, however no buildings are present at this location. This prediction assumes that groundwater inflows into the tunnel beneath Flat Rock Reserve are unconstrained. Additional modelling and settlement predictions at this location indicated that when reduced inflows and groundwater drawdown were taken into account, the maximum predicted total settlement reduced to 35 millimetres.

For most of the tunnelling works, the anticipated drawdown in the groundwater table would occur within the bedrock stratigraphy above the tunnel and this drawdown is assessed not to cause consolidation settlement in the overlying natural or filled soils, which are currently above the groundwater table. However, tunnelling works could potentially lower the groundwater table within poorly consolidated fill which could result in surface settlements where the tunnel crosses beneath the former Flat Rock Creek. At this location, the tunnelling works could drain the groundwater currently "ponded" within landfill in the former creek. Inflow of groundwater into the tunnels would result in a depressurisation of the groundwater surrounding the tunnels and could lead to ground settlement.

The groundwater and settlement modelling completed for this environmental impact statement is conservative in that it disregards the effects of the permanent concrete and waterproofing linings that will be installed within the tunnels. The tunnel will be designed to limit groundwater inflow into the tunnel, minimising the actual groundwater drawdown and associated settlement predicted to occur during construction.

A number of major design and construction method reviews have been carried out to better understand the Lane Cove Tunnel failure which occurred at Longueville in 2005. The causes of the failure are generally cited as a complex combination of factors, including the changing ground conditions and geological defects and the inadequacy of the tunnel support system.

The risks of a similar incident occurring during a Sydney tunnelling project are considered extremely low. The reasons for this include:

- Vastly improved geotechnical assessment and modelling
- Improved predictive two dimensional and three dimensional modelling of geology, excavation spans, temporary and permanent loads

- Fit for purpose design to develop the appropriate type of ‘support’ to match the ground conditions as the excavation progresses on a day to day basis
- Continuous independent review of the temporary and permanent works design and construction methods
- Continual construction verification that tunnel support is installed and performing as per the design
- Robust change management processes for conditions that are out of the ordinary or unexpected, including probe drilling and ground treatment through suspected poor ground zones
- Continuous assessment of likely excavation and groundwater conditions
- Detailed survey monitoring of surface roads, buildings and structures in the tunnel vicinity.

In addition to the consideration of the above, the project design and tunnel construction methods have been informed by early geotechnical investigations to reduce the construction risks associated with uncertain ground conditions (additional geotechnical investigations would be carried out during further design development to confirm ground conditions, where required). Primary support for the tunnels would be installed as the excavation progresses, as recommended by an appropriately qualified geotechnical or tunnel engineer, to ensure tunnel stability during construction.

23.2.4 Interactions between maritime traffic and tunnel infrastructure

The project would require marine vessel movements during construction of the immersed tube tunnels in Middle Harbour, including:

- Barges for construction activities including delivering construction materials, removing cofferdam spoil and removing dredged material
- Dredging vessels
- Barges with piling equipment and cranes
- Tugboats for manoeuvring barges
- Transport vessels for workers.

The steel shells for the immersed tube tunnel units for the Middle Harbour crossing would be prepared at a location outside of Middle Harbour. Once prepared, the immersed tube tunnel steel shells would be transported by sea either on a barge or directly towed and guided by several tug boats to Middle Harbour, through the Spit Bridge navigation channel and moored at Spit West Reserve construction support site (BL9) to be completed.

There is a shallow sand bar located near the entrance to Middle Harbour which would need to be navigated by the barge or tug boat and immersed tunnel unit steel shells. While the waterway at the Middle Harbour entrance is relatively wide, the water depths through the deepest part of the channel are about 4.5 metres, becoming shallower at low tide. The immersed tube tunnel units have been designed as incomplete steel shells so that they would be lighter during transportation into Middle Harbour. The steel shell design would enable the barge or floating immersed tube tunnel unit steel shells to float higher in the water, enabling their safe and efficient transport over the shallow sand bar and into Middle Harbour. This would minimise the potential for the vessel (barge or tug boat) transporting the immersed tube tunnel unit steel shells, or the floating steel shells, grounding on the shallow sand bar. Casting of the steel shells with reinforced concrete and fitout of the completed immersed tube tunnels would be carried out at Spit West Reserve construction support site (BL9) prior to immersion.

During immersion of the tube tunnel units, there is a risk that maritime traffic could collide with the units if they pass the location of the Middle Harbour crossing before the tube tunnel units are in their final position on the bed of the harbour. The timeframe for immersion would be very short

(less than two days per unit), and measures would be put in place to manage potential risks, including restrictions such as partial or full closures to marine vessel movements through the crossing location during immersion of the tube tunnels. As outlined in Chapter 8 (Construction traffic and transport), simulation modelling has demonstrated that the transportation of both steel shell and completed immersed tube tunnel units can be carried out safely.

23.2.5 Damage or disruption to underground and above ground utilities

The project has been designed, where possible, to avoid utilities, taking into account the results of utility investigations and consultation with utility providers carried out during the design process (refer to Chapter 7 (Stakeholder and community engagement)). Where the project is unable to avoid utilities, if possible, they would be adjusted, relocated or protected prior to the commencement of construction to avoid impacts. Alternatively, adjustment, relocation or protection would occur during construction.

Consultation with utility providers would continue during the further design development and construction planning phases of the project to mitigate the risk of unplanned and unexpected disturbance of utilities. In rare circumstances, the relocation of utilities may result in planned short term outages of some utilities to surrounding areas. Utilities which would be directly impacted and require adjustment, protection or relocation have been considered in Appendix D (Utilities management strategy).

23.2.6 Bushfires

A bushfire risk assessment was carried out to assess potential bushfire implications of the project. In accordance with *Planning for Bushfire Protection* (RFS, 2019) the predominant vegetation class (bushfire prone land) has been assessed to a distance of 140 metres from the project in all directions. Table 23-4 provides the assessed bushfire risk level for temporary construction support sites located on, or close to, bushfire prone land. The level of bushfire risk is determined using a combination of likelihood and consequence, with the likelihood of bushfire risk for all assets being defined as the chance of a bushfire igniting and spreading and the consequence being the outcome or impact of a bushfire event (RFS, 2008).

Table 23-4 Bushfire risk level for temporary construction support sites

Temporary construction support site(s)	Bushfire risk level	Proximity to bushfire prone land
Cammeray Golf Course (BL1)	Low	No bushfire prone land within 140 metres.
Flat Rock Drive (BL2)	Low	The northern, eastern and southern areas of the temporary construction support site would be within 10 metres of bushfire prone land.
Punch Street (BL3) Dickson Avenue (BL4) Barton Road (BL5) Gore Hill Freeway median (BL6)	Low	The northern portion of the Punch Street construction support site (BL3) would be located more than 70 metres from bushfire prone land (and separated by Gore Hill Freeway). Other temporary construction support sites would be located greater than 100 metres from bushfire prone land.
Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)	N/A	Not applicable as the temporary construction support sites would be located within Middle Harbour.

Temporary construction support site(s)	Bushfire risk level	Proximity to bushfire prone land
Spit West Reserve (BL9)	Low	No land based structures are proposed within the temporary construction support site, with site access only proposed.
Balgowlah Golf Course (BL10) Kitchener Street (BL11)	Low	The northern portion of the Balgowlah Golf Course construction support site (BL10) would be located within 60 metres of bushfire prone land.
Wakehurst Parkway south (BL12) Wakehurst Parkway east (BL13)	Medium	These two temporary construction support sites would be located in an area classified as bushfire prone land.
Wakehurst Parkway north (BL14)	High	This temporary construction support site would be located in an area classified as bushfire prone land.

The bushfire risk assessment identified that during construction, all areas of the project, with the exception of areas along the Wakehurst Parkway, would have a bushfire risk level of 'low'. With respect to the Wakehurst Parkway, the risk of bushfires would be considered higher, with the Wakehurst Parkway south (BL12) and Wakehurst Parkway east (BL13) temporary construction support sites assessed as having a bushfire risk level of 'medium' and Wakehurst Parkway north construction support site (BL14) having a rating of 'high'. The difference in these ratings is largely as a result of greater consequences should a bushfire occur.

Several areas associated with the project, including areas within Naremburn, Northbridge and Frenchs Forest are identified in the *Mosman North Sydney Willoughby Bushfire Risk Management Plan 2017-2022* (Mosman North Sydney Willoughby Bush Fire Management Committee, 2008) and the *Warringah Pittwater Bush Fire Risk Management Plan 2010–2015* (Warringah Pittwater Bush Fire Management Committee, 2010) as being subject to bushfire planning measures. Council management of these areas would contribute to the bushfire protection measures for the relevant temporary construction support sites.

Strategies to reduce risk from bushfire, such as site layout, setbacks from bushfire prone vegetation, access and emergency procedures along the Wakehurst Parkway would be developed and implemented during construction (refer to Section 23.4).

23.3 Assessment of potential operational impacts

During operation, potential hazards and risks to public safety, the surrounding community or the environment may be associated with:

- Storage and handling of dangerous goods and hazardous substances (Section 23.3.1)
- Transport of dangerous goods and hazardous substances (Section 23.3.2)
- Traffic incidents on surface roads and within tunnels (Section 23.3.3)
- Interactions between maritime traffic and tunnel infrastructure (Section 23.3.4)
- Bushfires (Section 23.3.5)
- Atmospheric turbulence caused by discharges from the ventilation outlets and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and the Wakehurst Parkway and the interface with aviation (Section 23.3.6).

Other potential environmental hazards resulting from the operation of the project are considered and addressed in the relevant chapters of this environmental impact statement.

23.3.1 Storage and handling of dangerous goods and hazardous substances

Dangerous goods and hazardous materials would be stored at the operational facilities to be provided as part of the project and used during operation of the project. The types and quantities of dangerous goods and hazardous materials to be stored on-site during operation are summarised in Table 23-5. Additional small quantities of other materials may be required on-site from time to time to support maintenance activities. Managed in accordance with the measures in Section 23.4, these materials would not pose a substantial risk to the general public during operation of the project.

Comparison of the types and quantities of dangerous goods and hazardous materials to be stored on-site with the thresholds outlined in Applying SEPP 33, demonstrates that operational inventories would not pose a substantial risk of harm beyond the boundary of the operational facilities.

Table 23-5 Indicative dangerous goods and hazardous substances stored on site during operation

Material and Australian Dangerous Goods Code class	Storage method (amount stored at any one time)	Inventory thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 inventory thresholds
Diesel C1 ¹ , 3 PG III ²	Bunded tanks on site.	N/A	Diesel would be less than five tonnes and would not be stored with Class 3 materials. It would therefore not be subject to the Applying SEPP 33 thresholds.
Grease C2	400-gram cartridge, 20 litre containers stored undercover on site.	N/A	Grease would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Adhesives C2, PGIII	375-gram cartridge, 20 litre containers stored on site.	Five tonnes	Adhesives would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Acetylene C2.1	Size G cylinders on site.	100 kilograms	Individual cylinders containing acetylene would not trigger the Applying SEPP 33 thresholds. Maximum stored inventories would not trigger the Applying SEPP 33 thresholds if considered in aggregate.
Linemarking aerosol C2.1	375 millimetre aerosol container stored undercover on site.	100 kilograms	Linemarking aerosol would not trigger the Applying SEPP 33 thresholds.
Oxygen C2.2	Size G cylinders on site.	N/A	Industrial grade oxygen is a Class 2.2 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Kerosene C3, PGIII	20 litre containers stored in an undercover bunded area on site.	Five tonnes	Kerosene would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Oxygen (subsidiary risk) C5.1	Size G cylinders on site.	Five tonnes	Oxygen has a subsidiary risk Class of 5.1. It would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.

Material and Australian Dangerous Goods Code class	Storage method (amount stored at any one time)	Inventory thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 inventory thresholds
Sodium hydroxide C8, PGII	10,000 litre feed tank in an undercover bunded area on site.	25 tonnes	Sodium hydroxide would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Bitumen C9	12,000 litre tanker (brought onto site as required).	N/A	Bitumen is a Class 9 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Coagulant N/A	12,000 litre feed tank in an undercover bunded area on site.	N/A	Coagulant is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Polymers N/A	20 kilogram bags stored in a container and undercover on site.	N/A	Polymers are not classified as a dangerous good and would not trigger the Applying SEPP 33 thresholds.
Non-shrink grout N/A	20 kilogram bags stored undercover on site.	N/A	Non-shrink grout is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Release agent (lanolin-based) N/A	20 litre drums stored undercover on site.	N/A	Release agent (lanolin-based) is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.

Note 1: Classified as C1 if not stored with other Class 3 flammable liquids

Note 2: Classified as 3 PG III if stored with other Class 3 flammable liquids

23.3.2 Transport of dangerous goods and hazardous substances

Dangerous goods and hazardous materials that would be transported to the project during operation are outlined in Table 23-6. The risks associated with transport of dangerous goods and hazardous materials would not be high.

Prior to opening to traffic, the mainline tunnels would be listed as prohibited areas under Road Rules 2014 – Rule 300-2: NSW rule: carriage of dangerous goods in prohibited areas (Regulation 300-2). The transport of dangerous goods in prohibited areas, including the mainline tunnels, would be prohibited. Signage would be provided near tunnel entry points advising of applicable restrictions to ensure compliance with Rule 300-2.

Table 23-6 Indicative dangerous goods and hazardous substances transported during operation

Material and Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Transport thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 transport thresholds
Diesel C1 ¹ , 3 PG III ²	As required	As required	N/A	Diesel would not be transported with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Grease C2	Weekly	50 cartridges (20 kilograms)	N/A	Grease would not be transported with Class 3 materials and would therefore not be subject to Applying SEPP 33 thresholds.
Adhesives C2, PGIII	Weekly	50 cartridges (19 kilograms)	Minimum transport load or transport frequency of 10 tonnes, more than 60 times per week	Adhesives would not trigger the Applying SEPP 33 thresholds.
Acetylene C2.1	Weekly	50 cylinders	Minimum transport load or transport frequency of two tonnes, more than 30 times per week	Industrial grade acetylene would not trigger the Applying SEPP 33 thresholds for minimum transport load or transport frequency of two tonnes, more than 30 times per week.
Line-marking aerosol C2.1	Quarterly	50 cans	Minimum transport load or transport frequency of two tonnes, more than 30 times per week	Line-marking aerosol would not trigger the Applying SEPP 33 thresholds.
Oxygen C2.2	Weekly	50 cylinders	N/A	Industrial grade oxygen is a Class 2.2 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Kerosene C3, PGIII	Monthly	80 litres	Minimum transport load or transport frequency of 10 tonnes, more than 60 times per week	Kerosene would not trigger the Applying SEPP 33 thresholds.
Oxygen (subsidiary risk) C5.1	Weekly	50 cylinders	Minimum transport load or transport frequency of two tonnes, more than 30 times per week	Oxygen has a subsidiary risk Class of 5.1. It would not trigger the Applying SEPP 33 thresholds.

Material and Australian Dangerous Goods Code class	Transport frequency	Transport quantity	Transport thresholds in Applying SEPP 33	Assessment against Applying SEPP 33 transport thresholds
Sodium hydroxide C8, PGII	Six monthly	10,000 litres	Minimum transport load of 25 tonnes	Sodium hydroxide would not trigger the Applying SEPP 33 thresholds if considered as individual containers or in aggregate.
Bitumen C9	Quarterly	12,000 litres	Minimum transport frequency of more than 60 times per week	Bitumen would not trigger the Applying SEPP 33 thresholds.
Coagulant N/A	Quarterly	10,000 litres	N/A	Coagulant is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Polymers N/A	Quarterly	1000 kilograms	N/A	Polymers are not classified as a dangerous good and would not trigger the Applying SEPP 33 thresholds.
Non-shrink grout N/A	Monthly	1900 kilograms	N/A	Non-shrink grout is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Release agent (lanolin-based) N/A	Twice monthly	180 litres	N/A	Release agent (lanolin-based) is not classified as a dangerous good and does not trigger the Applying SEPP 33 thresholds.

Note 1: Classified as C1 if not stored with other Class 3 flammable liquids

Note 2: Classified as 3 PG III if stored with other Class 3 flammable liquids

23.3.3 Traffic incidents

The project has been designed to provide efficient, free flowing traffic conditions with capacity to safely accommodate forecast traffic volumes. The project design incorporates all feasible and reasonable traffic safety measures including those related to geometry, pavement, lighting, signage and shared user infrastructure consistent with current Australian Standards, road design guidelines and industry best practice. In doing so, the design of the project inherently minimises the likelihood of incidents and accidents.

Each project tunnel would be one-directional, reducing the risk of crashes through head on collisions and simplifying smoke management and egress requirements. The transport of dangerous goods and hazardous substances would be prohibited through the mainline and ramp tunnels and on and off ramps, reducing the risk of very large fires or the release of toxic materials in the tunnels.

Notwithstanding, human factors in particular cannot be entirely removed during operation of the project and there would remain a residual risk of incidents and accidents. In the event of incidents and accidents, the project has been designed to meet appropriate fire and life safety requirements. The key fire and life safety aspects of the project are described in Chapter 5 (Project description), and would include maintenance and emergency breakdown bays, fire and incident detection equipment, communications systems, fire suppression systems, emergency lighting, smoke management and power systems, cross passages or longitudinal egress passages, and tunnel closure systems. The fire and life safety systems would be installed in accordance with Australian Standard *AS 4825:2011 Tunnel Fire Safety*, applicable Austroads and Transport for NSW guidelines, and the outcomes of consultation with emergency services.

In the event of an incident, approaching traffic would be prevented from entering the mainline and ramp tunnels. Vehicle occupants upstream of the fire or incident would be instructed to stop their vehicles, and exit in the opposite direction through the section of carriageway that would be protected by the smoke management system, or through an exit door to a pressurised and fire rated cross-passage leading to the other non-incident tunnel.

Occupants downstream of the fire or incident would be encouraged to continue driving out of the tunnel. If this is not possible and they are forced to evacuate on foot, egress would be provided via exit doors to pressurised and fire rated cross-passages leading to the non-incident tunnel. Emergency services would be able to reach the fire or incident via the non-incident tunnel, or from the upstream direction in the affected tunnel. Emergency vehicle cross passages have also been included in the design at key locations.

During emergency conditions the ventilation system would extract smoke from the affected tunnels. Depending on the location of the incident, smoke would be emitted from one or more of the ventilation outlets and from the ramp tunnel portals at the ramp tunnel surface connections.

23.3.4 Interactions between maritime traffic and tunnel infrastructure

The crossing of Middle Harbour would comprise two immersed tube tunnels between Northbridge and Seaforth. The immersed tube tunnels would be located within a tunnel trench on the bed of Middle Harbour. The immersed tube units would be placed to provide sufficient clearance for all maritime traffic in Middle Harbour.

With respect to maritime traffic, the immersed tube tunnel units would be appropriately designed including with an additional layer of concrete to protect against:

- Falling and dragging anchors
- Sinking vessels
- High currents
- Propeller wash and vessel wake.

As such, it is not expected that there would be any risk to the tunnels during operation of the project as a result of maritime traffic.

23.3.5 Bushfires

Most of the project's operational facilities would not be vulnerable to bushfire attack due to its incombustible nature (road surface materials, retaining walls, road barriers), fire safety ratings and/or location underground.

However, some operational facilities would be located on or close to bushfire prone land. These facilities and their associated bushfire risk are listed in Table 23-7.

Table 23-7 Bushfire risk level for operational sites

Operational facilities	Bushfire risk level	Proximity to bushfire prone land
Ventilation outlet and motorway facilities at Warringah Freeway	Low	The ventilation outlet and motorway facilities would not be located within 140 metres of bushfire prone land.
Motorway control centre at the Gore Hill Freeway at Artarmon	Low	The motorway control centre would not be located within 140 metres of bushfire prone land.
Ventilation outlet and motorway facilities at the Gore Hill Freeway	Low	The ventilation outlet and motorway facilities would not be within 140 metres of bushfire prone land (separated by the Gore Hill Freeway).
Tunnel support facilities at the Gore Hill Freeway	Low	The tunnel support facilities would not be located within 140 metres of bushfire prone land.
Ventilation outlet and motorway facilities at the Burnt Bridge Creek Deviation	Low	The ventilation outlet and motorway facilities would not be located within 140 metres of bushfire prone land.
Ventilation outlet and motorway facilities at the Wakehurst Parkway	Medium	The ventilation outlet and motorway facilities would be located in an area classified as bushfire prone land.
Tunnel support facilities at the Wakehurst Parkway	High	The tunnel support facilities would be located in an area classified as bushfire prone land.

Operational facilities along the Wakehurst Parkway were assessed as having a medium or high bushfire risk level. The difference in bushfire risk ratings is largely as a result of greater consequences should there be the occurrence of bushfires. Bushfire risks associated with operational infrastructure along the Wakehurst Parkway would be minimised through continued application of bushfire management practises on the adjoining National Parks land, in accordance with the *Garigal National Park Fire Management Strategy* (DEC, 2006b) administered by the National Parks and Wildlife Service, Crown Land in accordance with the *Manly Warringah War Memorial Park Fire Regime Management Plan* (Eco Logical Australia, 2006) administered by Northern Beaches Council, and routine maintenance within the road reserve.

Strategies to reduce risk from bushfire during operation of the project are included in Section 23.4.

23.3.6 Aviation risks

The operational design of the project has considered airspace protection and associated risks and hazards. As discussed in Chapter 2 (Assessment process), under the *Airports Act 1996*, a 'controlled activity' in relation to a prescribed airspace must not be carried out or caused to be

carried out without the approval of the Secretary of the Department of Infrastructure, Transport, Regional Development and Communications or otherwise exempt under the Airspace Regulations 2007.

Regulations define the 'prescribed airspace' for Sydney Airport as the airspace above any part of either an obstacle limitation surface (OLS) or procedures for air navigation systems operations (PANS-OPS) surface for Sydney Airport.

The OLS is an invisible level that defines the limits to which objects may project into the airspace around an aerodrome so that aircraft operations may be conducted safely. The OLS defines the airspace to be protected for aircraft operating during the initial and final stages of flight, or manoeuvring near Sydney Airport. This has been established in accordance with International Civil Aviation Organisation specifications, as adopted by the Civil Aviation Safety Authority.

PANS-OPS surfaces are conceptual surfaces in space that establish the airspace that is to remain free of any potential disturbance (including physical objects and other disturbances such as emissions from ventilation outlets) so that aircraft operations may be conducted safely. Where structures may (under certain circumstances) be permitted to penetrate the OLS, they would not normally be permitted to penetrate any PANS-OPS surface.

Operational buildings and structures that form part of the project, including the ventilation outlets and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway are designed to be below the prescribed airspace heights.

The Civil Aviation Safety Authority stipulates requirements for the construction and operation of new infrastructure that has the potential to influence aviation safety. The Civil Aviation Safety Authority may determine that exhaust from a ventilation outlet is a hazardous object if the vertical velocity of the emissions exceeds 4.3 metres per second within the OLS and/or PANS-OPS surfaces.

A plume rise assessment was carried out in accordance with the *Civil Aviation Safety Authority Advisory Circular Plume Rise Assessments AC 139-5(1) November 2012* to determine whether plume rise resulting from the operation of the ventilation outlet and motorway facilities at the Warringah Freeway, Gore Hill Freeway, Burnt Bridge Creek Deviation and Wakehurst Parkway would be a controlled activity as defined in section 183 of the *Airports Act 1996*. The modelling considered an expected case, based on predicted typical operational conditions of the project, and a capacity case, based on the maximum theoretical airflow that can be discharged from each ventilation outlet. The capacity case scenario is conservative and represents the upper bound of potential plume rise extents from the ventilation outlets. It is noted that the ventilation outlets are not expected to operate at design capacity on a regular basis. In addition, the cumulative case was modelled, which considered the merged ventilation outlets at the Warringah Freeway for the Western Harbour Tunnel and Beaches Link program of works.

The plume rise assessment found that air exhausted from the majority of the ventilation outlets and motorway facilities would not exceed a vertical velocity of 4.3 metres per second, nor penetrate the OLS and PANS-OPS surfaces under the expected and capacity case scenarios. At the Warringah Freeway, under the capacity case when the ventilation outlet is considered in conjunction with the ventilation outlet for the Western Harbour Tunnel at the Warringah Freeway, the combined exhausted air from the ventilation outlets is predicted to penetrate the OLS at a vertical velocity of greater than 4.3 metres per second about 0.5 per cent of the time. There would be no penetration of the PANS-OPS surface or exceedance of the critical vertical velocity of 4.3 metres per second at the PANS-OPS surface under this scenario.

The design of the ventilation outlets and motorway facilities would be finalised during further design development and designed to satisfy requirements set by the Department of Infrastructure, Transport, Regional Development and Communications in relation to erected structures (such as ventilation outlets), equipment manoeuvring and lighting. A plume rise application would be prepared for approval under the *Airports Act 1996* for the Warringah Freeway ventilation outlet and motorway facilities where they may constitute a controlled activity.

23.4 Environmental management measures

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, risks to public safety and achieve the desired performance outcomes in relation to the hazards identified in this chapter. Environmental management measures relating to hazards and risks identified in this chapter are outlined in Table 23-8. Management measures relating to other potential environmental hazards resulting from the construction or operation of the project are outlined in Chapter 8 (Construction traffic and transport) to Chapter 27 (Cumulative impacts) of this environmental impact statement.

Table 23-8 Environmental management measures – hazards and risks

Ref	Phase	Impact	Environmental management measure	Location
HR1	Construction and operation	Storage of dangerous goods and hazardous substances	Dangerous goods and hazardous materials will be stored in accordance with supplier's instructions and relevant legislation, Australian Standards, and applicable guidelines and may include bulk storage tanks, chemical storage cabinets/containers or impervious bunds.	BL/GHF
HR2	Construction	Transportation of dangerous goods and hazardous substances	Dangerous goods and hazardous substances will be transported in accordance with relevant legislation and codes, including the <i>Dangerous Goods (Road and Rail Transport) Act 2008</i> , Road and Rail Transport (Dangerous Goods) (Road) Regulation 1998 and the <i>Australian Code for the Transport of Dangerous Goods by Road and Rail</i> (National Transport Commission, 2007).	BL/GHF
HR3	Construction	Bushfire	Adequate access and egress for fire fighting vehicles and staff will be provided at the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites. Access roads will have a minimum width of four metres to allow passage of fire fighting vehicles.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.
HR4	Construction	Bushfire	Adequate setbacks from bushfire prone vegetation to allow for fire fighting vehicle access will be provided for the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.

Ref	Phase	Impact	Environmental management measure	Location
HR5	Construction	Bushfire	An emergency response plan will be prepared for the construction of the project at the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites, including a bushfire risk matrix.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.
HR6	Construction	Bushfire	First response capabilities, including fire extinguishers, water carts and hoses will be assessed and provided at the Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites, where needed.	Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites.
HR7	Operation	Bushfire	Adequate access and egress for fire fighting vehicles and operation vehicles will be provided at the Beaches Link tunnel support facilities at the Wakehurst Parkway at Frenchs Forest.	Beaches Link tunnel support facilities at Wakehurst Parkway at Frenchs Forest.
HR8	Operation	Bushfire	Adequate setbacks from bushfire prone vegetation will be provided for the Beaches Link tunnel support facilities at the Wakehurst Parkway at Frenchs Forest and ventilation outlet at the Wakehurst Parkway at Killarney Heights.	Beaches Link tunnel support facilities at the Wakehurst Parkway at Frenchs Forest and ventilation outlet at the Wakehurst Parkway at Killarney Heights.

Ref	Phase	Impact	Environmental management measure	Location
HR9	Operation	Fire and life safety	The fire and safety systems and measures adopted for the project will be equivalent to or exceed the fire safety measures recommended by NFPA502 (American) (National Fire Protection Association (NFPA), 2020), Permanent International Association of Road Congresses (PIARC) (European), AS4825-2011 (Standards Australia, 2011) and AS3959-2018 (Standards Australia, 2018), and Transport for NSW standards.	BL/GHF
HR10	Operation	Transportation of dangerous goods and hazardous substances	The transport of dangerous goods and hazardous substances will be prohibited through the mainline and ramp tunnels.	BL/GHF
HR11	Operation	Incident response	The response to incidents within the motorway will be managed in accordance with the memorandum of understanding between Transport for NSW and the NSW Police Service, NSW Rural Fire Service, NSW Fire Brigade and other emergency services.	BL/GHF
HR12	Operation	Aviation risks	The ventilation outlet and motorway facilities at the Warringah Freeway will be operated in accordance with any conditions of approval from the Secretary of Department of Infrastructure, Transport, Regional Development and Communications to manage penetration of the OLS layers.	BL

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 24

Resource use and waste management

24 Resource use and waste management

This chapter describes the resources and materials, including potential sources and expected quantities that would be used to construct and operate the project, and identifies measures which address these impacts.

Construction and operation of the project would generate waste streams which would require management and disposal in accordance with relevant state policies and guidelines. This chapter also provides a description of likely waste streams, expected quantities, and waste management strategies.

The Secretary's environmental assessment requirements as they relate to resource use and waste management, and where in the environmental impact statement these have been addressed, are detailed in Table 24-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to resource use and waste management are discussed in Section 24.6.

Table 24-1 Secretary's environmental assessment requirements – resource use and waste management

Secretary's requirement	Where addressed in EIS
Spoil	
1. The Proponent must identify and assess spoil generation and reuse including: <ol style="list-style-type: none"> a. type and quantity 	Spoil balance and management is outlined in Section 24.3.3 . Estimates of the type and quantities of spoil are provided in Section 24.3.3 .
<ol style="list-style-type: none"> <li value="2">b. onsite storage (including capacity to minimise amenity impacts); 	Indicative stockpile locations, volumes and descriptions of onsite storage is provided in Section 24.3.3 .
<ol style="list-style-type: none"> <li value="3">c. reuse potential and disposal sites; 	The reuse of construction spoil is discussed in Section 24.3.3 . Waste disposal locations are discussed in Section 24.5 .
<ol style="list-style-type: none"> <li value="4">d. transport and handling options (including traffic, distance, road safety and related amenity and environmental impacts); and 	Spoil transport alternatives that were considered for the project are outlined in Section 4.5.8 of Chapter 4 (Project development and alternatives).
<ol style="list-style-type: none"> <li value="5">e. illegal dumping 	The potential for illegal dumping of spoil generated by the project is discussed in Section 24.3.3 . Management of waste disposal is outlined in Section 24.6.2 .
Waste	
1. The Proponent must assess predicted waste generated from the project during construction and operation, including:	Waste streams are classified in Section 24.3.2 and Section 24.4.2 .

Secretary's requirement	Where addressed in EIS
a. classification of the waste in accordance with the current guidelines;	
b. estimates/details of the quantity of each classification of waste to be generated during the construction of the project, including bulk earthworks and spoil balance;	Estimates of the quantities of waste are provided in Sections 24.3.2 and 24.4.2 . Spoil balance and management is outlined in Section 24.3.3 .
c. handling of waste including measures to facilitate segregation and prevent cross contamination;	Construction waste management measures are provided in Section 24.6 .
d. management of waste including estimated location and volume of stockpiles;	Indicative stockpile locations and volumes is provided in Section 24.3 .
e. waste minimisation and reuse;	The reuse of construction and operational waste is discussed in Section 24.3.1 and Section 24.4.1 .
f. lawful disposal or recycling locations for each type of waste; and	Disposal and recycling options are outlined in Section 24.3.2 and Section 24.6 .
g. contingencies for the above, including managing unexpected waste volumes.	Contingencies for managing unexpected waste are discussed in Section 24.6 .
2. The Proponent must assess potential environmental impacts from the excavation, handling, storage on site and transport of the waste particularly with relation to sediment/leachate control, noise and dust.	Potential environmental impacts associated with the handling, storage and transport of waste are discussed in Section 24.3 and Section 24.4 . Dust impacts and management are discussed in Chapter 12 (Air quality). Noise impacts and management are discussed in Chapter 10 (Construction noise and vibration). Sediment control and potential environmental impacts associated with the excavation of waste are described in Chapter 16 (Geology, soils and groundwater) and Chapter 17 (Hydrodynamics and water quality).

24.1 Legislative and policy framework

Waste management and recycling is regulated in NSW through the *Protection of the Environment Operations Act 1997*, the *Protection of the Environment Operations (Waste) Regulation 2014* (including the requirement to track certain types of waste) and the *Waste Avoidance and Resource Recovery Act 2001*.

The *Waste Avoidance and Resource Recovery Act 2001* aims to promote efficient use of resources, and avoidance and minimisation of waste through the following resource management hierarchy:

- Avoidance of unnecessary resource consumption
- Resource recovery, including reuse, reprocessing, recycling and energy recovery
- Disposal.

By minimising consumption and encouraging the efficient use of resources, the *Waste Avoidance and Resource Recovery Act 2001* aims to reduce the generation and impacts of waste.

The following guidelines inform or respond to the regulatory framework and have been applied to the assessment of the project:

- *Waste Classification Guidelines* (NSW EPA, 2014a)
- *Technical Guide: Management of Road Construction and Maintenance Wastes* (Roads and Maritime Services, 2016b)
- *Sustainable Design Guidelines*, Version 4.0 (Transport for NSW, 2017)
- *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom, 2004) and *Volume 2* (DECC, 2008).

A number of policies and strategic documents are relevant to the project's resource use and waste management. The *NSW Government Resource Efficiency Policy* (Office of Environment and Heritage (OEH), 2019) aims to drive resource efficiency by NSW Government agencies and reduce harmful air emissions from government operations. As a government agency, Transport for NSW has a responsibility under this policy to incorporate resource-efficiency considerations in all major decisions to address rising costs for energy, water, clean air and waste management.

The *NSW Waste Avoidance and Resource Recovery Strategy 2014–21* (NSW EPA, 2014b) supports the avoidance and minimisation of waste and provides a framework and targets for waste management and recycling in NSW until 2021–2022.

Transport for NSW, as a NSW Government agency, supports these targets by:

- Implementing complementary policies and programs, including sustainable procurement policies
- Incorporating resource recovery and waste reduction objectives into its operations
- Complying with relevant regulations.

The aims of these policies are incorporated into the *Environmental Sustainability Strategy 2019–2023* (Roads and Maritime Services, 2019), which outlines specific focus areas for integrating sustainability into Transport for NSW road projects and services. Under the *Environmental Sustainability Strategy 2019–2023*, resource use and waste reduction initiatives include:

- Consideration of earthworks in project design and construction, including the recovery of materials for reuse
- Recycling materials
- Reducing resource use through appropriate project design and operation.

The Department of Planning, Industry and Environment is leading the development of a 20-year waste strategy for NSW with a focus on sustainability, reliability and affordability. The *20-Year Waste Strategy Issues Paper* and complementary NSW Plastics Plan Discussion Paper *Cleaning Up Our Act: Redirecting the Future of Plastic* were released for public consultation in early 2020. The Department of Planning, Industry and Environment is currently reviewing the feedback received through the consultation process.

24.2 Assessment methodology

The assessment of resource use and waste management comprised:

- A review of the likely resources required for the construction and operation of the project, including construction materials, water and power
- A review of the likely waste streams, volumes and classifications
- Identification of opportunities for the avoidance, minimisation and reuse of waste, including targets for the beneficial reuse of solid waste, wastewater and other waste consistent with the project's sustainability framework (refer to Chapter 25 (Sustainability))
- Identification of the environmental impacts associated with resource use and the generation (and subsequent disposal) of residual waste materials
- Management strategies for waste during construction and operation, including:
 - Managing construction waste through the resource management hierarchy established under the *Waste Avoidance and Recovery Act 2001*
 - Developing procedures for the assessment, handling, stockpiling and disposal of potentially contaminated materials and wastewater, in accordance with the *Waste Classification Guidelines* (NSW EPA, 2014a).

24.3 Assessment of potential construction impacts

Potential impacts during construction of the project relate to:

- Construction resource use, including construction materials, water and electricity
- Generation and management of waste (non-spoil)
- Generation and management of spoil, including dredged and excavated materials from Middle Harbour.

24.3.1 Construction resource use

Construction materials

Given the scale of the project, substantial quantities of materials would be used for construction. Indicative quantities and the potential sources of construction materials are provided in Table 24-2. Other items such as timber, electrical materials and landscaping materials would also be required.

Table 24-2 Indicative quantities of resources required for construction

Material	Estimated quantity required	Anticipated source/origin
Asphalt	124,400 tonnes	Sydney suppliers
Sprayed bitumen	500 tonnes	Sydney suppliers
Ready-mixed concrete	322,100 cubic metres	Sydney suppliers located close to the project and on-site concrete batching plants
Precast concrete	8600 cubic metres	Sydney, NSW Central and Mid North Coast
Aggregates – gravel/sand	25,400 cubic metres	NSW South Coast and Central Coast

Material	Estimated quantity required	Anticipated source/origin
Aggregates – general fill	183,400 cubic metres	Reuse spoil from tunnelling works if timing permits, or imported fill from the Greater Sydney region
Steel	58,400 tonnes	Australia and/or overseas
Aluminium	20 tonnes	Overseas
Glass	2 tonnes	Australia and/or overseas
PVC piping	3000 tonnes	Australia and/or overseas
Concrete piping	2100 tonnes	Australia
Plastic sheeting	30 cubic metres	Australia and/or overseas
Composites – cement fibreboard	500 tonnes	Australia
Coatings and finishes	less than 1 tonne	Australia and/or overseas
Water treatment chemicals	1 tonne	Australia and/or overseas

Construction material requirements for the project are typical for a motorway project of this scale. While the resource requirements of the project do have the potential to impact resource availability within the Sydney metropolitan region over the construction period, the concurrent construction of NorthConnex, M8, M4-M5 Link and Sydney Metro City & Southwest demonstrates that the market is able to manage the concurrent construction of major infrastructure projects given sufficient opportunity to forward plan. The period between the approval of the project and the start of major construction would be sufficient to allow the market to prepare for the needs of the project in conjunction with the concurrent infrastructure projects listed in Chapter 27 (Cumulative impacts).

The design of the project has included careful consideration of the construction methodology and selection of materials and resources to ensure fit for purpose and minimise resource consumption. Consistent with the resource management hierarchy of the *Waste Avoidance and Resource Recovery Act 2001*, resource consumption would be further minimised during construction through reuse, where possible. For example, temporary work structures such as road plates and tunnel formwork would be reused, and asphalt from decommissioned pavements would be reused in temporary and new pavements, where technically feasible.

Water

Water would be required during construction activities including:

- Tunnelling activities such as dust suppression and equipment wash down
- Surface works such as during compaction of earthworks and pavement materials and for dust suppression and equipment wash down
- Concrete batching
- Site offices and ablutions
- Irrigation for landscaping.

Measures to avoid and minimise water consumption, particularly of potable water, have been included in the design and construction planning for the project. Examples of these measures include:

- Use of dust extraction and ventilation systems to control dust in tunnels during construction to minimise the use of water as a dust suppressant
- Collection, treatment and use of wastewater and rainwater at temporary construction support sites to minimise the use of potable water sources during construction.

Water for construction of the project would be sourced according to the following hierarchy, where feasible and reasonable, and where water quality and volume requirements are met:

- Stormwater harvesting (non-potable water)
- On-site construction water treatment and reuse, including groundwater sourced from infiltration into tunnelling works (non-potable water)
- Mains supply (potable water).

The average total water demand during construction is estimated to be 2645 kilolitres per day. About 1442 kilolitres per day would be sourced from mains supply (potable water) with the remainder coming from treated groundwater or harvested rainwater (non-potable water).

A summary of the indicative construction water balance is presented in Chapter 17 (Hydrodynamics and water quality). Connection to, and supply of, mains water would be confirmed during further design development, in consultation with Sydney Water.

Electricity

Electricity supply would be required at all temporary construction support sites, including high voltage supply for tunnelling support sites. Table 24-3 summarises the indicative electricity demand at temporary construction support sites where tunnelling is proposed.

Infrastructure required to connect each temporary construction support site with the electricity supply network outside the project corridor would be subject to separate design, assessment and approval. Further information on the coordination and management of electricity infrastructure delivery is provided in Appendix D (Utilities management strategy).

Measures to avoid and minimise electricity consumption have been included in the design and construction planning for the project. Examples of these measures include:

- Use of guidance systems for tunnel excavation and rock bolting to ensure efficient use of tunnelling equipment to minimise excessive electricity consumption
- Use of energy efficient site buildings and equipment at temporary construction support sites, including use of solar powered lights and signage, where feasible and reasonable
- Efficient design of electricity transmission systems to supply power as efficiently as possible.

Table 24-3 Indicative construction electricity demand for tunnel support sites

Temporary construction support site	Indicative temporary power requirement (megavolt ampere (MVA))
Cammeray Golf Course (BL1)	3
Flat Rock Drive (BL2)	7
Punch Street (BL3)	3
Balgowlah Golf Course (BL10)	3
Wakehurst Parkway east (BL13)	3

24.3.2 Construction waste generation and management (non-spoil)

This section details the solid and liquid waste, and the wastewater expected to be generated during construction of the project. Generation and management of spoil, including dredged and excavated materials, is considered in Section 24.3.3.

Solid and liquid waste

Measures to minimise the generation of waste and maximise resource recovery have been included in the design and construction planning for the project. Examples of these measures include:

- Prioritisation of pre-cast concrete structural elements to improve efficiency and minimise waste
- On-site sorting of materials like timber, steel and concrete to maximise resource reuse on site or near to the site where possible
- Chipping and mulching of cleared vegetation for reuse on site as a preference to disposal where appropriate or reusing salvaged logs for fauna connectivity structures and habitat enhancement measures.

Table 24-4 summarises indicative solid and liquid waste streams that would be generated during construction, including examples of these waste streams, indicative waste stream quantities and anticipated waste classifications.

These waste streams are typical of construction and demolition activities and can be adequately managed with the implementation of well-established environmental management measures (refer to Section 24.6). Consistent with the resource management hierarchy under the *Waste Avoidance and Resource Recovery Act 2001*, solid waste would be reused and recycled where feasible and reasonable. Construction waste would be disposed of at appropriate licenced facilities.

Table 24-4 Indicative solid and liquid waste streams generated during construction

Waste stream	Examples of waste	Indicative quantity	Likely waste classification
Demolition waste	Concrete, bricks, tiles, timber, metals, plasterboard, carpets, electrical and plumbing fittings, furnishings	12,585 cubic metres	General solid waste (non-putrescible)
Aggregates – crushed rock/concrete	Concrete	3,206,710 cubic metres	General solid waste (non-putrescible)
Hazardous waste	Asbestos, heavy metals	1000 tonnes (subject to further investigation)	Hazardous waste and/or special waste
Vegetation waste	Trees, shrubs, ground cover	Up to 12,552 tonnes ¹ (noting vegetation waste would be reused on site if possible)	General solid waste (putrescible)
General construction waste	Timber formwork, scrap metal, steel, concrete, plasterboards, packaging materials	19,600 tonnes	General solid waste (non-putrescible)
Waste from the operation and maintenance of construction vehicles and equipment	Adhesives, lubricants, waste fuels, oils, engine coolant, batteries, hoses, tyres	5 tonnes	Hazardous waste

Waste stream	Examples of waste	Indicative quantity	Likely waste classification
General waste from site offices	Putrescibles (food waste), paper, cardboard, plastics, glass, printer cartridges	960 tonnes	General solid waste (putrescible and non-putrescible)

Note 1: Vegetation waste has been assumed as 600 tonnes per hectare of vegetation removal.

Wastewater

Wastewater volumes generated during construction would vary depending on the types of construction activities being carried out and the stage of construction. The majority of wastewater generated during construction would be through groundwater infiltration in the tunnels.

The average infiltration rate across the project tunnels is expected to be less than the design standard of an average one litre per second per kilometre applied to other recent motorway tunnel projects, including NorthConnex and M4-M5 Link. Further information on groundwater infiltration and groundwater effects is provided in Chapter 16 (Geology, soils and groundwater).

Smaller volumes of wastewater would be generated by other construction activities, such as dust suppression and equipment washdown.

Opportunities for wastewater reuse would be investigated and pursued, where feasible and reasonable, and subject to meeting water reuse quality requirements. Options for wastewater reuse may include on-site reuse for construction purposes, such as dust suppression and compaction of earthworks and pavement materials.

The anticipated generation of wastewater from tunnel construction would be greater than the potential for reuse. Therefore, treatment of surplus wastewater and off-site discharge would be required. Chapter 2 (Assessment process) outlines the requirement for an environment protection licence for road construction under Chapter 3 of the *Protection of the Environment Operations Act 1997*. The wastewater collected from tunnelling activities would be tested and treated at construction wastewater treatment plants prior to reuse or discharge. Discharges from wastewater treatment plants during the construction phase would be required to meet the following discharge criteria:

- The relevant physical and chemical stressors set out in of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000)
- The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 95 per cent species protection levels
- The ANZG (2020) default guideline values for iron (in fresh and marine water) and zinc (in marine water).

Indicative wastewater treatment plant discharge volumes at the temporary construction support sites used to support tunnelling are summarised in Table 24-5. These volumes conservatively assume that all wastewater would be treated and discharged, and do not take into account the opportunities for wastewater reuse identified above. Further information on water treatment and discharge water quality, as well as the complete water balance for the project is provided in Chapter 17 (Hydrodynamics and water quality).

Table 24-5 Indicative daily average wastewater discharge volumes

Temporary construction support site	Estimated daily discharge (kilolitres)	Treated wastewater available for reuse daily (kilolitres)	Discharge point
Cammeray Golf Course (BL1)	296	127	Willoughby Creek via stormwater system
Flat Rock Drive (BL2)	711	305	Flat Rock Creek via stormwater system
Punch Street (BL3)	308	130	Flat Rock Creek via stormwater system
Balgowlah Golf Course (BL10)	428	263	Burnt Bridge Creek via stormwater system
Wakehurst Parkway east (BL13)	10	199	Drainage pit on the eastern boundary of the support site. Discharge would subsequently flow into nearby golf course dam via overland flow, for reuse by the golf course.
Surface works	0	185	N/A
Total	1754	1208	

24.3.3 Spoil generation and management

About three million cubic metres of spoil would be produced from land-based construction activities (terrestrial spoil) during construction, made up of:

- Soil and rock from construction of the project tunnels underground
- Soil and rock from bulk excavation works on the surface.

The majority of land-based spoil generated by the project would be crushed sandstone from tunnelling. This material is generally considered a desirable engineering fill and is typically reused in development sites and major earthworks projects across Greater Sydney.

In addition, marine construction works for the project within Middle Harbour would produce around 163,000 cubic metres of dredged and excavated materials, made up of:

- Soft soils, sediment and rock excavated from the two temporary cofferdams in Middle Harbour
- Soft soils, sediment and rock dredged for the installation of the immersed tube tunnels.

The management of spoil and dredged and excavated materials during construction of the project would depend on its composition, the location from which it was removed (ie land-based or marine-based construction), and whether it is considered to be suitable or unsuitable for reuse. The approach to management of land-based spoil and dredged and excavated materials is shown in Figure 24-1.

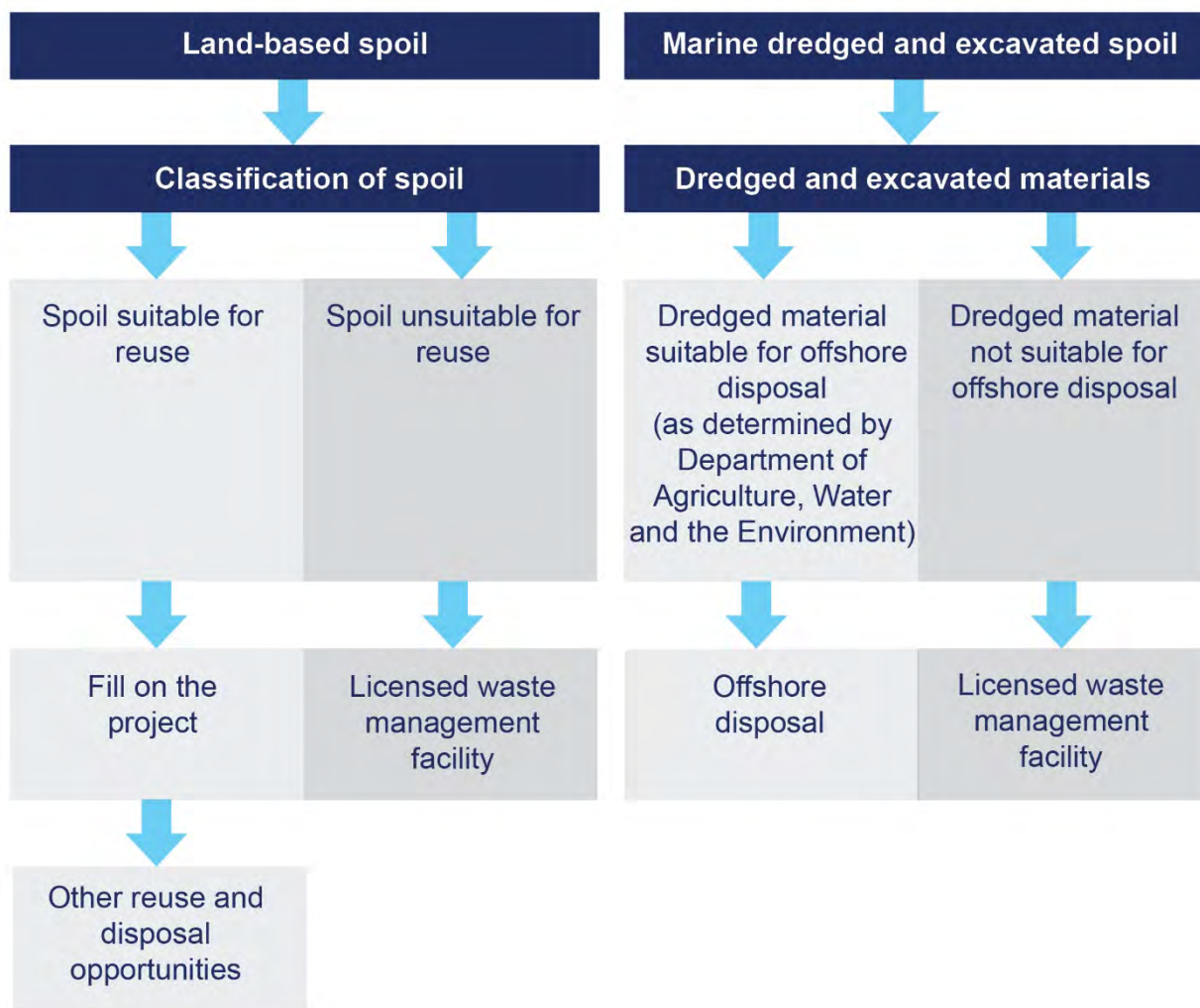


Figure 24-1 Spoil management approach

Spoil from land-based construction activities

Land-based spoil generation

The project's land-based construction activities would generate about three million cubic metres of spoil.

The temporary construction support sites supporting tunnelling operations would be the main generators of spoil during construction. Additional, smaller quantities of spoil would be generated at other construction areas along the project alignment, associated with surface road works. The indicative volume of surplus land-based spoil to be extracted and managed through each of the temporary construction support sites is summarised in Table 24-6.

Table 24-6 Indicative land-based spoil generation

Construction site	Spoil volume (cubic metres)	Spoil composition
Cammeray Golf Course (BL1)	222,000	Sandstone
Flat Rock Drive (BL2)	929,880	Sandstone
Punch Street (BL3)	450,860	Sandstone
Balgowlah Golf Course (BL10)	673,940	Sandstone and soil
Wakehurst Parkway surface works	157,120	Sandstone and soil

Construction site	Spoil volume (cubic metres)	Spoil composition
Wakehurst Parkway east (BL13)	564,850	Sandstone
Gore Hill Freeway surface works	32,080	Sandstone and soil
Total land-based spoil generation	3,030,730	-

Spoil from tunnelling works would be transported from the tunnel face to the surface using dump trucks. Where required, tunnel spoil stockpiles would be largely contained within acoustic sheds or below ground within the tunnels being excavated. This would also minimise the potential for impacts from runoff (including from contaminated materials) and sedimentation associated with stockpiling. Storage of stockpiles within the acoustic sheds would also minimise amenity impacts to the surrounding area.

Spoil would be classified prior to leaving the site in accordance with NSW and Australian standards and guidelines. It is anticipated that the majority of this material would be used at development, construction or remediation sites across Greater Sydney.

Other earthworks, such as those required for surface road works, cut and cover and trough structures may require the stockpiling of material on site if the material cannot be loaded directly into trucks. These stockpiles would be located outside of acoustic sheds; however, appropriate measures, including bunding, would be in place to avoid potential impacts associated with runoff, sedimentation and leachate. Environmental management measures provided for construction noise and vibration (Chapter 10), air quality (Chapter 12) and urban design and visual amenity (Chapter 22) would minimise potential amenity impacts from the proposed stockpiles. Several of the temporary construction support sites that would require stockpiling outside of acoustic sheds are large sites that are located away from residential receivers or within industrial areas which would further minimise potential amenity impacts. Construction stockpiles would also allow for contingency management of unexpected waste materials, including contaminated materials. The indicative location and volume of spoil stockpiles located outside of acoustic sheds is provided in Table 24-7.

Potential impacts from runoff and sedimentation would be further minimised through the implementation of the environmental management measures described in Chapter 17 (Hydrodynamics and water quality).

Potential impacts related to leachate (ie contaminated liquid that drains from a landfill or stockpile) are considered to be unlikely during construction as the project does not involve the excavation or disturbance of known historical landfill areas with the exception of the Flat Rock Drive construction support site (BL2). In this instance, it is anticipated that excavated materials would generally be building type waste and non-putrescible waste. Further information is provided in Chapter 16 (Geology, soils and groundwater).

Table 24-7 Indicative stockpile locations and volumes – outside of acoustic sheds

Location	Indicative stockpile volume
Cammeray Golf Course (BL1)	4500 cubic metres
Flat Rock Drive (BL2)	500 cubic metres
Dickson Avenue (BL4)	2500 cubic metres
Balgowlah Golf Course (BL10)	1000 cubic metres per stockpile (up to five stockpiles, totalling 5000 cubic metres) 3300 cubic metre stockpiles for concrete batch plants
Wakehurst Parkway south (BL12)	500 cubic metres
Wakehurst Parkway upgrade	Multiple stockpiles of varying volumes up to 2500 cubic metres

The design of the project and preferred construction methodology has taken into consideration the waste hierarchy by aiming to reduce the volume of excess spoil generated, as far as practical. Where possible, the project would maximise reuse of spoil generated during construction before alternative off-site spoil disposal options are pursued.

The geochemistry of the spoil material as well as its consistency and quality would determine the reuse options. The spoil produced by the project would have the following potential reuse opportunities:

- Granular sandstone fill is likely to be suitable for use as engineering fill
- Excavated clay and clayey sand material is likely to be suitable for use as general fill following moisture conditioning
- Excavated weathered shale and sandstone could be suitable for use as engineering fill following moisture conditioning to reduce the shrink-swell capacity of the material
- Medium strength or better quality shale is likely to be suitable for use as engineering fill
- Medium to high strength sandstone may be suitable for use as engineering fill
- Wet clay and wet shale spoil is unlikely to be suitable for reuse on site without substantial moisture conditioning.

Where spoil cannot be reused for the project, opportunities to reuse this material on other projects (preferably within the Sydney region to reduce transport distances) would be identified.

The following sites are potential options for spoil reuse/disposal:

- Western Sydney Airport (about 60 kilometres from the project)
- Moorebank Intermodal Terminal Precinct (about 40 kilometres from the project)
- Kurnell Landfill (about 40 kilometres from the project)
- Penrith Lakes Scheme (about 60 kilometres from the project).

These sites have a need for spoil or fill material and represent viable reuse locations. Other reuse or disposal sites may be used depending on need at the time the spoil is generated. The final destination(s) for excess spoil from construction of the project would be planned prior to construction commencing.

With the consideration of the above commitment to maximising reuse of spoil generated during construction, the potential options for off-site spoil reuse/disposal, and the environmental management measures included in Section 24.6, the potential risk for illegal dumping of spoil generated by the project is considered negligible.

Disposal of contaminated material

There is potential to discover contaminated material during excavation works for the project. A Stage 1 contamination assessment has been carried out to determine the potential for encountering contaminated material during construction (refer to Chapter 16 (Geology, soils and groundwater)).

The contamination assessment identified twelve locations within or adjacent to the construction footprint of the project that are considered to be potential areas of interest. These locations and types of potential contaminated material are provided in Chapter 16 (Geology, soils and groundwater). Further investigations of these sites including a Stage 2 contamination assessment are required to quantify the exposure risk. These investigations would be carried out prior to construction activities so that contamination (if present) can be adequately planned for and managed.

Management of contaminated spoil would be in accordance with the measures outlined in Chapter 16 (Geology, groundwater and soils). Any contaminated material disturbed during construction would be separated from uncontaminated material on site to prevent cross contamination. Contaminated material would be encapsulated on site where appropriate, and in

accordance with relevant regulatory requirements. Any material that is not suitable for encapsulation would be loaded into sealed and covered trucks for disposal at a suitably licensed facility. Further site investigations during the further design development and construction planning phases would inform contamination management including determining where encapsulation is appropriate.

Dredged and excavated materials from harbour construction activities

About 163,000 cubic metres of soft soil, sediments and rock would need to be removed from Middle Harbour during the dredging activities required for the installation of the immersed tube tunnels and associated transition structures. The indicative volume and composition of dredged and excavated materials to be removed as part of marine construction activities is included in Table 24-8.

Table 24-8 Indicative dredged and excavated material volumes

Construction area	Dredged and excavated material volume (cubic metres)	Indicative composition of dredged and excavated materials
Middle Harbour south cofferdam (BL7)	5000	Soft soils and sediment suitable for offshore disposal under Australian Government permit
Middle Harbour north cofferdam (BL8)	30,000	Sandstone suitable for offshore disposal under Australian Government permit
Middle Harbour immersed tube tunnel construction	58,000	Soft soils and sediment suitable for offshore disposal under Commonwealth permit
	60,000	Sandstone suitable for offshore disposal under Australian Government permit
	10,000	Soft soils and sediment not suitable for offshore disposal
Total material	163,000	

Dredged and excavated materials suitable for offshore disposal

Transport for NSW has submitted an application to the Australian Government Department of Agriculture, Water and Environment for an offshore disposal permit relating to sediments dredged and excavated from Middle Harbour. Dredged and excavated materials suitable for offshore disposal would be transported from Middle Harbour on split hopper barges and disposed of at a designated offshore disposal site (in accordance with legislative requirements). The appropriateness of offshore disposal would be assessed in accordance with the Australian Government *National Assessment Guidelines for Dredging* (NAGD) (Department of Environment, Water, Heritage and the Arts, 2009). Offshore disposal would only be appropriate for material that meets the requirements outlined in the NAGD. Offshore disposal would reduce the number of heavy vehicle movements required to transport dredged and excavated materials. As detailed in Chapter 2 (Assessment process), assessment for offshore disposal of dredged and excavated materials is subject to a separate assessment process by the Australian Government Department of Agriculture, Water and the Environment.

The potential impacts to marine water quality from the transport, treatment and/or temporary storage of dredged and excavated materials is assessed in Chapter 17 (Hydrodynamics and water quality). The potential impact of shipping movements is discussed further in Chapter 8 (Construction traffic and transport).

Dredged and excavated materials unsuitable for offshore disposal

Some soft soils and sediments in Middle Harbour contain high concentrations of metallic and non-metallic contaminants (refer to Chapter 16 (Geology, soils and groundwater)). Most of the harbour's contamination results from a combination of historical inputs that remain in the sediments and other ongoing sources of input such as stormwater.

Of the 163,000 cubic metres of material requiring removal from Middle Harbour, it is expected that about 10,000 cubic metres from the top 0.5 metre to one metre of the bed of the harbour may not be suitable for offshore disposal. The nature of existing contamination within Middle Harbour is described in more detail in Chapter 16 (Geology, soils and groundwater).

Dredged and excavated materials not suitable for offshore disposal would be loaded onto hopper barges and transferred to a suitable onshore facility for treatment (if required) and disposal.

Dredged and excavated materials would be subject to waste classification under the *Waste Classification Guidelines 2014* (NSW EPA, 2014a) and would be treated to make the material spadable (a consistency which allows the material to be spaded or shovelled). During this process, additives such as lime or absorbent polymers would be mixed into the material to assist in mitigating potential odour and to neutralise acid sulfate soils. This process is widely used on marine construction projects and has been applied on recent projects in Sydney Harbour, including Garden Island dredging works completed in 2010 and 2019.

Once treated, materials would be loaded into sealed and covered trucks for transport to a suitably licensed facility.

24.4 Assessment of potential operational impacts

Potential impacts during operation of the project relate to:

- Operational resource use, including operational materials, water and electricity
- Generation and management of waste.

24.4.1 Operational resource use

Operational materials

Materials used for the operation of the project would be limited to those required for ongoing maintenance activities, and the operation of the motorway control centre and tunnel support facilities. As outlined in Chapter 5 (Project description), ongoing maintenance activities are not included as part of the project and would be considered separately at the relevant time in the future.

Water

During operation of the project, water would be required for:

- Testing and operation of the tunnel deluge system, which forms part of the fire and life safety system
- Tunnel cleaning systems
- Motorway control centre ablutions
- Landscape irrigation.

Measures to avoid and minimise water use, particularly of potable water, have been included in the project design. An example of these measures includes the reuse of groundwater entering the project tunnels where possible to satisfy the project's operational water requirements and reduce the demand for potable water.

Water for operation of the project would be sourced according to the following hierarchy, where feasible and reasonable, and where water quality and volume requirements are met:

- Groundwater which has been treated after infiltrating into tunnels (non-potable water)
- Rainwater harvesting (non-potable water)
- Mains supply (potable water).

Indicative volumes and potential sources of water for each operational activity are provided in Table 24-9. Connection to and supply of mains water would be confirmed during further design development, in consultation with Sydney Water.

Table 24-9 Indicative operational water requirements

Activity	Total water demand
Washdown	730 kilolitres/year
Deluge testing	2920 kilolitres/year

Electricity

An operational electricity supply would be required for the mainline and ramp tunnels (including associated mechanical and electrical equipment), traffic control facilities (including the motorway control centre, tunnel support facilities and electronic signage) and surface street lighting. As described in Chapter 5 (Project description), the project includes underground substations at regular intervals within the tunnel and aboveground substations at the Beaches Link motorway facilities.

The project would likely be connected to the Warringah sub-transmission substation. Initial discussions with Ausgrid indicate that this substation would have sufficient capacity to supply the project without negative impacts on the local power supply.

Measures to minimise energy consumption and maximise energy efficiency have been included in the project design. Examples of these measures include:

- Use of low heat emission LED lighting to reduce operational energy requirements
- Efficient and effective longitudinal ventilation system design with outlets located in close proximity to tunnel portals, taking advantage of the movement of vehicles within tunnels to reduce fan usage and reducing energy needed to move exhaust to outlet locations
- Opportunities to install solar panels at the tunnel portals and on tunnel support and traffic control facility buildings to supplement non-renewable power sources, where feasible and reasonable.

Opportunities to further minimise energy consumption and maximise energy efficiency would be considered during further design development, where feasible and reasonable.

The anticipated operational electricity consumption of the project would be about 28 MVA.

24.4.2 Operational waste generation

This section details the solid and liquid waste, and the wastewater expected to be generated during operation of the project.

Solid and liquid waste

The types and volumes of waste generated from the operation of the motorway would depend on the nature of the activity but would predominantly consist of minor volumes of general office waste (paper, plastics, food waste).

The volumes and types of waste would be typical of motorway operations and could be accommodated by existing metropolitan licenced facilities. With the implementation of standard waste management practices, the overall impact of operational waste streams would be minimal.

Maintenance and repair activities would be subject to separate assessment processes, which would include the assessment of waste impacts associated with these activities.

Wastewater

The project tunnels would include drainage infrastructure to collect groundwater, stormwater, maintenance wastewater, fire deluge and other potential water sources. The tunnel drainage streams would receive water containing a variety of potential pollutants (such as fuel, oil grease, and fire suppressants) requiring different treatment before discharge.

Tunnel wastewater (including collected groundwater) would be pumped to an operational wastewater treatment facility at the Gore Hill Freeway (refer to Chapter 5 (Project description)). Volumes of tunnel wastewater to be pumped and treated would be minimised through the installation of tunnel linings which would minimise the ingress of groundwater. On average, the project tunnels would generate about 551 megalitres per year of treated groundwater in the first year of operation, falling to about 436 megalitres per year after 100 years of operation. Tunnel water would be treated to comply with (ANZECC/ARMCANZ, 2000), ANZG (2018) and ANZG (2020) guidelines (refer to Section 17.1.3), and spill controls and water quality monitoring would be implemented to manage operational impacts on ambient water quality within the receiving waterways.

Following treatment, discharges would enter into the local stormwater network. Further information is provided in Chapter 17 (Hydrodynamics and water quality) including potential impacts associated with operational stormwater runoff and water discharge.

24.5 Waste disposal locations

There are a number of options for recycling and disposal of construction and operational waste generated by the project. A large number of waste facilities in Greater Sydney are licensed to accept general solid waste (putrescible) and general solid waste (non-putrescible). Specific facilities and collection contractors for the disposal of putrescible and non-putrescible general solid waste would be selected during the later stages of the project and documented in the construction waste management plan.

Recyclables generated during construction and operation of the project would be collected by an authorised contractor for off-site recycling. There are a number of resource recovery facilities in Sydney. Recycling facilities for the project would be determined by the contractor engaged to collect the material.

Special and hazardous wastes would be disposed of at appropriately licensed waste management facilities to be selected during the later stages of the project and documented in the construction waste management plan.

24.6 Environmental management measures

24.6.1 Contingency management of waste

Contingency measures would be implemented to manage unexpected waste volumes and types of waste materials generated from the construction of the project. Suitable areas would be identified, where feasible, to allow for contingency management of unexpected waste materials, including contaminated materials. These areas would be hardstand or lined areas that are appropriately stabilised and bunded, with sufficient area for stockpile storage and segregation.

As detailed in Chapter 16 (Geology, soils and groundwater), in the event of discovery of previously unidentified contaminated material, all relevant work would cease in the vicinity of the discovery and the unidentified contaminated material would be managed in accordance with an unexpected contaminated lands discovery procedure, as outlined in the *Guideline for the Management of Contamination* (Roads and Maritime Services, 2013a).

The environmental management measures outlined in Table 24-10 would be consistently implemented in the event of unexpected waste volumes and materials generated from the construction of the project, along with adherence to all waste principles and relevant legislation and regulations.

24.6.2 Management of waste

The project design has taken into account the principles of the resource management hierarchy as defined in the *Waste Avoidance and Resource Recovery Act 2001* and as described in Section 24.1. Where feasible and reasonable, resources would be managed according to the following hierarchy:

- Avoidance of unnecessary resource consumption through design, efficient construction methodologies and management
- Resource recovery, including reuse, reprocessing, recycling and energy recovery within the project
- Resource recovery, including reuse, reprocessing, recycling and energy recovery outside the project
- Where resource recovery is not feasible or reasonable, disposal would be the last resort.

As described in Section 28.5, the construction environmental management plan would outline the management of waste and resources during construction. Waste and resource management would include waste monitoring, reporting and compliance tracking of construction waste generated by the project.

Measures to avoid, minimise or manage resource consumption and waste generation as a result of the project are detailed in Table 24-10. Environmental management measures relating to contamination, including acid sulfate soils, are provided in Chapter 16 (Geology, soils and groundwater).

Table 24-10 Environmental management measures - resource use and waste management

Ref	Phase	Impact	Environmental management measure	Location
WM1	Construction	Resource use	Construction materials will be sourced in accordance with the project's Sustainability Framework and with a preference for Australian materials and prefabricated products with low embodied energy, where feasible and reasonable.	BL/GHF
WM2	Construction	Resource management	The resource management hierarchy principles established under the <i>Waste Avoidance and Recovery Act 2001</i> of avoid/ reduce/ reuse/recycle/dispose will be applied.	BL/GHF
WM3	Construction	Waste generation and disposal	Any surplus material requiring offsite disposal to land, including marine sediments unsuitable for offshore disposal, will be classified in accordance with <i>Waste Classification Guidelines</i> (NSW EPA, 2014).	BL/GHF
WM4	Construction	Storage and transport of waste	Wastes will be appropriately transported, stored and handled according to their waste classification and in a manner that prevents pollution of the surrounding environment.	BL/GHF
WM5	Construction	Waste generation and disposal	Opportunities for terrestrial spoil reuse within the project corridor, so as to minimise the quantity of material disposed to land will be investigated and implemented where feasible and reasonable.	BL/GHF
WM6	Construction	Wastewater generation and disposal	Opportunities for wastewater reuse and recycling, including use of stormwater from sediment basins and recirculating water during tunnel excavation to use for dust suppression or off-site reuse, will be investigated and implemented where feasible and reasonable.	BL/GHF
WM7	Construction	Management of mulch	Mulch stockpiles and the potential generation of tannin leachates will be managed through the implementation of <i>Environmental Direction for the Management of Tannins from Vegetation Mulch</i> (Roads and Maritime Services, 2012).	BL/GHF
WM8	Construction	Reuse of vegetation waste	Where reasonable and feasible, salvaged logs from the clearing process will be reused on site and/or reused as part of the fauna	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			connectivity structures with consideration of the <i>Guide 5: Re-use of woody debris and bushrock of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects</i> (RTA, 2011).	
WM9	Construction	Waste disposal	<p>Further investigations will be carried out at the Flat Rock Drive (BL2), Balgowlah Golf Course (BL10) construction support sites and surface works and construction support site locations along the Wakehurst Parkway (BL12, BL13 and BL14) to determine the feasibility of encapsulation of contaminated materials on site.</p> <p>Where contaminated soils and other materials are to be encapsulated on-site, encapsulation will be designed in accordance with the requirements detailed in the <i>Guidelines for the Assessment of On-site Containment of Contaminated Soil</i> (ANZECC, 1999).</p>	Flat Rock Drive (BL2), Balgowlah Golf Course (BL10), Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14) construction support sites
WM10	Operation	Resource use and waste generation	The project will be operated in accordance with the relevant aims of the project's Sustainability Framework to optimise resource efficiency and waste management.	BL/GHF
WM11	Operation	Waste generation and disposal	Waste will be managed and disposed of in accordance with relevant applicable legislation, policies and guidelines, including the <i>Waste Avoidance and Resource Recovery Act 2001</i> and the <i>NSW Waste Avoidance and Resource Recovery Strategy 2014–21</i> (NSW EPA, 2014b).	BL/GHF
WM12	Operation	Water use and discharge	Opportunities to reuse treated groundwater during project operation will be considered where feasible and reasonable.	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 25

Sustainability

25 Sustainability

This chapter describes the overall approach to sustainability through design, construction and operation of the project, and identifies management measures relating to sustainability. A sustainability framework has been prepared for the project (refer to Section 25.2).

The Secretary’s environmental assessment requirements as they relate to sustainability, and where in the environmental impact statement these have been addressed, are detailed in Table 25-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to sustainability are discussed in Section 25.4.

Table 25-1 Secretary’s environmental assessment requirements – sustainability

Secretary’s requirement	Where addressed in EIS
Sustainability	
1. The Proponent must assess the sustainability of the project in accordance with the Infrastructure Sustainability Council of Australia (ISCA) Infrastructure Sustainability Rating Tool and recommend an appropriate target rating for the project.	The assessment of the sustainability of the project in accordance with the ISCA <i>Infrastructure Sustainability Rating Tool</i> is discussed in Section 25.2 . A Sustainability Management Plan would be developed during further design development. The Sustainability Management Plan would detail measures to meet the sustainability objectives and targets.
2. The Proponent must assess the project against the current guidelines including targets and strategies to improve Government efficiency in use of water, energy and transport.	Discussion of the sustainability framework and relevant legislation, policies and guidelines is provided in Table 25-2 . The sustainable use of water and energy resources is discussed in Chapter 24 (Resource use and waste management).

25.1 Overview

Sustainable development refers to “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987).

The Infrastructure Sustainability Council of Australia provides a definition specific to sustainable infrastructure development, being that which is “designed, constructed and operated to optimise environmental, social and economic outcomes over the long term” (Infrastructure Sustainability Council of Australia, 2016c).

This chapter describes how sustainability principles have been applied to the design, construction and operation of the project including:

- The sustainability framework that has been developed for the project, including the application of the Infrastructure Sustainability Council of Australia’s Infrastructure Sustainability rating scheme to the project

- Legislation and policies relevant to the project
- Application of the principles of ecologically sustainable development to the project.

25.2 Beaches Link and Gore Hill Freeway Connection sustainability framework

A sustainability framework has been developed for the project. The sustainability framework has been prepared to ensure that sustainability is embedded in project planning, design, construction and operation. The sustainability framework provides the overarching vision, objectives, targets and implementation approaches for the project.

Figure 25-1 shows the key elements of the sustainability framework. Each element is described in detail in the following sections.

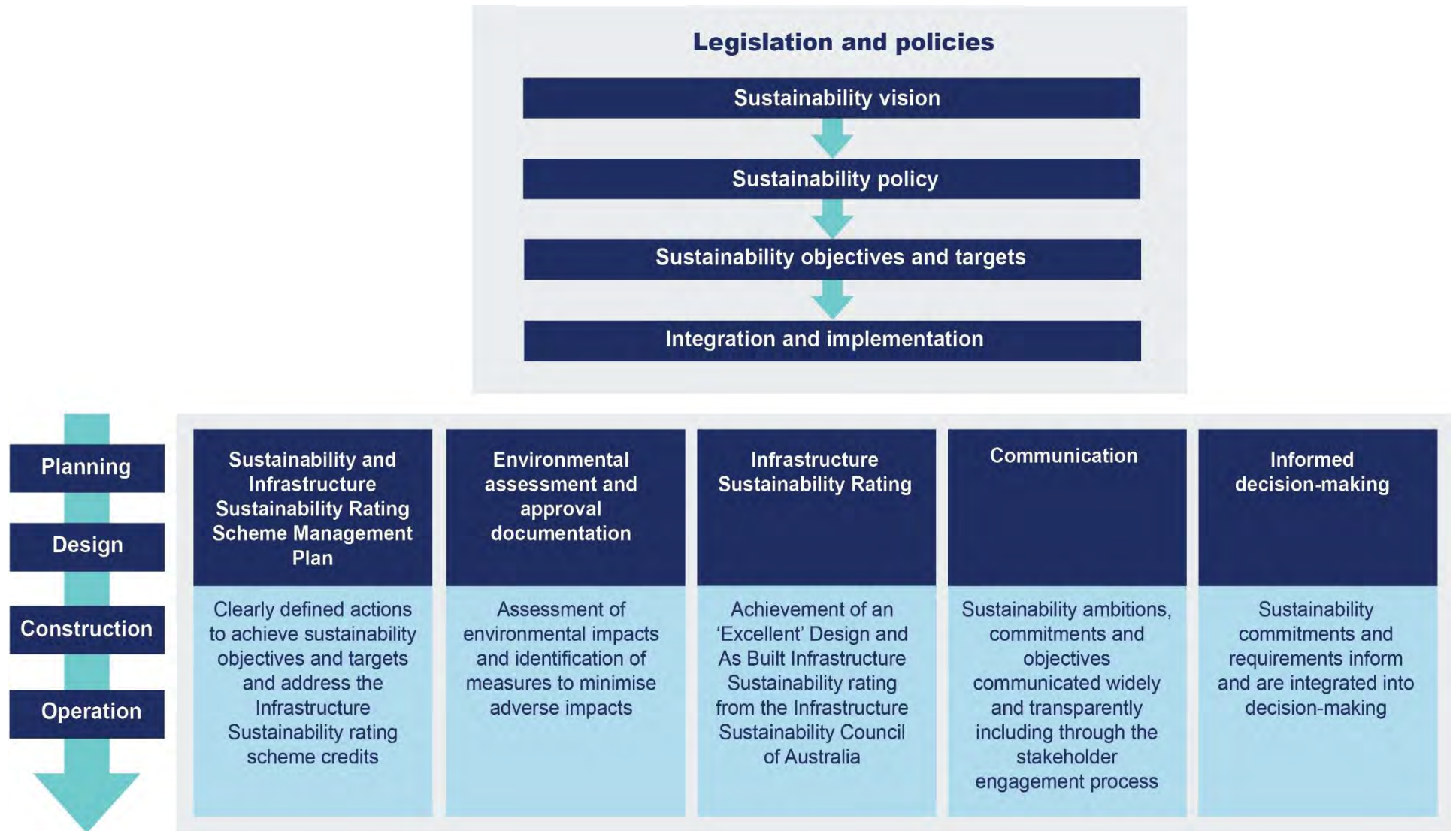


Figure 25-1 Beaches Link and Gore Hill Freeway Connection sustainability framework

25.2.1 Legislative and policy framework

The sustainability framework is underpinned by sustainability principles outlined in applicable legislation, policies and guidelines. The NSW Government, Transport for NSW, and the Infrastructure Sustainability Council of Australia each set sustainability principles, objectives and targets within their respective policies.

Key legislation, policies and guidelines that have directed the consideration and integration of sustainability in the project design and assessment are summarised in Table 25-2. Other relevant legislation, policies and guidelines that include sustainability outcomes relevant to the project are outlined in Table 25-3. Table 25-3 shows the recurring sustainability themes found in these documents and where specific principles, objectives and targets are set.

Table 25-2 Key legislation, policies and guidelines

Legislation, policy or guideline	Overview
<i>Environmental Planning and Assessment Act 1979</i>	The <i>Environmental Planning and Assessment Act 1979</i> facilitates ecologically sustainable development in NSW by integrating relevant economic, environmental and social considerations in decision making about environmental planning and assessment. As an object of the Act, ecologically sustainable development must be incorporated in the planning of the project (refer to Section 25.3).
<i>Transport Environment and Sustainability Policy</i> (Transport for NSW, 2020c)	The <i>Transport Environment and Sustainability Policy</i> outlines the commitment of Transport for NSW and key transport agencies to deliver transport projects and services in a manner that balances economic, environmental and social issues.
<i>Environmental Sustainability Strategy 2019-23</i> (Roads and Maritime Services, 2019)	The <i>Environmental Sustainability Strategy 2019-2023</i> (Roads and Maritime Services, 2019) aligns with the <i>Transport Environment and Sustainability Policy</i> and outlines specific focus areas for integrating sustainability into Transport for NSW road projects and services.
<i>Infrastructure Sustainability Rating Tool</i> version 1.2 (Infrastructure Sustainability Council of Australia, 2016a)	The Secretary's environmental assessment requirements for the project require the assessment of the project in accordance with the <i>Infrastructure Sustainability Rating Tool</i> and recommendation of an appropriate target rating. The Infrastructure Sustainability rating scheme was developed by the Infrastructure Sustainability Council of Australia as a comprehensive process for evaluating sustainability across the design, construction and operation of infrastructure.
<i>Sustainable Design Guidelines</i> version 4.0 (Transport for NSW, 2017)	The Transport for NSW <i>Sustainable Design Guidelines version 4.0</i> are aimed at embedding sustainability initiatives across seven key themes, into the planning, design, construction, operations and maintenance of infrastructure projects. The Secretary's environmental assessment requirements for the project reference the <i>Sustainable Design Guidelines version 4.0</i> as the current guidelines to be considered as part of the preparation of this environmental impact statement.

Table 25-3 Relevant sustainability legislation, policies and guidelines

Sustainability theme	NSW Government legislation, policies and guidelines								Transport for NSW's policies and guidelines						Infrastructure Sustainability Council of Australia	
	<i>Environmental Planning and Assessment Act 1979</i>	Future Transport 2056 plan	NSW Sustainable Design Guidelines v4.0	NSW Government Resource Efficiency Policy	NSW Waste avoidance and Resource recovery Strategy	NSW Government Training Management Guidelines	Aboriginal Participation in Consultation Guidelines	Aboriginal Participation in Construction Policy	Transport Social Procurement Policy	Transport Environment and Sustainability Policy	Sydney's Cycling Future, Cycling for everyday transport	Sydney's Walking Future, Connecting people and places	Roads and Maritime Services Sustainability Strategy	Beyond the Pavement		
<ul style="list-style-type: none"> Principle Objective Target 																
Management and participation																
Energy, carbon and materials																
Resources and waste																
Climate change																
Communities and liveability																
Water																
Pollution and emissions																
Ecology																
Employment and opportunities																

25.2.2 Sustainability vision and policy

The sustainability framework establishes the sustainability vision and policy for the project (refer to Figure 25-2). The sustainability vision and policy set the overall direction for implementing sustainability initiatives during the delivery of the project. The vision and policy reflect and align with NSW Government legislation and policies and Transport for NSW's strategic sustainability policy (refer to Section 25.2.1). The policy acknowledges the need to deliver services and infrastructure that benefit the community and minimise negative environmental, social and economic impacts while maximising positive outcomes. The vision and policy may continue to be refined as the project progresses.

Vision

The Beaches Link and Gore Hill Freeway Connection project is committed to improving quality of life for current and future generations by maximising social, economic and environmental value. The project will achieve excellence in sustainability, and embed sustainability thinking across all stages, moving industry forward by setting the bar higher for both the process and delivery of sustainability.

Policy

The Beaches Link and Gore Hill Freeway Connection project is committed to:

- Aligning with the *Transport Environment and Sustainability Policy* (Transport for NSW, 2020)
- Aligning with, supporting and, wherever feasible, exceeding the ambitions of the *Environmental Sustainability Strategy 2019-2023* (Roads and Maritime, 2019)
- Optimising sustainability outcomes, transport service quality, and cost effectiveness
- Being environmentally responsible by avoiding pollution, enhancing the natural environment and maintaining or reducing the project ecological footprint
- Using resources (energy, water and materials) efficiently and reducing waste
- Providing a safe and accessible motorway integrated into the urban environment and transport system
- Raising awareness of environmental issues and sharing sustainability knowledge with the community and broader industry
- Creating desirable places, promoting liveability and cultural heritage, and optimising both community and economic benefit

To deliver these commitments, the Beaches Link and Gore Hill Freeway Connection project will:

- Establish robust sustainability objectives and targets
- Ensure balanced consideration of environmental, social and economic costs and benefits during decision making
- Encourage innovation and setting high environmental and sustainability standards
- Establish positive relationships with community and stakeholders to maximise opportunities to add value to local communities
- Develop and maintain an environmental management framework to embed best practice pollution management and sustainable outcomes during construction
- Apply effective assurance processes to monitor performance against the project environment and sustainability objectives and identify appropriate reward or corrective action, as required
- Integrate environment and sustainability-specific processes into the procurement of delivery activities and suppliers
- Hold employees and contractors accountable for proactively meeting their environmental and sustainability responsibilities
- Provide local training, education, apprenticeships and employment opportunities

The project will comply with environmental legislation and regulations, and proactively support initiatives that go beyond compliance requirements. The project will also exhibit leadership in environmental practices and sustainability, supporting innovation, creating beneficial social and environmental impacts, and creating a positive economic legacy.

Figure 25-2 Beaches Link and Gore Hill Freeway Connection sustainability vision and policy

25.2.3 Sustainability objectives and targets

To achieve the sustainability vision for the project and to contribute to the desired outcomes of the relevant NSW Government and Transport for NSW policies and guidelines (refer to Section 25.2.1) the project would establish robust sustainability objectives and targets. The process being followed to develop the objectives and targets is shown in Figure 25-3.

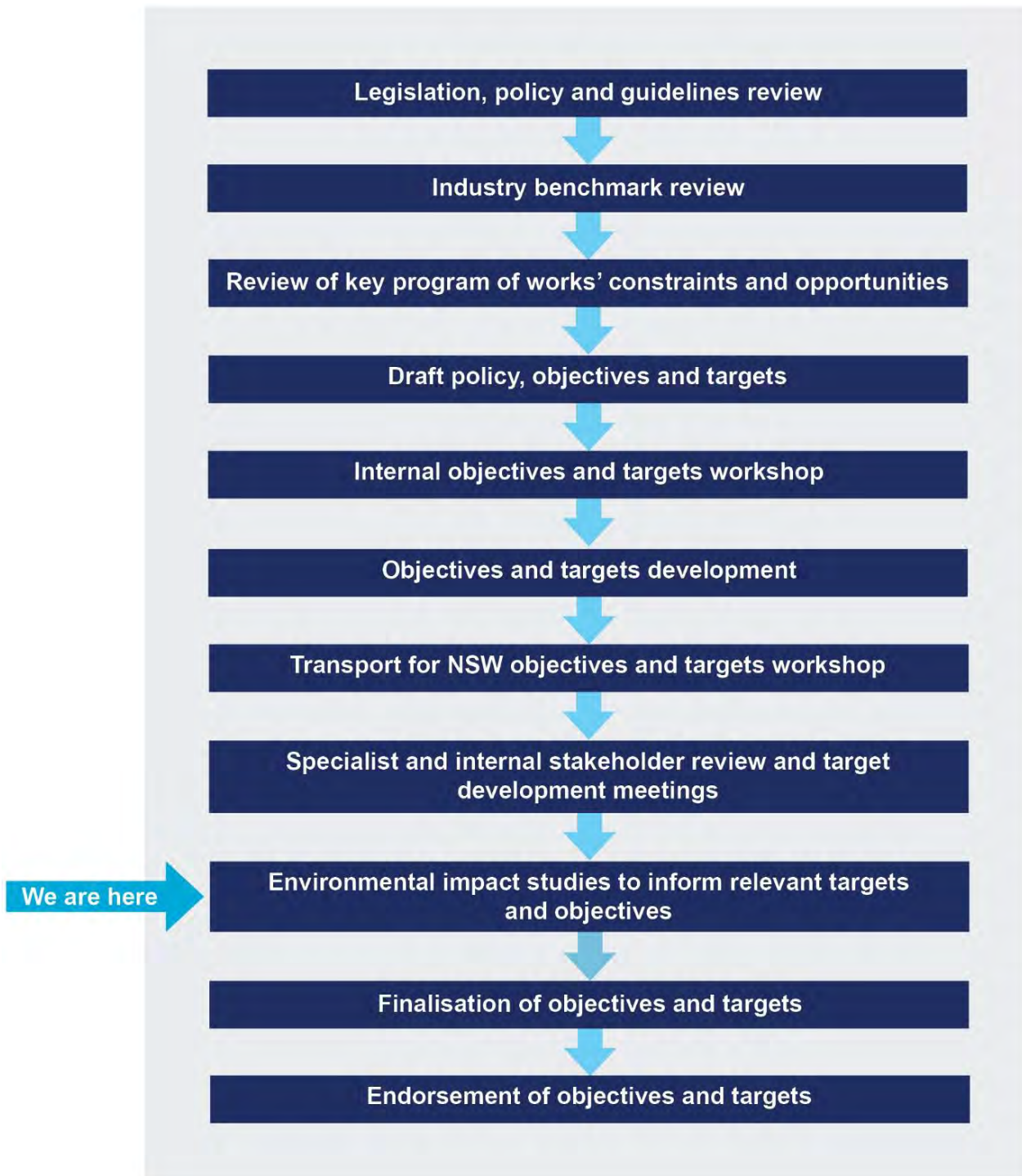


Figure 25-3 Beaches Link and Gore Hill Freeway Connection sustainability objectives and targets development process

The outcomes from this environmental impact statement, including any relevant conditions that may be applied to the project by the Minister for Planning and Public Spaces, would be used to finalise the sustainability objectives and targets for the project. Indicative objectives and targets (subject to later refinement to allow for incorporation of any relevant approval conditions) are outlined in Table 25-4.

Table 25-4 Indicative sustainability objectives and target themes

Objective	Target themes
Maximise sustainability knowledge and awareness	<ul style="list-style-type: none"> • Sustainability commitments (including procurement commitments) • Sharing of sustainability outcomes with the community/stakeholders and industry • Sustainability awareness training.
Minimise energy use and greenhouse gas emissions	<ul style="list-style-type: none"> • Embodied energy within construction materials • Construction greenhouse gas emissions • Operational greenhouse gas emissions • Energy efficient lighting.
Optimise resource efficiency and waste management	<ul style="list-style-type: none"> • Resource recovery of virgin excavated natural material • Reuse of topsoil • Diversion of office waste from landfill • Resource recovery of concrete and reclaimed asphalt • Encapsulation of contaminated material on site where appropriate • Cementitious substitution materials • Recycled content in road base • Recycling of other waste and wastewater • Recycled paper use • Avoidance of single use kitchen items.
Maximise resilience to climate change impacts	<ul style="list-style-type: none"> • Climate change risk mitigation and/or adaptation measures.
Enhance liveability of local communities	<ul style="list-style-type: none"> • Heritage values • Community benefit initiatives • Public open space • Urban design.
Maximise employment and training opportunities for young people, Aboriginal and Torres Strait Islanders, disadvantaged groups, long term unemployed and people who live along the project's alignment	<ul style="list-style-type: none"> • Apprenticeships • Training and development • Workforce participation.

Objective	Target themes
Efficiently manage water	<ul style="list-style-type: none"> • Water use during construction • Water use during operation • Use of non-potable water.
Minimise pollution generated by the project	<ul style="list-style-type: none"> • Air quality • Noise and vibration • Water quality • Reporting and tracking of environmental incidents.
Minimise impacts on biodiversity	<ul style="list-style-type: none"> • Ecological value and biodiversity.
Maximise sustainable procurement	<ul style="list-style-type: none"> • Sustainability and social aspects selection criteria • Labour practices • Procurement of sustainable timber.

25.2.4 Integration and implementation of sustainability framework

The sustainability framework would continue to be developed and refined in future phases of the project's delivery. The key implementation tools and processes that have been, and would continue to be, applied to the delivery of the sustainability framework are shown in Figure 25-1.

Activities to implement the sustainability framework, including requirements from the Infrastructure Sustainability rating scheme, would be implemented through a Sustainability Management Plan. The management plan would detail measures to meet the sustainability objectives and targets and Infrastructure Sustainability rating scheme credit requirements (refer to Section 25.4).

The project would seek to achieve an 'Excellent' 'Design' and 'As Built' Infrastructure Sustainability rating under version 1.2 of the Infrastructure Sustainability Council of Australia rating scheme.

25.3 Ecologically sustainable development

Facilitating ecologically sustainable development is adopted as an object of the *Environmental Planning and Assessment Act 1979*. This object requires the integration of "relevant economic, environmental and social considerations in decision making about environmental planning and assessment".

Ecologically sustainable development is defined under the *Protection of the Environment Administration Act 1991* (NSW) and includes four principles:

- The precautionary principle
- Intergenerational equity
- Conservation of biological diversity and ecological integrity
- Improved valuation and pricing of environmental resources.

The principles of ecologically sustainable development have been an integral part of the design and assessment of the project. This has included the integration of relevant economic, environmental and social considerations in project design and assessment decisions, as summarised in Table 25-5.

The environmental impact statement has been prepared with regard to the key issues associated with the project and the integration of biophysical, economic and social considerations, including the principles of ecologically sustainable development and cumulative impacts (refer to Chapter 28 (Synthesis of the environmental impact statement) for additional information).

Table 25-5 Application of the principles of ecologically sustainable development to the project

Principle	Application to the project
<p>Precautionary principle</p> <p>If there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.</p>	<p>Applied during the design and development of the project:</p> <ul style="list-style-type: none"> • Potential environmental impacts associated with the project considered in the alternatives and options analysis • Opportunities identified to avoid and minimise surface disturbance • Sustainability workshops and meetings held during design development with planning and design teams to develop draft sustainability targets and objectives for the project. <p>Applied during the preparation of this environmental impact statement:</p> <ul style="list-style-type: none"> • Prepared with a conservative approach, including assessment of worst case impacts and scenarios • Carried out using the best available technical information and has adopted best practice environmental standards, goals and measures • Potential environmental risks associated with the project identified and considered, with safeguards and management measures developed to manage and reduce identified risks • Sustainability workshops and meetings held during the development of the environmental impact statement with planning and design teams to inform relevant sustainability targets and objectives for the project.
<p>Intergenerational equity</p> <p>The present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations.</p>	<ul style="list-style-type: none"> • Project designed to meet with needs of both current and future generations with a design life of 100 years • Support for Sydney’s long term economic growth through improved motorway access and connections across Sydney’s Global Economic Corridor, particularly the strategic centres of Sydney CBD and North Sydney and the Northern Beaches, with improved connection to Macquarie Park and north-west Sydney • Contribution to improving the capacity, functionality and safety of the road network servicing the Northern Beaches for motorists, buses and freight • Contribution to the increased resilience of the road network servicing the Northern Beaches through the provision of an additional crossing of Middle Harbour • Reduction of operational greenhouse gas emissions on Sydney’s road network when compared to the project not being built • The project’s resilience to future climate change is considered in Chapter 26 (Climate change and greenhouse gas), which identifies potential climate change risks to the project, and adaptation measures incorporated into the design or options for further consideration during further design development

Principle	Application to the project
	<ul style="list-style-type: none"> • Management measures for potential environmental impacts have been provided throughout this environmental impact statement to protect the future health, diversity and productivity of the environment • During construction and operation of the project, opportunities would be taken to reduce material use and maximise the use of materials with low embodied environmental impact, where feasible • The mainline tunnel ventilation system has been designed for coordinated operation with the adjacent and connecting Western Harbour Tunnel and Warringah Freeway Upgrade project. The tunnel ventilation would meet the in-tunnel air quality criteria and would be operated in accordance with licensing requirements.
<p>Conservation of biological diversity and ecological integrity</p> <p>Conservation of biological diversity and ecological integrity should be a fundamental consideration of the project.</p>	<ul style="list-style-type: none"> • As outlined in Chapter 4 (Project development and alternatives), five different alignment alternatives were considered as part of the project development process to avoid and minimise potential impacts • Through this process, consideration was given to avoiding and minimising biodiversity impacts by way of locating project elements away from areas of biodiversity value as far as practicable. Where this was not possible, project elements were situated in areas with lower biodiversity values • The design of the project within the preferred corridor was then refined and assessed with the aim of further identifying, avoiding, minimising and mitigating impacts. The construction methodology has also been developed to avoid and minimise adverse impacts on biodiversity • The project would require the removal of native vegetation and potential fauna habitat. Detailed terrestrial and marine biodiversity assessments were carried out for the project to identify potential impacts on biodiversity and to provide a range of mitigation measures to further avoid and minimise potential impacts • A Biodiversity development assessment report (BDAR) was prepared in accordance with the Biodiversity Assessment Method (BAM) to establish how biodiversity impacts could be avoided and minimised and to identify the biodiversity credits that would need to be offset to achieve no net loss of biodiversity • Residual biodiversity impacts would be offset in accordance with the requirements of the <i>Biodiversity Conservation Act 2016</i> and relevant guidelines. The offsets required for the project were calculated using the BAM Calculator. A total of 391 ecosystem credits and 1099 species credits are required to offset the direct impacts of the project. An additional 50 ecosystem credits may be required to offset indirect impacts; these would be in addition to BAM credit obligations and are at the discretion of the Minister for Planning and Public Spaces.

Principle	Application to the project
<p>Improved valuation and pricing of environmental resources</p> <p>Environmental factors should be included in the valuation of assets and services.</p>	<p>Value placed on avoiding and minimising environmental impacts demonstrated by:</p> <ul style="list-style-type: none"> • The opportunities identified in the design development to improve local amenity, improve public transport access and active transport connections, and create new open space and recreation facilities • The opportunities identified to avoid and minimise environmental impacts in the project development and alternatives analysis • The extent of environmental investigations carried out to inform this environmental impact statement • The measures developed to further avoid and minimise potential impacts of the project detailed in this environmental impact statement • The inclusion of costs associated with planning, design and implementation of avoidance and mitigation measures in the overall project costs.

25.4 Environmental management measures

Environmental management measures relating to sustainability are outlined in Table 25-6.

Table 25-6 Environmental management measures – sustainability

Ref	Phase	Impact	Environmental management measure	Location
SU1	Design	Project sustainability outcomes	Project sustainability objectives and targets will be finalised during further design development, informed by the requirements of the project planning approval.	BL/GHF
SU2	Construction	Project sustainability outcomes	Activities to implement the sustainability framework, including requirements from the Infrastructure Sustainability rating scheme, will be implemented through a Sustainability Management Plan. The management plan will detail measures to meet the sustainability objectives and targets as well as achieving 'Design' and 'As Built' ratings of Excellent under the Infrastructure Sustainability Council of Australia (ISCA) rating scheme.	BL/GHF

Note: BL = Beaches Link, Gore Hill Freeway Connection = GHF



Transport for NSW

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Chapter 26

Climate change and greenhouse gas

26 Climate change and greenhouse gas

This chapter assesses the potential impacts of climate change on the project and adaptation measures that have been incorporated into the design of the project. Greenhouse gas emissions generated by the construction and operation of the project are also assessed within this chapter. Detailed greenhouse gas calculations and climate change projections are provided in Appendix X (Technical working paper: Climate change and greenhouse gas calculations).

The Secretary's environmental assessment requirements relating to climate change and greenhouse gas emissions, and where in the environmental impact statement these have been addressed, are detailed in Table 26-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to adaptation for climate change risk and greenhouse gas emissions are included in Section 26.1.5 and Section 26.2.5 respectively.

Table 26-1 Secretary's environmental assessment requirements – climate change risk

Secretary's requirement	Where addressed in EIS
Climate change risk	
1. The Proponent must assess the risk and vulnerability of the project to climate change in accordance with the current guidelines.	This chapter and Appendix X (Technical working paper: Climate change and greenhouse gas calculations), present a climate change risk assessment for the project in accordance with current guidelines as listed in Section 26.1.1 .
2. The Proponent must quantify specific climate change risks with reference to either the NSW Government's climate projections at 10 km resolution (or lesser resolution if 10 km projections are not available) or equivalent projection tool (such as the Climate Futures Tool from CSIRO and BoM (attenuated for project region)) and incorporate specific adaptation actions in the design.	Climate change risks to the project are identified in Section 26.1.4 , and Appendix X (Technical working paper: Climate change and greenhouse gas calculations), with reference to current climate change projections presented in Section 26.1.3 .

26.1 Climate change risk assessment

This section outlines the legislation, policies and climate change projections relevant to the project, assesses the risks of climate change to the project and outlines adaptations to manage those risks.

26.1.1 Legislative and policy framework

The climate change risk assessment has been conducted in line with the following relevant standards and current guidelines:

- *National Climate Resilience and Adaptation Strategy* (Department of the Environment and Energy, 2015)
- *NSW Climate Change Policy Framework* (Office of Environment and Heritage (OEH), 2016a)

- *Environmental Sustainability Strategy 2019-2023* (Roads and Maritime Services, 2019)
- *Australian Standard AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk-based approach* (Standards Australia, 2013)
- *Australian and New Zealand Standard AS/NZ ISO 31000:2009 Risk management – Principles and guidelines* (Australian and New Zealand Standard, 2009)
- *Climate Change Impacts and Risk Management – A Guide for Business and Government* (Australian Government, 2006)
- *Technical Guide for Climate Change Adaptation for the State Road Network* (Roads and Maritime Services, 2015e)
- *Guideline for Climate Change Adaptation, Revision 2.1* (Australian Green Infrastructure Council, 2011)
- *Climate Risk Assessment Guideline* (Transport for NSW, 2019b).

26.1.2 Assessment methodology

The methodology for the climate change risk assessment was based on the Australian Standard *AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk based approach*. This standard follows the International Standard *ISO 31000:2009, Risk management – Principles and guidelines* (adopted in Australian and New Zealand as *AS/NZ ISO 31000:2009*), which provides a set of internationally endorsed principles and guidance on how organisations can integrate decisions about risks and responses into its existing management and decision-making processes. The methodology was also guided by the draft *Technical Guide for Climate Change Adaptation for the State Road Network* (Roads and Maritime Services, 2015e).

While adhering to the above guidance documents, the following key steps were carried out to complete the climate change risk assessment:

- Determination of the climate change context, including greenhouse gas emissions scenarios and projections, data on climate variables and past meteorological record
- Identification of the climate risks and assess the likelihood and consequence of each risk
- Identification of adaptation responses.

To assist with the determination of the climate change context as well as the identification of climate change risks and the likelihood of such risks, a multidisciplinary risk workshop was held with members of the project team (ie members of the design and environmental assessment teams) early in the design phase. The preliminary risks identified at the workshop were then formalised in a risk register and thorough risk descriptions, including cause, impact/consequence and current and proposed future treatment were identified.

A climate change risk update was subsequently carried out based on the design that forms the basis of this environmental impact statement. The update identified treatments that had been incorporated into the design since the initial climate change risk workshop, risk treatments to be implemented or investigated in future design stages, and some updates to risk ratings.

A hazard-receiver pathway model has been applied to identify and analyse risks to the project with respect to climate change. Climate or climate influenced attributes with potential to influence the project were identified (hazards), along with the component of the project, user or surrounding environment that would be impacted by the hazard (receivers).

The appropriate risk rating level was identified by:

- Determining the likelihood of each risk occurring
- Determining the consequences of each risk occurring
- Considering what is already inherent in the design, and the business as usual controls expected to be applied through design, construction, maintenance and operation

- Determining the residual risk, incorporating the above factors.

The risk assessment matrix in Appendix X (Technical working paper: Climate change and greenhouse gas calculations) was applied to determine risk ratings for the identified hazards and receivers.

26.1.3 Climate change projections

Climate change projections used for the climate change risk assessment are summarised below in Table 26-2.

The projections were developed for three periods, broadly reflecting the operating timeframes of different elements of the project:

- Year 2030: assets and systems with short operating timeframes, such as communications and other electronic systems, landscaping and road surfaces
- Year 2050: assets and systems with long operating timeframes, such as drainage structures and barriers/rails
- Year 2090: 'permanent' assets, which would become fixed and ongoing features of project, such as tunnel civil structures (including rock bolts), bridges, embankment culverts (and other inaccessible drainage), and buildings.

Projections were derived from the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5) (IPCC, 2013) which are incorporated into the Climate Futures Tool by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and Department of Agriculture, Water and Environment. Projections are provided for a number of emissions and pathway scenarios for a range of climate parameters. The projections are based on the 'worst-case' scenario (Representative Concentration Pathways 8.5), which reflects the highest emissions projected for the time period.

Table 26-2 Summary of climate change projections – Sydney region

Climate variable	Baseline (1986 - 2005)	2030	2050	2090
Temperature				
Mean minimum temperatures (°C) – annual	14.4	15.5	16.3	18.4
Mean maximum temperatures (°C) – annual	22.4	24.3	24.4	26.5
Days over 35°C – annual	3.5	5.6	5.9	11.3
Rainfall				
Mean precipitation (mm) – annual	1238	1206	1151	1049
Extreme rainfall events – max 1-day rainfall	Projected to increase 2 – 22%			
Extreme rainfall events – 20-year return level of max. 1-day rainfall	Projected to increase 5 – 42%			
Evapotranspiration				
Annual change in potential evapotranspiration (% change)	375 mm (1961-1990)	4.2	No data	14.3
Fire regimes				
The number of days where the fire danger rating is 'severe' or 'extreme'	0.9	1.3	No data	2.1

Climate variable	Baseline (1986 - 2005)	2030	2050	2090
Severe wind				
Average maximum daily wind speed (% change)	120 km/h	-0.2 to 1.9	1.8 to 3.2	0.3 to 5.7
Sea conditions				
Sea level rise (m)	0	0.14	No data	0.66
Sea surface temperature (°C)	Varies	1.0	No data	3.1
Atmospheric CO₂				
Atmospheric CO ₂ concentration	401 ppm	No data	No data	940 ppm (2100)

Note: "No data" is where projections are not available for the time period; "Varies" is where data varies both within the year and range identified.

26.1.4 Climate change risk evaluation

Climate change risks with a medium or high rating (based on the design presented in this environmental impact statement), prior to the implementation of further treatment measures, are summarised in Table 26-3 (ie 'initial rating'). These 'initial ratings' assume the incorporation of business as usual design, construction and operational controls. Treatment methods have been identified and are proposed for those 'initial ratings', based on the current design, or are proposed to be carried out as part of future investigations during further design development.

The 'final rating' (ie post-treatment), incorporating further additional treatment options and investigations, is also presented in Table 26-3.

Low risks identified during the assessment were not considered to require any additional risk treatment, as these risks are considered tolerable. As such, risks classified as 'low' or 'negligible' have not been included in the table below.

In summary, the assessment of climate change risks identified no extreme or high initial risk ratings, and only four medium risk ratings. These medium risks are anticipated in respect to rainfall and surface flooding, bushfires (particularly in the area adjoining to Wakehurst Parkway), and sea level rise. Two of these medium risks, for rainfall and surface flooding and sea level rise, drop to a final risk rating of low when incorporating further additional treatment or investigations.

Table 26-3 Climate change risk assessment

Risk ID	Hazard Category	Description	Initial Rating	Measures incorporated into the current design and business as usual practice	Proposed further treatment or investigation	Final Rating
38	Rainfall and surface flooding	Potential for key project elements (ie tunnel portals, motorway facilities and motorway control centre) to be flooded in extreme rainfall/stormwater events, resulting in operational failure.	Medium	Facilities have been designed to be immune in the probable maximum flood.	Further flood modelling for detailed design would continue to use sea level rise projections and rainfall projections.	Low
18	Bushfires	Damage to road infrastructure especially along Wakehurst Parkway from bushfires where bushland surrounds the project.	Medium	Standard asset protection zones around buildings.	No additional measures.	Medium
22	Bushfires	An increased likelihood in the occurrence of bushfires which may increase the potential for injuries and/or fatalities to pedestrians and cyclists along Wakehurst Parkway. An increased patronage is anticipated as a result of improved access facilitated by the project.	Medium	Variable message signs incorporated into the design at Wakehurst Parkway.	No additional measures.	Medium
26	Sea level rise	Potential for key project elements (ie tunnel portals, motorway facilities and motorway control centre) to be flooded as a result of sea level rise, resulting in operational failure.	Low	Key project elements are designed above probable maximum flood and above future projected sea levels.	Further flood modelling in detailed design would continue to use sea level rise projections and rainfall projections.	Low

26.1.5 Adaptation for climate change

Table 26-4 lists the actions that would be carried out during further design development to mitigate the effects of climate change.

Table 26-4 Environmental management measures – climate change risks

Ref	Phase	Risks	Environmental management measure	Location
CC1	Design	Climate change risks and flood modelling projections	The following actions will be carried out during further design development to ensure climate change is adequately addressed: a) Flood modelling will continue to use sea level rise projections and future climate change rainfall projections b) The extent of scour protection will be refined c) Sensitivity testing for future climate change will be carried out in the detailed design of drainage channels and culverts. Increased capacity will be provided where feasible and reasonable.	BL/GHF

Beaches Link = BL, Gore Hill Freeway = GHF

26.2 Greenhouse gas

Atmospheric greenhouse gases absorb and re-radiate heat from the sun, trapping heat in the lower atmosphere and influencing global temperatures. This is known as the greenhouse effect and is linked to climate change.

The emission of greenhouse gases into the atmosphere occurs as a result of both natural processes (eg bushfires) and human activities (eg burning of fossil fuels to generate electricity).

This section outlines the legislation and policies relevant to the project, and the greenhouse gas emissions and potential impacts caused by the construction and operation of the project.

26.2.1 Legislative and policy framework

This assessment was prepared according to the principles and objectives outlined in the following legislation and policies:

- *Kyoto Protocol to the United Nations Framework Convention on Climate Change* (the Kyoto Protocol) (UNFCCC, 1998)
- *Doha Amendment to the Kyoto Protocol* (UNFCCC, 2012)
- *Paris Agreement* (UNFCCC, 2015)
- *National Greenhouse and Energy Reporting Act 2007* (Cwth)
- *Direct Action Plan* (Australian Government, 2014)
- *NSW Climate Change Policy Framework* (OEH, 2016a)
- *Environmental Sustainability Strategy 2019-2023* (Roads and Maritime Services, 2019).

26.2.2 Assessment methodology

The methodology for this greenhouse gas and energy assessment is based on the following tools and protocols:

- *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* (World Resources Institute & World Council for Sustainable Business Development (WRI & WBCSD), 2004)
- *Greenhouse Gas Assessment Workbook for Road Projects* (the TAGG Workbook) (Transport Authorities Greenhouse Group (TAGG), 2013)
- *Infrastructure Sustainability Materials Calculator* (Infrastructure Sustainability Council of Australia, 2016b)
- *Tools for Roadside Air Quality* (Roads and Maritime Services, 2012).

Greenhouse gas emissions are reported as kilotonnes of carbon dioxide equivalent (kt CO₂-e). Emissions are categorised into three different scopes in accordance with the Greenhouse Gas Protocol.

The three greenhouse gas scopes are:

- Scope 1 emissions – direct emissions generated by the project, eg emissions generated by the use of diesel fuel in project construction plant, equipment or vehicles
- Scope 2 emissions – indirect emissions from the consumption of purchased electricity for project equipment or operation of the project
- Scope 3 emissions – all other indirect emissions (not included in Scope 2) generated as a consequence of the project, eg emissions associated with the mining, production and transport of materials used in construction.

26.2.3 Assessment of potential construction impacts

The primary sources of construction greenhouse gas emissions and the indicative Scope 1, 2 and 3 emissions for the project are presented in Table 26-5 and Figure 26-1.

The construction stage of the project is expected to generate about 724 kt CO₂-e of greenhouse gas emissions. As shown in Figure 26-1, about 38 per cent of emissions are expected to be contributed from terrestrial electricity consumption, and about 42 per cent by construction materials.

The estimated construction stage emissions represent about 0.6 per cent of NSW emissions and about 0.13 per cent of Australia’s national emissions in 2018. Due to the indirect nature of Scope 3 emissions, a proportion of these emissions may be generated interstate or internationally. While these percentage contributions are small within the NSW and national contexts, measures have been outlined in Section 26.2.5 to further minimise greenhouse gas emissions during the construction of the project.

Table 26-5 Indicative construction phase greenhouse gas emissions by scope

Emission source	Emissions (kt CO ₂ -e)			
	Scope 1	Scope 2	Scope 3	Total
Diesel combustion (plant and equipment)	23.9	-	1.2	25.1
Diesel combustion (generators for marine construction)	4.5	-	0.2	4.7
Diesel combustion (transport of materials to terrestrial temporary construction support sites)	-	-	9.6	9.6
Diesel combustion (transport of waste and spoil from terrestrial and harbour temporary construction support sites)	-	-	98.6	98.6

Emission source	Emissions (kt CO ₂ e)			
	Scope 1	Scope 2	Scope 3	Total
Vegetation removal	2.9	-	-	2.9
Electricity consumption (terrestrial)	-	249.5	27.7	277.2
Construction materials	-	-	305.6	305.6
Total	31.3	249.5	442.9	723.7

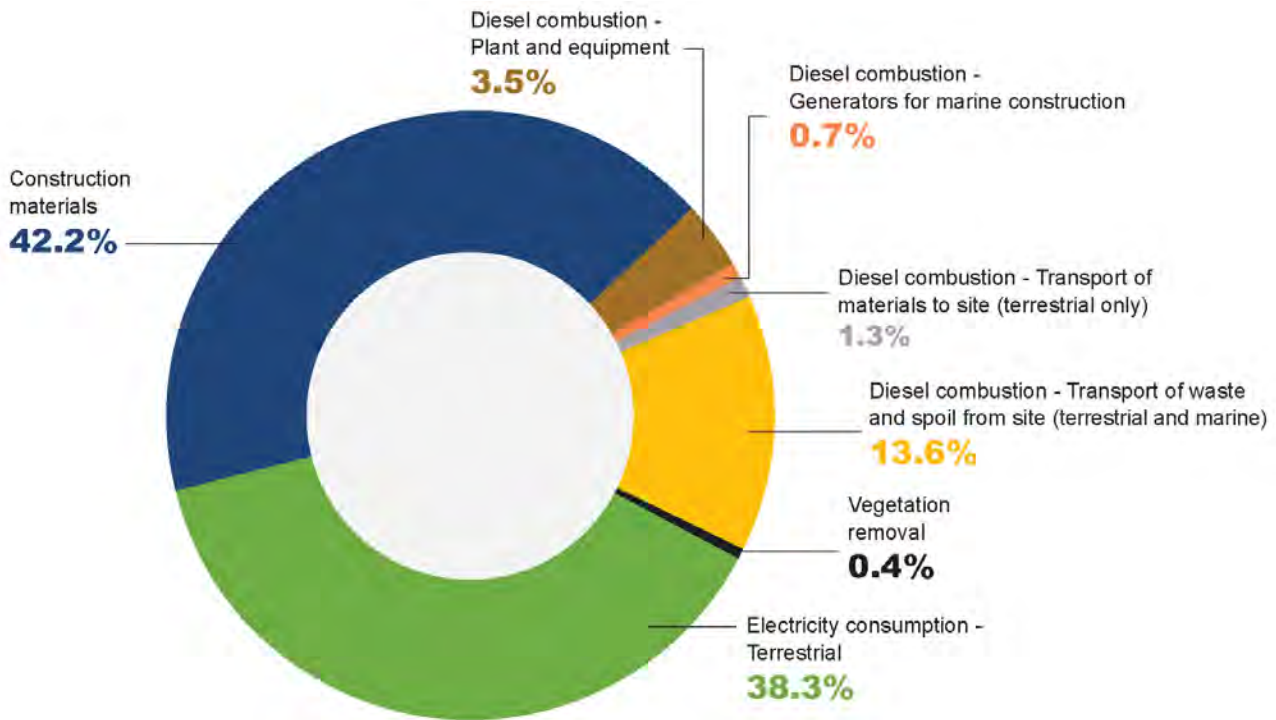


Figure 26-1 Estimated greenhouse gas emissions by source for construction

26.2.4 Assessment of potential operational impacts

The primary sources of operational greenhouse gas emissions and the indicative Scope 1, 2 and 3 emissions for the project are presented in Table 26-6. Emissions estimates are provided for operational scenarios in 2027 (opening) and 2037 (10 years after opening).

Electricity

Operational greenhouse gas emissions would be associated with the electricity consumption required to power operational infrastructure and facilities, including:

- Tunnel ventilation
- Surface and tunnel lighting
- Motorway control centre
- Wastewater treatment plant
- Substations.

Operational electricity consumption is projected to increase over time, due to the projected increase in traffic volumes using the roads, increasing tunnel ventilation requirements.

Maintenance

Greenhouse gas emissions generated from the maintenance of road infrastructure would be relatively small in comparison with other operational sources. Emissions would result from the use of diesel fuel maintenance vehicles and equipment, and are embedded in the construction materials used for maintenance activities.

Traffic

Operational greenhouse gas emissions would be associated with fuel consumed by vehicles using the road network. Greenhouse gas emissions are also projected to increase as traffic numbers across the road network grow. However, the expected reduction in congestion as a result of the project and expected improvements in fuel efficiency and increases in electric vehicles, are projected to result in improvements to the overall efficiency of emissions. The project would increase the number of road links across the network, but would result in fewer vehicle stop and start movements, less congestion and a greater average vehicle speed, which would further increase the efficiency of vehicles and assist in reducing emissions. Table 26-6 outlines the difference, with and without the project, between operational greenhouse gas emissions associated with traffic.

Emission estimates

The estimated operational emissions would represent about 0.03 and 0.04 per cent of projected NSW emissions in 2027 and 2037 respectively, and 0.01 per cent of Australia's projected national emissions in both 2027 and 2037. While these percentage contributions are small within the NSW and national contexts, the environmental management measures outlined in Section 26.2.5 would be implemented to further minimise greenhouse emissions during the operation of the project.

Table 26-6 Indicative operational phase greenhouse gas emissions by scope

Source	Emissions (kt CO ₂ -e)			
	Scope 1	Scope 2	Scope 3	Total
2027				
Operational electricity	-	27.9	3.1	31.0
Maintenance	0.3	-	0.3	0.6
Traffic (difference between existing levels and levels with the project)	-	-	13.7	13.7
Total	0.3	27.9	17.1	45.3
2037				
Operational electricity	-	29.2	3.2	32.4
Maintenance	0.3	-	0.3	0.6
Traffic (difference between existing levels and levels with the project)	-	-	19.5	19.5
Total	0.3	29.2	24.1	52.5

26.2.5 Environmental management measures

Environmental management measures relating to greenhouse gas emissions are outlined in Table 26-7.

Table 26-7 Environmental management measures – greenhouse gas

Ref.	Phase	Risks	Environmental management measure	Location
GHG1	Design	Energy efficiency	Energy efficiency will be considered during further design development with energy efficient systems installed where reasonable and practicable.	BL/GHF
GHG2	Construction	Emission of greenhouse gases during construction	Greenhouse gas emissions will be managed and minimised as part of the Sustainability Management Plan and will be implemented to assist in achieving 'Design' and 'As Built' ratings of Excellent under the Infrastructure Sustainability Council of Australia rating scheme (Version 1.2).	BL/GHF

Beaches Link = BL, Gore Hill Freeway = GHF



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 27

Cumulative impacts

27 Cumulative impacts

This chapter provides an overview of the potential cumulative impacts associated with the construction and operation of the project and identifies measures which address these impacts.

The Secretary's environmental assessment requirements as they relate to cumulative impacts and where in the environmental impact statement these have been addressed, are detailed in Table 27-1.

Avoiding or minimising impacts has been a key consideration throughout the design and development process for the Beaches Link and Gore Hill Freeway Connection project. A conservative approach has generally been used in the assessments, with potential impacts presented before implementation of environmental management measures. The environmental management measures proposed to minimise the potential impacts in relation to cumulative impacts are discussed in Section 27.5.

Table 27-1 Secretary's environmental assessment requirements – cumulative impacts

Secretary's requirement	Where addressed in EIS
Environmental Impact Statement	
1. The EIS must include, but not necessarily be limited to, the following: <ul style="list-style-type: none"> o. an assessment of the cumulative impacts of the project taking into account other projects that have been approved but where construction has not commenced, projects that have commenced, and projects that have recently been completed 	Projects that have been assessed and may have potential cumulative impacts are identified in Section 27.2 . Potential cumulative impacts are described in Section 27.3 and Section 27.4 .
Assessment of Key Issues	
2. For each key issue the Proponent must: <ul style="list-style-type: none"> c. identify, describe and quantify (if possible) the impacts associated with the issue, including the likelihood and consequence of the impact (comprehensive risk assessment), and the cumulative impacts of: <ul style="list-style-type: none"> a) concurrent project construction activities; and b) proposed and approved projects (where information is available at the time of writing) 	Potential cumulative impacts during construction and operation for the key issues discussed in Chapters 8 to 26 are described in Section 27.3 and Section 27.4 .
Consultation	
4. The Proponent must assess the potential for complaint fatigue to occur during construction of the project and describe how mitigation measures, complaint handling procedures and community consultation mechanisms will mitigate complaint fatigue. The assessment must consider the cumulative impacts from the project and other major projects in the local area.	The potential for complaint fatigue to occur and proposed mitigation measures and complaint handling procedures are described in Chapter 7 (Stakeholder and community engagement). Potential impacts of construction and complaint fatigue are described in Section 27.3.7 .

27.1 Assessment methodology

Cumulative impacts can occur when impacts from the project interact or overlap with impacts from other projects and potentially result in a larger overall effect on the environment, businesses or local communities. Cumulative impacts may also occur when projects are constructed consecutively with construction activities occurring over extended periods of time with little to no break in between, resulting in construction fatigue for local receivers. Construction fatigue incorporates the potential for complaint fatigue, which may impact communication of community concerns during construction.

This section provides:

- A description of how projects were initially identified for consideration of cumulative construction or operational impacts with the project
- The screening criteria applied to determine whether the identified projects should be assessed for cumulative impacts
- An overview of the type of assessment carried out for the relevant cumulative impacts.

The cumulative impact assessment in this environmental impact statement is based on the broad requirements set out by the Secretary's environmental assessment requirements.

The methodology is shown in Figure 27-1.

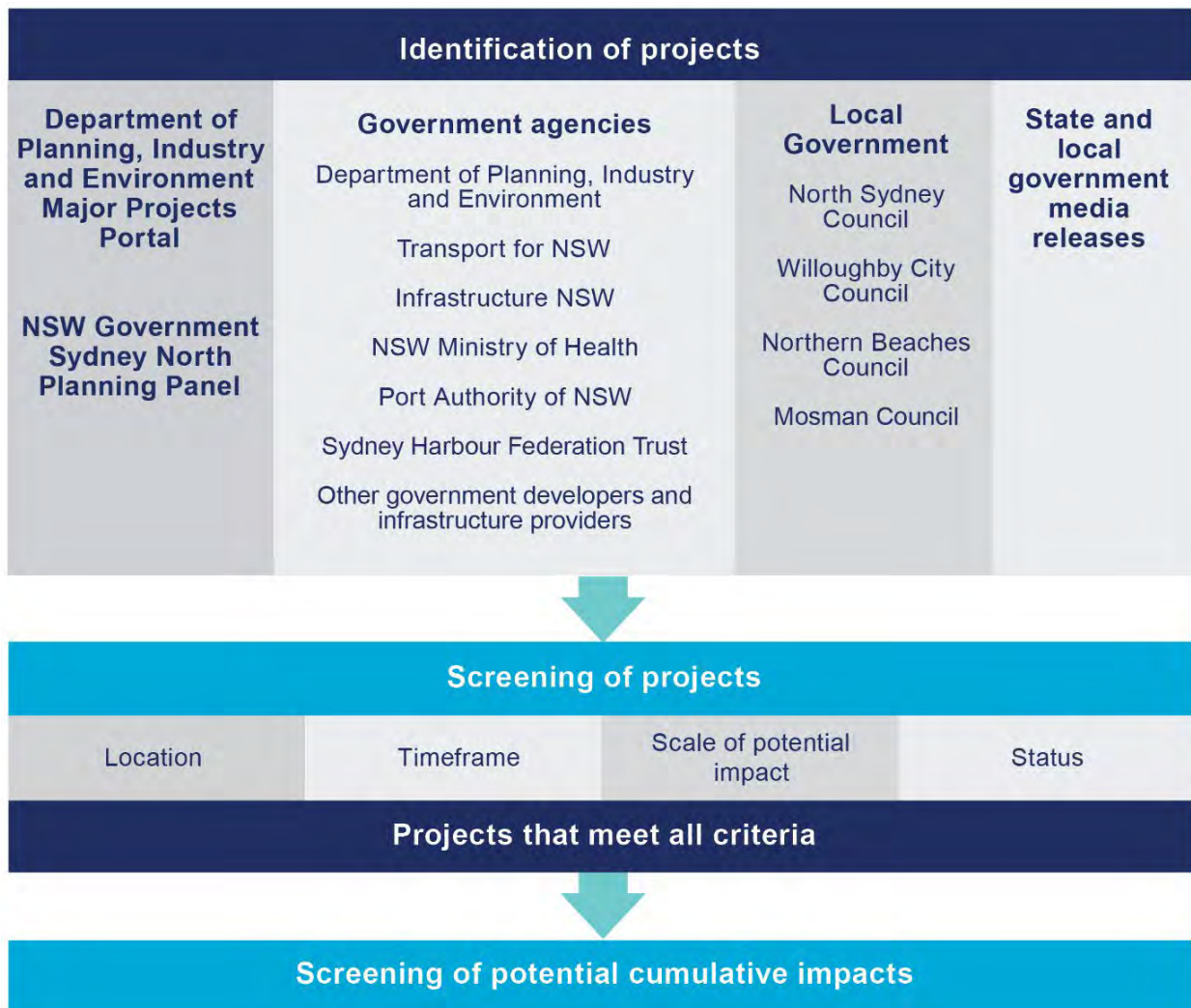


Figure 27-1 Overview of the cumulative impact assessment methodology

27.1.1 Identification of projects

An initial list of projects for potential inclusion in the cumulative impact assessment was identified from the sources outlined in Figure 27-1.

Projects identified for inclusion in the screening assessment were those likely to meet at least one of the screening criteria described in Table 27-2. The list of projects identified can be broadly categorised as:

- **Category 1:** The Western Harbour Tunnel and Beaches Link program of works, including the Western Harbour Tunnel and Warringah Freeway Upgrade
- **Category 2:** Other major transport infrastructure projects, including related Transport for NSW projects and public transport projects
- **Category 3:** Other projects and strategic development, including urban development, other infrastructure projects, and consideration of local strategic planning documents where they may result in future development and lead to potential cumulative impacts with the project.

27.1.2 Screening of projects

The screening criteria shown in Table 27-2 were applied to determine whether a project or strategic plan should be included in the cumulative impact assessment. Projects and plans that satisfied all of these criteria were included and are described in Section 27.2.

Table 27-2 Screening criteria for cumulative impact assessment

Criteria	Relevance
Location A project was considered relevant where that project was within one of the following areas:	• Direct overlap: construction footprints intersect
	• In close proximity: within 500 metres of the construction footprint
	• In the locality: within two kilometres of the construction footprint
Timeframe A project was considered relevant where that project involved one of the following timeframes:	• Concurrent construction programs
	• Consecutive construction programs (ongoing or recently completed projects resulting in construction fatigue considerations)
Scale of potential impact A project was considered relevant where that project involved one or more of the following impacts:	• Substantial temporary changes to existing traffic conditions
	• Substantial temporary changes to the existing noise environment
	• Impacts on numerous heritage items and/or heritage items with State, National, Commonwealth or World significance
	• Substantial changes to the existing land use
	• Substantial changes to the existing urban landscape and/or changes to biodiversity

Criteria	Relevance
<p>Status</p> <p>A project was considered relevant where that project was at one of the following stages of the statutory assessment and approval process:</p>	<ul style="list-style-type: none"> • Approved projects (statutory approvals received), including approved projects that have not started construction, projects currently under construction, and recently completed projects • Proposed projects (currently under statutory environmental impact assessment) • Future strategic government projects (where commitment on construction program and methodology has been made)

27.1.3 Screening of potential cumulative impacts

The assessment of potential cumulative impacts has considered the following key locations:

- North Sydney and Cammeray
- Artarmon
- Naremburn and Willoughby
- Middle Harbour
- Balgowlah
- Seaforth, Killarney Heights and Frenchs Forest.

Potential cumulative impacts have been considered based on likely interactions of the Beaches Link and Gore Hill Freeway Connection project with other projects and plans listed in Table 27-3 and Table 27-4.

Where potential cumulative impacts may occur, these could relate to:

- Additional impacts due to concurrent construction periods
- Prolonged impacts due to consecutive construction periods.

The assessment of potential cumulative impacts has considered the key issues identified in Chapters 8 to 26 of this environmental impact assessment. In locations where cumulative impacts relating to a key issue has been assessed as negligible, the issue is not considered further.

The potential cumulative impacts during construction and operation are described in sections 27.3 and 27.4 respectively.

27.2 Projects assessed

Following the application of the screening criteria to identified projects, the projects included in Table 27-3 have been considered in the cumulative impact assessment. The location of these projects is shown in Figure 27-2.

Local strategic plans listed in Table 27-4 have been considered in the assessment where relevant, as they will influence development that has the potential to result in cumulative impacts with the project. The potential impacts are not able to be considered in detail given the uncertainty of the status and timing of associated projects, construction methodologies, and the existing coordination arrangements between Transport for NSW and Sydney Metro for works in North Sydney and Artarmon.

Table 27-3 Projects assessed in the cumulative impact assessment

Project name, status and expected construction period	Brief project description	Relevant locations where cumulative impacts might occur ¹
Category 1: Western Harbour Tunnel and Beaches Link program of works		
Western Harbour Tunnel and Warringah Freeway Upgrade Proposed 2020 – 2026	The Western Harbour Tunnel and Warringah Freeway Upgrade project comprises a new tolled motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and connect to the Beaches Link and Gore Hill Freeway Connection project.	<ul style="list-style-type: none"> • North Sydney and Cammeray • Artarmon • Naremburn and Willoughby
Category 2: Other major transport infrastructure projects		
Sydney Metro City & Southwest (Chatswood to Sydenham) Approved 2017 – 2024	<p>The Chatswood to Sydenham component of Sydney Metro City & Southwest involves the construction and operation of a 15.5 kilometre metro line from Chatswood, under Sydney Harbour and through Sydney’s CBD out to Sydenham.</p> <p>Components of the project relevant to this assessment include:</p> <ul style="list-style-type: none"> • Chatswood dive site • Artarmon substation • Crows Nest Station • Victoria Cross Station. 	<ul style="list-style-type: none"> • North Sydney and Cammeray • Artarmon • Naremburn and Willoughby
Northern Beaches Hospital road upgrade project Completed 2015 – August 2020	<p>This recently completed project involved staged construction works to enhance connectivity to the new Northern Beaches Hospital and to improve the broader road network capacity.</p> <p>The following locations were upgraded as part of the works:</p> <ul style="list-style-type: none"> • Warringah Road from its intersection with Maxwell Parade to its intersection with Courtley Road • Naree Road/Frenchs Forest Road from its intersection with Forest Way to its intersection with Warringah Road 	<ul style="list-style-type: none"> • Seaforth, Killarney Heights and Frenchs Forest

Project name, status and expected construction period	Brief project description	Relevant locations where cumulative impacts might occur ¹
	<ul style="list-style-type: none"> Wakehurst Parkway from about 500 metres north of Frenchs Forest Road to about 500 metres south of Warringah Road Forest Way from around Adams Street about 750 metres south to its intersection with Warringah Road. 	
Category 3: Other projects and strategic developments		
Sydney Metro Victoria Cross over station development Approved 2021 – 2024 ²	This project involves the construction of a 40-storey (plus two storey rooftop plant) commercial office building above the southern entrance of Victoria Cross station.	<ul style="list-style-type: none"> North Sydney and Cammeray
Marist Catholic College North Shore Proposed Prepare EIS 2020 – 2026	This project involves the demolition of existing buildings and construction of a new six storey building to accommodate teaching facilities, early learning centre and premises for independent tertiary education.	<ul style="list-style-type: none"> North Sydney and Cammeray
Channel 9 site staged residential redevelopment Part 3A concept plan approved Construction stages 1 and 2 under assessment No timeframe information (construction overlap assumed)	Redevelopment of the Channel 9 site (14 Artarmon Road, Willoughby) for up to 400 residential dwellings with non-residential land uses such as retail/commercial space and landscaping and public domain works.	<ul style="list-style-type: none"> Naremburn and Willoughby

Note 1: Relevant locations where cumulative impacts might occur includes locations where surface works for the Beaches Link and Gore Hill Freeway Connection project occur within two kilometres of a Category 1, 2 or 3 project

Note 2: Dates as per the Concept Development Application for the Victoria Cross over Station Development

Table 27-4 Strategic plans considered in the cumulative impact assessment

Strategic plan	Brief description	Relevant locations where cumulative impacts might occur
Northern Beaches Sportsground Strategy	<p>The <i>Northern Beaches Sportsground Strategy</i> (Northern Beaches Council, 2017a) is a 15 year plan to provide a single approach to the management and long term planning of sporting facilities on the Northern Beaches. The <i>Northern Beaches Sportsground Strategy</i> has been informed by the <i>Northern Beaches Sportsgrounds and Golf Courses Discussion Paper</i> (Northern Beaches Council, 2017c) which was prepared in response to independent analyses commissioned by Northern Beaches Council to review sportsgrounds supply and demand, and assess the feasibility of golf courses on the Northern Beaches. The discussion paper included strategic directions for addressing a shortfall in sporting fields across the local area including the potential conversion of existing golf courses to provide additional sporting grounds and parkland areas.</p>	<ul style="list-style-type: none"> • Balgowlah
Northern Beaches Hospital Precinct Structure Plan	<p>The <i>Northern Beaches Hospital Precinct Structure Plan</i> (Northern Beaches Council, 2017b) defines the desired future land uses and consequent multi-modal transport operation and infrastructure requirements to, from and through Frenchs Forest. The plan acknowledges that a suite of regional transport network upgrades including both public transport and road upgrades would be required to maintain effective transport connections to, from and through Frenchs Forest in the medium to long term.</p> <p>The plan provides the strategic land use planning framework for Frenchs Forest for the next 20 years. The plan includes proposed land use rezoning around the Northern Beaches Hospital to the north and west of the Wakehurst Parkway/Warringah Road intersection as part of a strategy to support long term growth in the area (including a proposed 5360 new dwellings in the next 20 years).</p>	<ul style="list-style-type: none"> • Seaforth, Killarney Heights and Frenchs Forest
North Sydney Integrated Transport Program	<p>The <i>North Sydney Integrated Transport Program</i> (North Sydney Program) is an ongoing multi-agency collaboration between Transport for NSW, North Sydney Council, Greater Sydney Commission and the Government Architect of NSW, to guide future integrated transport planning and investment in the North Sydney CBD and interconnected areas over the next 20 years and beyond. Led by Transport for NSW since 2018, it aims to deliver a shared place-based vision for the North Sydney CBD.</p> <p>The North Sydney Program considers strategic public transport connections to the North Sydney CBD, land use and public domain objectives, improved pedestrian amenity and safety, road network changes, improved access for cyclists to and through the CBD, convenient interchanges between bus and rail services, management of kerbside access to support business activity across the day,</p>	<ul style="list-style-type: none"> • North Sydney and Cammeray

Strategic plan	Brief description	Relevant locations where cumulative impacts might occur
	<p>and place outcomes within the CBD. As such, a key focus of the North Sydney Program is to ensure major projects, such as the Western Harbour Tunnel and Beaches Link program of works, integrate with the North Sydney CBD in a manner that supports the globally connected 'Harbour CBD' and enables delivery of befitting place-based outcomes.</p> <p>The timing for deliverables in the North Sydney Program would be cognisant of the Western Harbour Tunnel and Beaches Link program of works delivery timeframes.</p> <p>Further information on the North Sydney Program is provided in Section 9.1.1</p>	



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Indicative only – subject to design development

Legend

- | | |
|---|---|
| — Western Harbour Tunnel | Approved |
| — Warringah Freeway Upgrade | Proposed |
| — Beaches Link and Gore Hill Freeway Connection | |
| — Sydney Metro City & Southwest (Chatswood to Sydenham) | |
| — Northern Beaches Hospital road upgrade project (Completed 2020) | |

Figure 27-2 Projects assessed in the cumulative impact assessment

27.3 Assessment of potential cumulative construction impacts

The following sections describe the potential cumulative impacts during construction of the project based on likely interactions with the projects and plans listed in Table 27-3 and Table 27-4.

Impacts outlined in each section are unmitigated potential cumulative impacts. Mitigation measures are included in Section 27.5.

27.3.1 North Sydney and Cammeray

Projects

Construction activities at North Sydney and Cammeray would occur in close proximity to the following projects:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Victoria Cross and Crows Nest stations
- Marist Catholic College North Shore
- Sydney Metro Victoria Cross over station development.

Potential cumulative impacts

Potential cumulative construction impacts at North Sydney and Cammeray are identified in Table 27-5.

In summary, cumulative impacts are most likely to be experienced by receivers around Cammeray Golf Course and the Warringah Freeway corridor in North Sydney and Cammeray as a result of interactions with the Western Harbour Tunnel and Warringah Freeway Upgrade project.

Cumulative traffic impacts have the potential to be experienced at Cammeray due to the interaction of the project with the Western Harbour Tunnel and Warringah Freeway Upgrade project. In particular, the wider road network at the Warringah Freeway and surrounds, including the suburb of Cammeray, is likely to be affected due to the consecutive use of Cammeray Golf Course as temporary construction support sites for the Western Harbour Tunnel and Beaches Link program of works.

Cumulative temporary construction noise, visual amenity, and social and economic impacts may also be experienced by receivers at North Sydney and Cammeray due to the proximity of the project's construction sites to construction sites for the Western Harbour Tunnel and Warringah Freeway Upgrade. It is likely that some construction sites for the two projects would operate both concurrently and consecutively, with prolonged impacts to residential, commercial and recreational receivers.

The concurrent and/or consecutive use of Cammeray Golf Course as temporary construction support sites for the Western Harbour Tunnel and Beaches Link program of works also has the potential to result in prolonged cumulative land use and heritage impacts, and impacts to public open space.

However, these projects may provide cumulative benefits for local construction workers and to local business and services in these areas by increasing passing trade and demand for services during construction periods.

The potential for construction fatigue and complaint fatigue at North Sydney and Cammeray is discussed in Section 27.3.7.

Potential cumulative impacts resulting from the construction of the projects considered are expected to be negligible for the following issues:

- Air quality
- Aboriginal heritage
- Geology, groundwater and soils
- Hydrology and water quality
- Flooding
- Biodiversity
- Hazards and risks
- Resource use and waste management
- Sustainability
- Climate change and greenhouse gases.

As such, these issues are not considered further in Table 27-5.

Negligible cumulative impacts are expected to result from construction activities at North Sydney and Cammeray from the following projects:

- Marist Catholic College North Shore
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Victoria Cross and Crows Nest stations
- Sydney Metro Victoria Cross over station development.

Additional cumulative construction impacts at North Sydney may be generated by future projects associated with the North Sydney Program (refer to Table 27-4). As discussed in Chapter 9 (Operational traffic and transport), the development of the North Sydney Program is ongoing, with validation of the vision for North Sydney currently underway. The timing for deliverables in the North Sydney Program would be cognisant of the Western Harbour Tunnel and Beaches Link program of works delivery timeframes.

As such, these projects and strategic plan have not been considered further in Table 27-5.

Table 27-5 Potential cumulative construction impacts – North Sydney and Cammeray

Environmental impact	Potential cumulative construction impacts
	Category 1 projects
	Western Harbour Tunnel and Warringah Freeway Upgrade
Traffic and transport ¹	Additional and prolonged reduction in level of service Ernest Street, Falcon Street and Miller Street at Cammeray due to construction traffic volumes. Increase in delays at intersections including Brook Street/Warringah Freeway ramps due to introduction of construction traffic. Increases in bus travel times on the Warringah Freeway due to increased traffic demand across the southbound bus lane south of Falcon Street ¹ .
Health and safety	Health effects for residential receivers around Cammeray from stress and anxiety from changes in the urban environment.
Noise and vibration	Additional and prolonged temporary increase in construction noise from construction work at Cammeray Golf Course construction support site (BL1) and temporary construction support sites at Cammeray Golf Course for the Western Harbour Tunnel and Warringah Freeway Upgrade project ² .
Urban design and visual amenity	Additional and prolonged moderate to high landscape and visual impacts for receivers around the Warringah Freeway corridor, residential receivers around Cammeray, North Cremorne and Neutral Bay, and recreational receivers at Cammeray Park.
Socio-economic, land use and property	<p>Additional temporary and permanent loss of open space, parks and recreation facilities at Cammeray Golf Course.</p> <p>Additional and prolonged:</p> <ul style="list-style-type: none"> • Increase in passing trade for local businesses and services in North Sydney and Cammeray, particularly along Miller Street • Land use impacts at Cammeray Golf Course due to consecutive construction periods • Amenity impacts for receivers around the Warringah Freeway and for residential and recreational receivers at Cammeray • Impacts to community perceptions of public health and safety due to increases in construction traffic for residential and recreational receivers at Cammeray • Increase in demand for construction workers, providing benefits for local workers.
Non-Aboriginal heritage	<ul style="list-style-type: none"> • Additional and prolonged moderate impacts on Cammeray Park (including golf course) • Minor temporary impacts to additional heritage items in the vicinity of North Sydney and Cammeray.

Note 1: Quantitative cumulative assessment presented in Chapter 8 (Construction traffic and transport)

Note 2: Cumulative assessment presented in Chapter 10 (Construction noise and vibration)

27.3.2 Artarmon

Projects

Construction activities for the Gore Hill Freeway Connection component of the project would occur in close proximity to the following projects:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Chatswood dive site and Artarmon substation site. The works at Artarmon substation are anticipated to conclude at the beginning of 2022 and are therefore considered in terms of construction fatigue only.

Potential cumulative impacts

Potential cumulative construction impacts at the Gore Hill Freeway Connection component of the project are identified in Table 27-6.

In summary, cumulative impacts are most likely to be experienced by receivers in the Artarmon area near the Gore Hill Freeway corridor as a result of interactions with the identified projects. The volume of traffic associated with construction works at the Gore Hill Freeway temporary construction support sites has the potential to result in cumulative impacts to the local road network at Artarmon, primarily at Dickson Avenue and Reserve Road.

There is potential that cumulative temporary construction noise, visual amenity, social and economic impacts may also be experienced by receivers at Artarmon due to the number of nearby projects under construction both concurrently and consecutively. Cumulative construction impacts would most likely be experienced by receivers near the Warringah Freeway and Gore Hill Freeway road corridors and around the Artarmon industrial area. There would be around a one year break between the completion of works for the Artarmon substation site as part of Sydney Metro City & Southwest (Chatswood to Sydenham) at the beginning of 2022 and the commencement of construction at the Gore Hill Freeway connections. Works prior to completion are likely associated with the testing/commissioning phase of the project and subsequently construction fatigue impacts may be reduced. These projects may also provide cumulative benefits for local construction workers and to local businesses and services in these areas by increasing passing trade and demand for services during construction periods.

The potential for construction fatigue and complaint fatigue at Artarmon is discussed in Section 27.3.7.

Potential cumulative impacts resulting from the construction of the projects considered are expected to be negligible for the following issues:

- Air quality
- Health and safety
- Non-Aboriginal heritage
- Aboriginal heritage
- Geology, groundwater and soils
- Hydrology and water quality
- Flooding
- Biodiversity
- Hazards and risks
- Resource use and waste management
- Sustainability
- Climate change and greenhouse gases.

As such, these issues are not considered further in Table 27-6.

Table 27-6 Potential cumulative construction impacts – Artarmon

Environmental impact	Potential cumulative construction impacts	
	Category 1 projects	Category 2 projects
	Western Harbour Tunnel and Warringah Freeway Upgrade	Sydney Metro City & Southwest
Traffic and transport	Negligible ¹	Prolonged heavy and light vehicle traffic on the local road network at Artarmon, including Dickson Road and Reserve Road.
Noise and vibration	Additional and prolonged temporary increase in construction noise for commercial, industrial and residential receivers from construction work at the Gore Hill Freeway temporary construction support sites and temporary construction support sites at the Warringah Freeway for the Western Harbour Tunnel and Warringah Freeway Upgrade project ² .	Prolonged temporary increase in construction noise for commercial and industrial receivers near construction works at the Gore Hill Freeway temporary construction support sites ² .
Urban design and visual amenity	Additional and prolonged minor landscape and visual impacts for motorists using the Warringah Freeway and Gore Hill Freeway.	Prolonged minor landscape and visual impacts for industrial and commercial receivers near Dickson Avenue and Reserve Road.
Socio-economic, land use and property	<p>Additional and prolonged:</p> <ul style="list-style-type: none"> • Increase in passing trade for local businesses and services in Artarmon near the Warringah Freeway and Gore Hill Freeway corridors • Amenity impacts in Artarmon near the Warringah Freeway and Gore Hill Freeway corridors, primarily due to works outside standard construction hours • Impacts to community perceptions of public health and safety due to increases in construction traffic • Increase in demand for construction workers, providing benefits for local workers. 	<p>Additional and prolonged:</p> <ul style="list-style-type: none"> • Increase in passing trade for local businesses and services in the Artarmon industrial area • Amenity impacts in the Artarmon industrial area • Increase in demand for construction workers, providing benefits for local workers.

Note 1: Quantitative cumulative assessment presented in Chapter 8 (Construction traffic and transport)

Note 2: Cumulative assessment presented in Chapter 10 (Construction noise and vibration).

27.3.3 Naremburn and Willoughby

Projects

Construction activities at the Flat Rock Drive construction support site (BL2) would occur in close proximity to the following projects:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site. The works at Artarmon substation site are anticipated to conclude at the beginning of 2022 and are therefore considered in terms of construction fatigue only
- Channel 9 site staged residential redevelopment.

Potential cumulative impacts

Potential cumulative construction impacts at Naremburn and Willoughby are identified in Table 27-7.

Cumulative impacts associated with the Western Harbour Tunnel and Warringah Freeway Upgrade project would be limited to potential temporary increases in construction noise for residential and recreational receivers in the Naremburn and Willoughby area resulting from concurrent and consecutive construction programs with the project. Cumulative construction impacts would most likely result from works at the Flat Rock Drive construction support site (BL2) and temporary construction support sites at the Warringah Freeway for the Western Harbour Tunnel and Warringah Freeway Upgrade project.

The construction of the proposed Channel 9 site staged residential development (14 Artarmon Road, Willoughby) is assumed to overlap with construction of the project. Cumulative construction impacts would most likely be experienced by residential receivers in Willoughby and Naremburn and would be associated with concurrent construction activities of the development and the project. Potential cumulative construction impacts for surrounding residents are likely to be associated with increased construction traffic, urban design, visual amenity and social and economic impacts associated with vegetation removal and demolition activities given the proximity of the development to the Flat Rock Drive construction support site (BL2).

The potential for construction fatigue and complaint fatigue at Naremburn and Willoughby is discussed in Section 27.3.7.

Potential cumulative impacts resulting from the construction of the projects considered are expected to be negligible for the following issues:

- Air quality
- Health and safety
- Non-Aboriginal heritage
- Aboriginal heritage
- Geology, groundwater and soils
- Hydrology and water quality
- Flooding
- Biodiversity
- Hazards and risks
- Resource use and waste management
- Sustainability
- Climate change and greenhouse gases.

As such, these issues are not considered further in Table 27-7.

Cumulative impacts expected to result from construction activities at Naremburn and Willoughby due to the Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site would be due to construction fatigue. Impacts are considered likely to be negligible and as such this project has not been considered further in Table 27-7.

Table 27-7 Potential cumulative construction impacts – Naremburn and Willoughby

Environmental impact	Potential cumulative construction impacts	
	Category 1 projects	Category 3 projects
	Western Harbour Tunnel and Warringah Freeway Upgrade	Channel 9 site staged residential redevelopment
Traffic and transport	Negligible ¹	Potential for prolonged heavy and light vehicle traffic on the local road network at Naremburn and Willoughby during assumed construction overlap.
Noise and vibration	Additional and prolonged temporary increase in construction noise for residential and recreational receivers from construction works at the Flat Rock Drive construction support site (BL2) and temporary construction support sites at the Warringah Freeway for the Western Harbour Tunnel and Warringah Freeway Upgrade project ² .	Negligible
Urban design and visual amenity	Negligible	Prolonged temporary minor landscape and visual impacts for residential receivers at Naremburn and Willoughby due to demolition and vegetation clearing works at the Channel 9 site and establishment of the Flat Rock Drive construction support site (BL2).
Socio-economic, land use and property	Negligible	Additional and prolonged amenity impacts: <ul style="list-style-type: none"> • In the Naremburn and Willoughby residential area during assumed construction overlap • To public open space and recreation facilities.

Note 1: Quantitative cumulative assessment presented in Chapter 8 (Construction traffic and transport).

Note 2: Cumulative assessment presented in Chapter 10 (Construction noise and vibration)

27.3.4 Middle Harbour

Works at the Middle Harbour cofferdams and the Spit West Reserve construction support site (BL9) would be unlikely to produce cumulative impacts with the projects identified in Table 27-3 and strategic plans in Table 27-4.

27.3.5 Balgowlah

Construction of the project in Balgowlah would be unlikely to produce cumulative impacts with the projects identified in Table 27-3 and strategic plans in Table 27-4.

Additional cumulative construction impacts at Balgowlah may be generated by future projects associated with the *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a) (refer to Table 27-4), however construction programs and specific scopes for individual projects have not yet been released.

27.3.6 Seaforth, Killarney Heights and Frenchs Forest

Construction of the project in Seaforth, Killarney Heights and Frenchs Forest would be unlikely to produce cumulative impacts with the projects identified in Table 27-3 and strategic plans in Table 27-4.

Additional cumulative construction impacts at Frenchs Forest may be generated by future projects associated with the *Northern Beaches Hospital Precinct Structure Plan* (Northern Beaches Council, 2017b) (refer to Table 27-4), however construction programs and specific scopes for individual projects have not yet been released.

27.3.7 Construction and complaint fatigue

Construction fatigue

There is potential for construction fatigue to be experienced by receivers near the project. Construction fatigue may be experienced by receivers that are near concurrent or consecutive project construction activities where the activities overlap or have little or no break between the activities of one project, or multiple adjacent projects.

Areas considered most likely to experience sustained impacts to receivers that may result in construction fatigue include residential receivers in North Sydney and Cammeray near the Cammeray Golf Course and the Warringah Freeway, and receivers in Artarmon near the Warringah Freeway and Gore Hill Freeway. Construction fatigue in the above areas may occur as a result of the close proximity of multiple construction sites for the project, and from construction activities associated with the following projects:

- North Sydney and Cammeray
 - Western Harbour Tunnel and Warringah Freeway Upgrade
- Artarmon
 - Western Harbour Tunnel and Warringah Freeway Upgrade
 - Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site.

Based on the environmental impact assessment for the project and those projects listed above, potential impacts that are considered most likely to result in construction fatigue include traffic and parking, noise and vibration, visual and amenity impacts, and impacts to community perceptions of public health and safety.

There is also potential for residential receivers around Naremburn and Willoughby to experience construction fatigue as a result of the project and its proximity to the Western Harbour Tunnel and Warringah Freeway Upgrade project. Construction fatigue at this location is likely to be limited to

temporary increases in construction noise and are expected to be minor. Work would be coordinated between the various project construction sites, where feasible and reasonable, to minimise construction fatigue.

There would be around a one year break between the completion of works at the Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site at the beginning of 2022, and the commencement of construction of the connections to and from the Gore Hill Freeway. Works prior to completion are likely associated with the testing/commissioning phase of the project and as a result, construction fatigue impacts may be reduced.

Community consultation would be carried out to understand key impacts and issues, and identify any unknown impacts from concurrent or consecutive sets of construction work. The community consultation framework is presented in Chapter 7 (Stakeholder and community engagement) and Appendix E (Community consultation framework).

Complaint fatigue

Complaint fatigue may occur where community perceptions of project complaint management systems result in failure to report concerns about construction impacts. Complaint fatigue may be compounded where multiple proponents are responsible for issues in the same area where construction of multiple projects occurs.

Areas considered most likely to generate complaint fatigue include North Sydney and Cammeray, and Artarmon, due to the proximity of the project to the following projects:

- North Sydney and Cammeray
 - Western Harbour Tunnel and Warringah Freeway Upgrade
- Artarmon
 - Western Harbour Tunnel and Warringah Freeway Upgrade
 - Sydney Metro City & Southwest (Chatswood to Sydenham) – Artarmon substation site.

A complaints management system would be implemented for the duration of construction, which would include a number of different complaint mechanisms to cater to different needs and preferences of the community (refer to Chapter 7 (Stakeholder and community engagement)). The complaints management system for the project is outlined in Appendix E (Community consultation framework).

The community relations team for the project would build a working relationship with the project teams for other major projects under construction at the same time as the project to identify stakeholders and community members who may be susceptible to complaint fatigue.

27.3.8 Summary

In summary, the potential cumulative impacts during construction of the project based on likely interactions with other projects may occur around North Sydney and Cammeray, Artarmon, and Naremburn and Willoughby. Potential cumulative impacts would be generated by interactions between the project and the Western Harbour Tunnel and Warringah Freeway Upgrade project at North Sydney and Cammeray, Sydney Metro City & Southwest (Chatswood to Sydenham) at Artarmon, and the Western Harbour Tunnel and Warringah Freeway Upgrade project and Channel 9 staged residential redevelopment at Naremburn and Willoughby.

Without mitigation, key potential cumulative impacts would likely include minor temporary increases in traffic volumes, construction noise and vibration, decreased visual amenity and land use impacts. There is also potential for construction fatigue and complaint fatigue to be experienced by surrounding receivers at these locations as a result of concurrent and consecutive construction programs.

The project design and construction methodology has been developed with consideration of these issues and attempts to mitigate many of these issues where possible. The community consultation

framework presented in Chapter 7 (Stakeholder and community engagement) and Appendix E (Community consultation framework) has also been developed with consideration of complaint fatigue and includes procedures to proactively manage this issue where possible. Potential cumulative construction impacts would be managed in accordance with the measures outlined in Section 27.5.

27.4 Assessment of potential cumulative operational impacts

Potential cumulative impacts during the operation of the project are included in the operational modelling and assessment of various issues. This has been used to inform the assessment of key issues, including for traffic and transport, noise and vibration, air quality and human health.

The operational modelling scenarios have considered cumulative impacts associated with the Category 1 and 2 projects listed in Table 27-3. Category 3 projects were excluded as they were considered unlikely to generate cumulative operational impacts. In addition to Category 1 and 2 projects, some additional projects have been considered outside the two-kilometre radius as they are considered to be relevant to some operational models, which operate on a wider scale to the cumulative assessment in this chapter.

Table 27-8 identifies the projects considered in the operational cumulative impact assessments carried out for some of the key individual issues in the environmental impact statement.

Table 27-8 External projects included in the operational modelling scenarios for the environmental impact assessment

Projects included in operational model	Traffic and transport	Noise and vibration	Air quality	Human health
WestConnex program of works	✓	✓	✓	✓
Sydney Gateway ³	✓	✓	✓	✓
M6 Motorway (Stage 1) ^{1, 3}	✓	✓	✓	✓
M6 Motorway (full project) ^{2, 3}	✓	✓	✓	✓
NorthConnex	✓			
Northern Beaches Hospital road upgrade project	✓			

Note 1: M6 Motorway (Stage 1) is considered as part of the 2027 'Do something – cumulative' scenario

Note 2: M6 Motorway (full project) is considered as part of the 2037 'Do something – cumulative' scenario

Note 3: Since the commencement of this assessment, the M6 Motorway (Stage 1) and Sydney Gateway projects have been approved. As these projects would not have a substantial influence on the current traffic network that would be impacted by the Beaches Link and Gore Hill Freeway Connection project, these projects have not been assumed in the 'Do minimum' scenarios.

The operational modelling considered the following scenarios:

- Without the project ('Do minimum')
- With the project ('Do something')
- With the project and other planned or proposed projects ('Do something cumulative').

Within the operational models:

- The 'Do minimum' scenarios include approved, under construction and/or recently opened motorway projects (NorthConnex and WestConnex) but without Western Harbour Tunnel and Warringah Freeway Upgrade, Beaches Link and Gore Hill Freeway Connection, Sydney Gateway and M6 Motorway (Stage 1) projects. It also reflects the operational effects of approved, under construction and/or recently completed major projects (eg Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade projects)

- The 'Do something' scenarios include NorthConnex, WestConnex, Beaches Link and Gore Hill Freeway Connection and Warringah Freeway Upgrade projects but without Western Harbour Tunnel, Sydney Gateway and M6 Motorway (Stage 1) projects. It also includes Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade projects
- The 'Do something cumulative' scenarios include NorthConnex, WestConnex, Western Harbour Tunnel and Warringah Freeway Upgrade, Beaches Link and Gore Hill Freeway Connection, Sydney Gateway and M6 Motorway projects. It also includes Sydney Metro City & Southwest and Northern Beaches Hospital road upgrade projects.

The Warringah Freeway Upgrade is considered as part of the 'Do something' scenarios (ie with the project) as the Warringah Freeway Upgrade component would need to be constructed and operational to facilitate Beaches Link connections to the Warringah Freeway at Cammeray.

The cumulative assessments for the issues identified in Table 27-8 are discussed in detail in their respective assessment chapters and technical working papers, as listed below, and are therefore not considered further in this chapter:

- Traffic and transport: Chapter 9 (Operational traffic and transport) and Appendix F (Technical working paper: Traffic and transport)
- Noise and vibration: Chapter 11 (Operational noise and vibration) and Appendix G (Technical working paper: Noise and vibration)
- Air quality: Chapter 12 (Air quality) and Appendix H (Technical working paper: Air quality)
- Human health: Chapter 13 (Human health) and Appendix I (Technical working paper: Health impact assessment).

Excluding the assessments identified in Table 27-8, the potential cumulative operational impacts are expected to be limited to social and economic, and visual amenity issues.

Potential cumulative social and economic impacts would be generated by Category 1 and 2 projects. The Category 3 projects identified in Table 27-3 were considered unlikely to generate cumulative operational social and economic impacts. Cumulative operational impacts would be associated with improved travel benefits for communities, business and industry, including freight, across the Sydney transport network. The project, in conjunction with the Western Harbour Tunnel and Warringah Freeway Upgrade project, would help to reduce traffic on major roads, including Military Road/Spit Road/Manly Road, Eastern Valley Way, Brook Street, Miller Street, Warringah Road, Ourimbah Road, Frenchs Forest Road (at Seaforth town centre), Pacific Highway and Western Distributor, supporting local environment and amenity improvements in areas surrounding the project. By providing new underground bypass routes, the Western Harbour Tunnel and Beaches Link program of works would enable express bus services to travel to and from the Northern Beaches region via the new tunnel and motorway network to destinations like North Sydney, the Sydney CBD, Macquarie Park and St Leonards, freeing up surface roads for local buses and local traffic, supporting amenity improvements for town centres and businesses.

In addition, the Western Harbour Tunnel and Beaches Link program of works would result in improved access and connectivity for residents, business and industry between the Northern Beaches and destinations across the Greater Sydney region, including the Sydney CBD.

Through the re-purposing of land at Balgowlah as new and improved open space and recreation facilities for the community, the project would support the implementation of the *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a). The strategy aims to increase sporting fields and recreational facilities in response to a growing shortfall in sporting fields and recreation facilities in the Northern Beaches local government area. Converting existing open space such as golf courses to sports fields was identified as one of six actions to address the need for more sportsgrounds and new and improved facilities. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved open space and recreation facilities at Balgowlah.

Potential adverse cumulative visual amenity impacts at Cammeray would be generated by the Western Harbour Tunnel and Beaches Link program of works. Operational facilities for both projects introduce new built forms into existing open space at Cammeray Golf Course and generate cumulative landscape character and visual amenity impacts for residential receivers at Cammeray and motorists on the Warringah Freeway and Ernest Street.

There would be no cumulative impacts to geology, groundwater and soils, hydrology and water quality, flooding, hazards and risks, resource use and waste management, sustainability, Aboriginal heritage, non-Aboriginal heritage, climate change and greenhouse gases, and biodiversity during the operation of the project, as impacts related to these aspects would generally be limited to the construction phase of the project.

27.5 Environmental management measures

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, negative cumulative impacts with surrounding development. As each of the study disciplines presented in this environmental impact statement have identified management measures to reduce potential impacts to acceptable levels, cumulative mitigation measures have focused on broader opportunities around inter-project coordination and communication with stakeholders.

Construction fatigue is recognised as an important issue for communities near large construction projects that overlap in time or space. Substantial effort to coordinate with other projects during construction would be made to further manage construction fatigue impacts where possible.

Further opportunities to more effectively manage construction fatigue would be considered during further design development and construction of the project.

Environmental management measures relating to cumulative impacts are outlined in Table 27-9.

Table 27-9 Environmental management measures – cumulative impacts

Ref	Phase	Impact	Environmental management measure	Location
CI1	Pre-construction	Cumulative impacts	Considered and tailored multi-party engagement and cooperation will be established prior to construction to ensure all contributors to impacts are working together to minimise adverse impacts or enhance benefits of multiple projects occurring concurrently or consecutively. Haulage routes and road occupancy will be coordinated with other major transport projects via Greater Sydney Operations.	BL/GHF
CI2	Pre-construction	Construction fatigue	Multi-party engagement and cooperation will be established prior to construction to coordinate with the following projects to manage construction fatigue impacts where possible: <ul style="list-style-type: none"> Western Harbour Tunnel and Warringah Freeway Upgrade Sydney Metro City & Southwest Channel 9 site staged residential redevelopment. 	BL/GHF
CI3	Construction	Cumulative impacts	Communication strategies for the project will be managed consistently across the NSW Government transport portfolio and in	BL/GHF

Ref	Phase	Impact	Environmental management measure	Location
			accordance with the Community consultation framework for the project.	
CI4	Construction	Complaint fatigue	Complaint fatigue will be managed as outlined in Chapter 7 (Stakeholder and community engagement). Complaint management tools for the project are outlined in Appendix E (Community consultation framework).	BL/GHF
CI5	Construction	Spoil management	Co-ordination and engagement with proponents of other major projects, including external to Transport for NSW, will be undertaken prior to construction to identify the opportunity for beneficial reuse of construction spoil where it cannot be reused on site and prior to consideration of disposal options.	BL/GHF

Note: BL = Beaches Link, GHF = Gore Hill Freeway Connection



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 28

Synthesis of the environmental
impact statement

28 Synthesis of the environmental impact statement

This chapter provides a synthesis of the findings of the environmental impact statement for the project, in response to the Secretary's environmental assessment requirements issued for the project. The main body of the environmental impact statement and appendices should be referred to for further details.

The Secretary's environmental assessment requirements as they relate to the synthesis of the environmental impact statement, and where in the environmental impact statement these have been addressed, are detailed in Table 28-1.

A summary of the proposed environmental management measures relevant to the project are included in Section 28.4.

Table 28-1 Secretary's environmental assessment requirements –synthesis of the environmental impact statement

Secretary's requirement	Where addressed in EIS
1. The EIS must include, but not necessarily be limited to, the following: q. a chapter that synthesises the environmental impact assessment and provides:	This Chapter 28 (Synthesis of the environmental impact statement) provides the following:
- a succinct, but full, description of the project for which approval is sought;	A full description of the project in Section 28.1 .
- a description of any uncertainties that still exist around design, construction methodologies and/or operational methodologies and how these will be resolved in the next stages of the project;	A description of any uncertainties related to the design, construction methodologies and/or operational methodologies and their proposed resolution in Section 28.3 .
- a compilation of the impacts of the project that have not been avoided;	A compilation of the impacts of the project that have not been avoided in Section 28.4 .
- a compilation of the proposed measures associated with each impact to avoid or minimise (through design refinements or ongoing management during construction and operation) or offset these impacts;	A compilation of the proposed measures associated with each impact to avoid or minimise (through design refinements or ongoing management during construction and operation) or offset these impacts in Section 28.4 .
- a compilation of the outcome(s) the proponent will achieve; and	A compilation of the outcome(s) the project would achieve in Section 28.6 .
- the reasons justifying carrying out the project as proposed, having regard to the biophysical, economic and social considerations, including ecologically sustainable development and cumulative impacts;	Project justification and conclusions in Section 28.1 and Section 28.7 . Section 27.2 of Chapter 27 (Cumulative impacts), presents the projects that have been assessed and may have potential cumulative impacts. Potential cumulative impacts are described in Section 27.3 and Section 27.4 of Chapter 27 (Cumulative impacts).

28.1 Overview and key features of the project

28.1.1 Overview of project need

Existing arterial road connections to Sydney's Northern Beaches, including Military Road/Spit Road, Mona Vale Road, Warringah Road and Eastern Valley Way, currently experience high levels of traffic congestion. This congestion adversely affects transport connectivity, travel times, economic prosperity and local amenity for both road users and local communities. These connections are integral to the economic growth of Sydney's Eastern Economic Corridor. As Sydney's population and economy continues to grow, so would the pressure on access to these connections. Consequently, improvements to transport networks would be essential for Sydney to continue to be competitive.

The Greater Sydney Region Plan – A Metropolis of Three Cities (Greater Sydney Commission, 2018a) identifies the importance of investing in and delivering efficient and effective transport systems including road infrastructure that would relieve congestion, improve travel times, improve road safety and enhance and expand capacity on key road corridors. The project would reduce congestion and improve road network performance and efficiency, enabling sustained growth and productivity across Sydney's Eastern Economic Corridor. By providing a new underground motorway bypass of existing surface arterial roads and a third Middle Harbour crossing, the project would also enhance the resilience of the road network across the Eastern Harbour City.

The public transport network connecting the Northern Beaches to destinations such as North Sydney, the Harbour CBD and Chatswood provides many people with direct access to employment hubs, as well as access to education facilities, health centres and hospitals, and sporting, cultural and entertainment facilities. The project would improve the capacity, journey times and reliability of bus services for the Northern Beaches region through reduced congestion on existing surface routes and would facilitate opportunities to expand the express bus service network through allowing express buses to travel within the new tunnels. This would improve access to key centres and result in more people having better access to jobs, goods and services.

The Beaches Link and Gore Hill Freeway Connection project is identified as a *priority initiative* by Infrastructure Australia's *Australian Infrastructure Plan: The Infrastructure Priority List* (Infrastructure Australia, 2018) in recognition of its importance in addressing urban congestion on Sydney's road network, enhancing critical cross-harbour capacity and Northern Beaches connectivity. This new connection would improve travel times to the international gateways of Sydney Airport and Port Botany, and strategic commercial and industrial centres including North Sydney, St Leonards and Macquarie Park. Increased network capacity and connectivity as a result of the project would also result in travel time savings for freight movements, further servicing the growth of Sydney's Eastern Economic Corridor.

In addition to addressing the transport challenges created by the limited arterial roads servicing the Northern Beaches region, by relieving congestion, through traffic and 'rat running' on arterial roads, the project would also deliver benefits for urban amenity in local centres. Improved amenity in town centres along and next to key road corridors such as Mosman, Cremorne, Neutral Bay, Forestville and Seaforth would be expected as a result of reduced through traffic due to the project.

Transport for NSW is seeking approval under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Beaches Link and Gore Hill Freeway Connection, which would comprise two main components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and Wakehurst Parkway at Killarney Heights, and an upgrade of Wakehurst Parkway (the Beaches Link)
- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon (the Gore Hill Freeway Connection).

Key features of the project are described in Section 28.1.3.

28.1.2 Project objectives

The project objectives were developed to respond to the current and future network challenges and include:

- Providing greater capacity on the road network by reducing congestion and through traffic on arterial roads in northern Sydney
- Creating faster, more reliable journeys for freight services, public transport and other road users between the Northern Beaches region and other strategic centres across Greater Sydney
- Creating opportunities to expand and improve the public transport network connecting the Northern Beaches and key centres across Greater Sydney
- Improving productivity and access to services by facilitating faster and more reliable journeys for commuters and freight to reach their destinations
- Increasing the resilience of the Northern Beaches and North Shore road network to traffic incidents
- Improving urban amenity.

28.1.3 Key features of the project

Key features of the Beaches Link component of the project would include:

- Twin mainline tunnels about 5.6 kilometres long and each accommodating three lanes of traffic in each direction, together with entry and exit ramp tunnels to connections at the surface. The crossing of Middle Harbour between Northbridge and Seaforth would involve three lane, twin immersed tube tunnels
- Connection to the stub tunnels constructed at Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- Twin two lane ramp tunnels:
 - Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at the Burnt Bridge Creek Deviation, Balgowlah (about 1.2 kilometres in length)
 - Northbound and southbound connections between the mainline tunnel between Seaforth and the surface at Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
 - Eastbound and westbound connections between Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length).
- New and improved public open space and recreation facilities at Balgowlah
- A new access road connection between the Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
- Upgrade and integration works along the Wakehurst Parkway at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New and upgraded active transport infrastructure (pedestrian and cyclist facilities)
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
- Operational facilities, including a motorway control centre at the Gore Hill Freeway in Artarmon and tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest

- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed-Circuit Television (CCTV) and other traffic management systems.

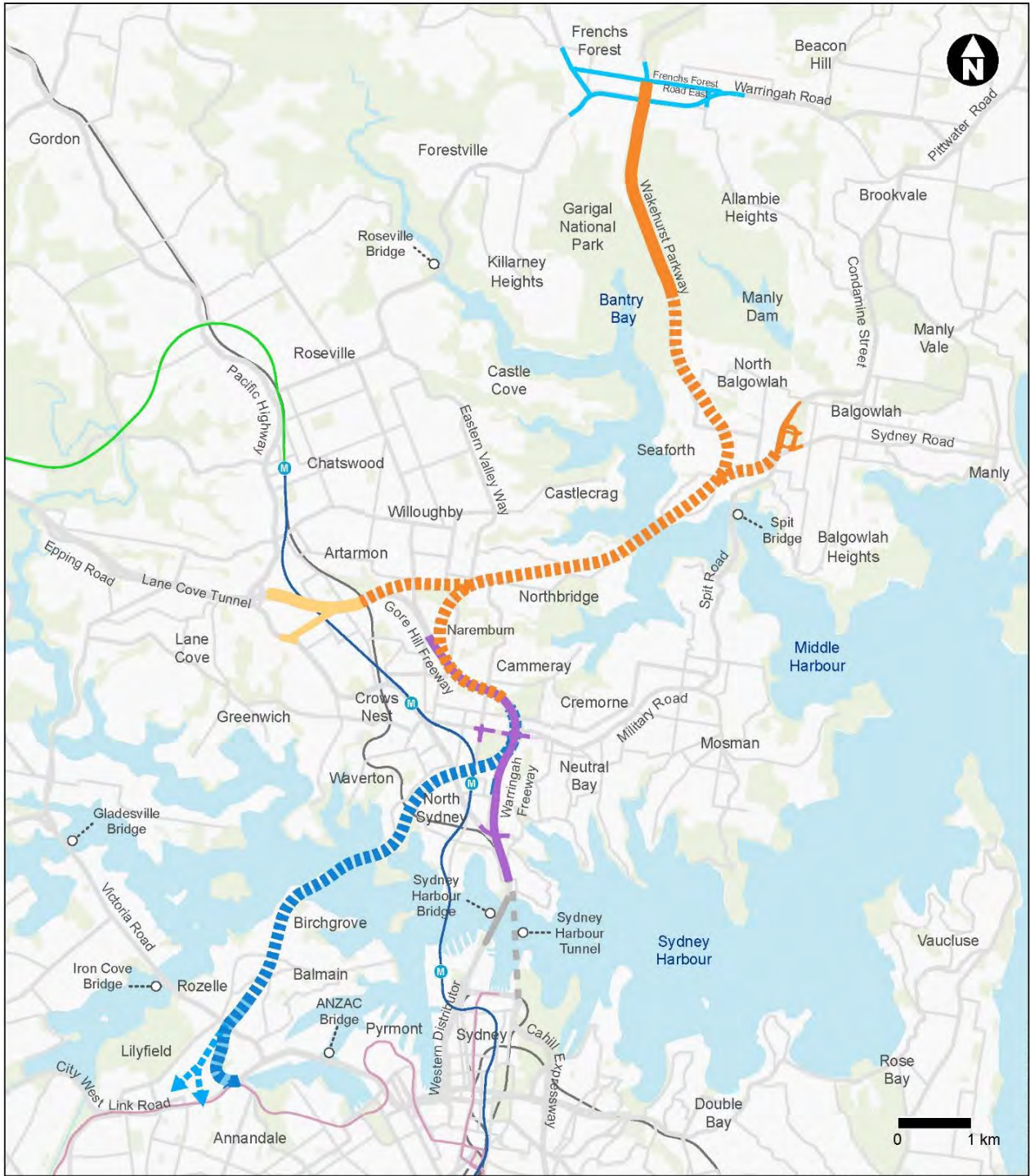
Key features of the Gore Hill Freeway Connection component of the project would include:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore and Western Line and T9 Northern Line overpass and the Pacific Highway overpass
- Modifications to the Reserve Road and Hampden Road bridges
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade and inclusion of traffic lights of the Dickson Avenue and Pacific Highway intersection
- New and upgraded active transport infrastructure (pedestrian and cyclist facilities)
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

The location of the project is shown in Figure 28-1 and key features are shown in Figure 28-2 and Figure 28-3.

The residual land created as a result of the project would largely continue to remain suitable for future development in accordance with the relevant land use zonings and applicable development standards. Where a part of any lot is identified as being usable post construction and surplus to operational requirements, or requiring boundary adjustment following the completion of construction, Deposited Plans of subdivision would be lodged at NSW Land Registry Services. Any future development of residual land would be subject to separate assessment and approval in accordance with the *Environmental Planning and Assessment Act 1979* and is beyond the scope of the project.






A detailed description of the project is provided in Chapter 5 (Project description).





Indicative only – subject to design development

Legend



Operational features

-  Beaches Link
-  Gore Hill Freeway Connection
-  Western Harbour Tunnel
-  Warringah Freeway Upgrade
-  M4-M5 Link tunnel fitout and commissioned as part of Western Harbour Tunnel

Connecting projects

-  M4-M5 Link connections (indicative)
-  Northern Beaches Hospital road upgrade project (Completed 2020)

Other projects

-  Sydney Metro City & Southwest (under construction)
-  Sydney Metro Northwest

Existing rail network



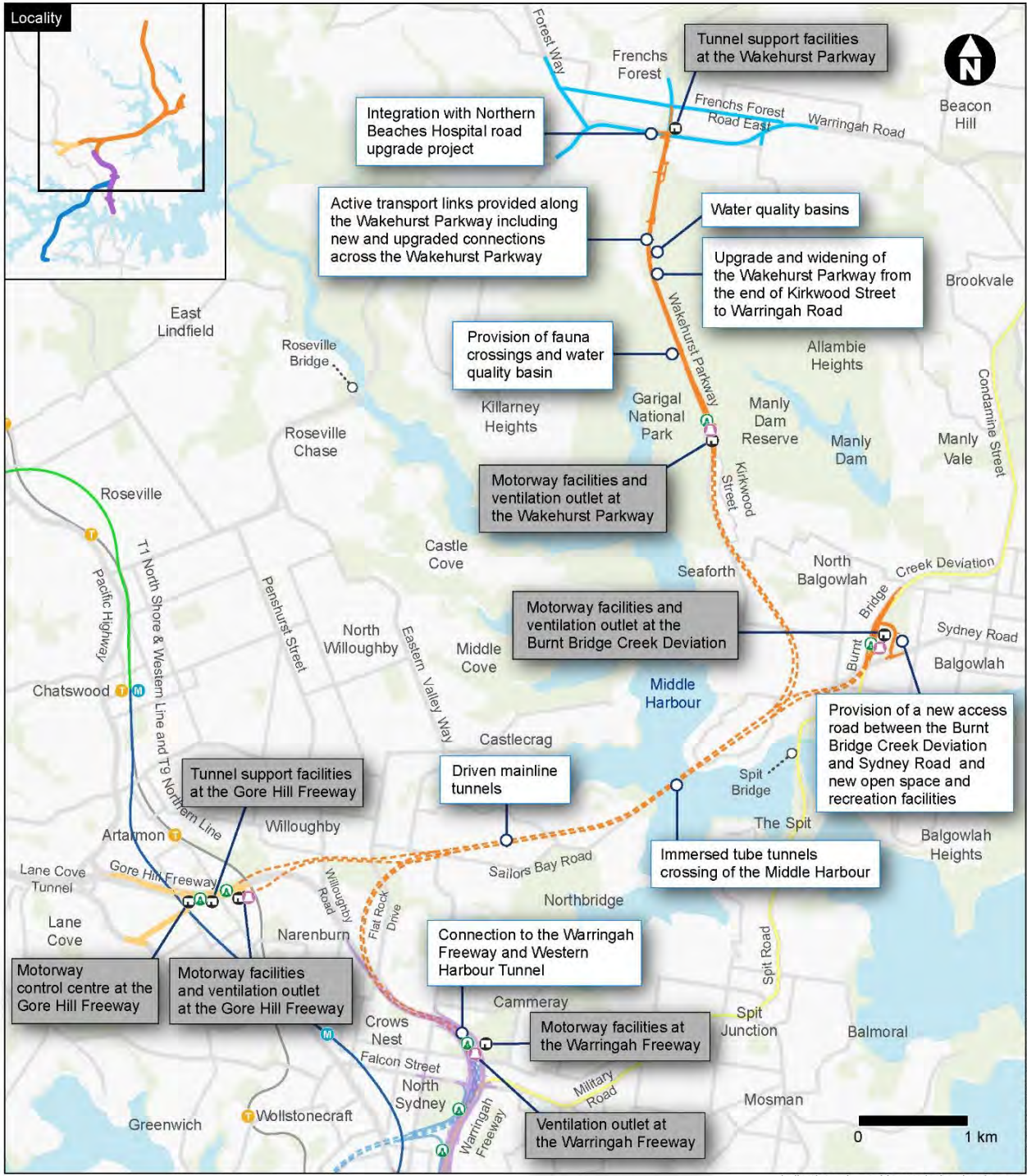
-  Suburban rail/Sydney Trains
-  Light rail

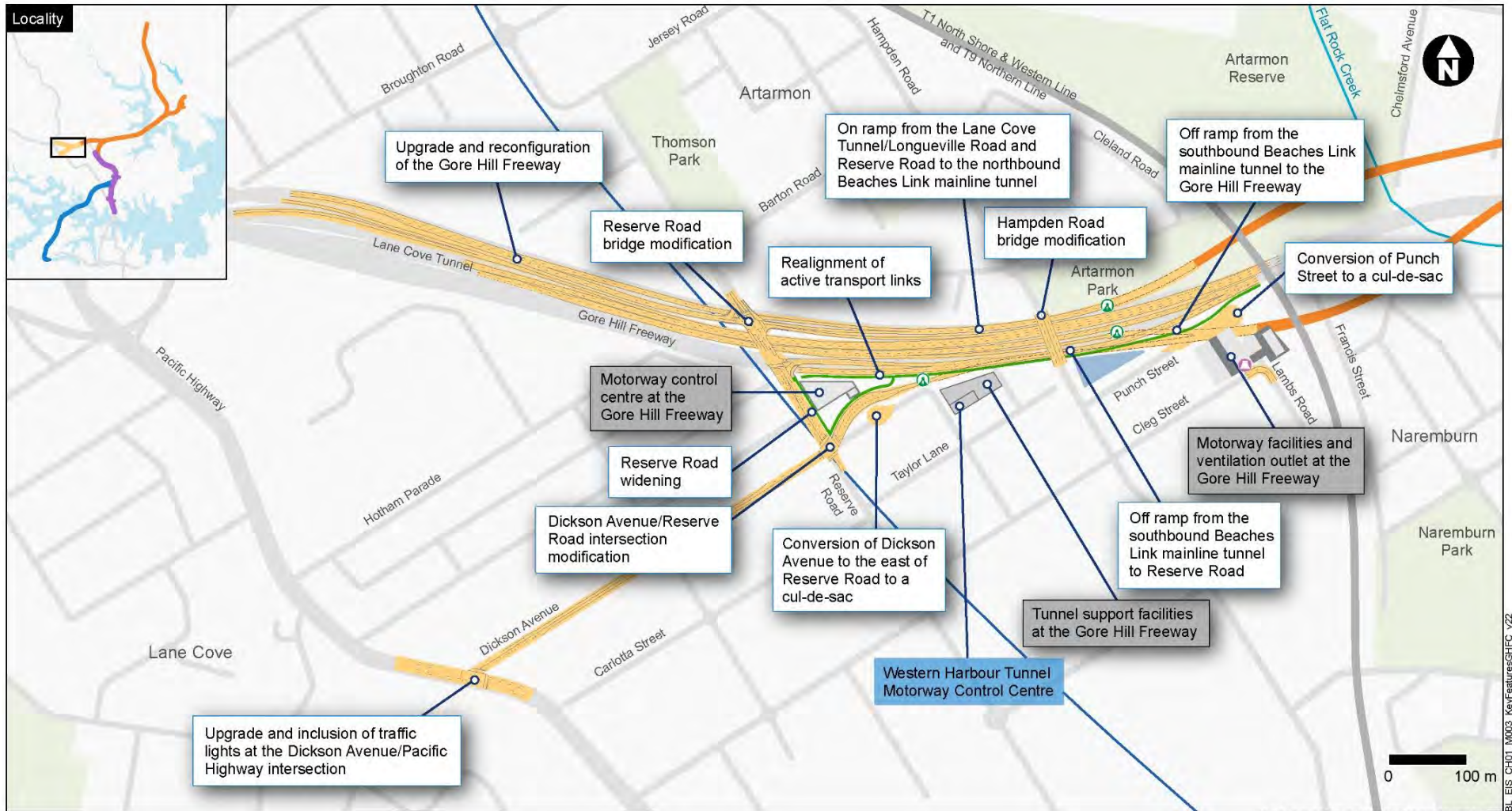
Figure 28-1 The Western Harbour Tunnel and Beaches Link program of works



Indicative only – subject to design development



Figure 28-2 Key features of the Beaches Link component of the project



Indicative only – subject to design development

Legend

Operational features

- Gore Hill Freeway Connection
- Beaches Link
- Permanent operational facility

- Surface connection
- Ventilation outlet

- Pedestrian / active transport links
- Permanent water quality basin

Existing rail network

- Suburban rail/Sydney Trains

Other projects

- Sydney Metro City & Southwest (under construction)

Figure 28-3 Key features of the Gore Hill Freeway component of the project

28.2 Construction of the project

A substantial amount of the work for the project would occur underground with the mainline and ramp tunnels being constructed using roadheaders. Where the tunnels cross Middle Harbour construction would involve excavation of the bed of the harbour and the placement of twin immersed tube tunnel units installed both on supporting piles and within a trench. The middle third of the tunnels would be installed on supporting piles and would sit generally just above the nominally dredged bed of the harbour. The northern and southern thirds of the tunnels would be installed within a trench of varying depth.

Large surface areas would be required to support underground construction activities and to support and construct the surface connections, tunnel portals, surface road works, active transport facilities (pedestrian and cyclist facilities) and operational facilities.

Construction activities for the Gore Hill Freeway Connection would generally include surface earthworks, bridgeworks, construction of retaining walls, installation of stormwater drainage and pavement construction.

Subject to planning approval and procurement, construction of the Beaches Link and Gore Hill Freeway Connection project (the project) is currently planned to commence in early 2023. On that basis, completion of the main construction works would be around around the end of 2027 with a likely opening to traffic in early 2028. Construction works for the new and improved open space and recreation facilities are planned to commence in 2023 and progressively staged to be fully completed in late 2028.

28.2.1 Key construction activities

The area required to construct the project is referred to as the construction footprint. A substantial amount of the construction footprint would be located underground within the mainline and ramp tunnels. However, surface areas would be required to support tunnelling activities and to construct the tunnel connections, tunnel portals, surface road upgrades and operational facilities.

Key construction activities would include:

- Early works and site establishment, with typical activities being property acquisition and condition surveys, utilities installation, protection, adjustments and relocations, installation of site fencing, environmental controls (including noise attenuation and erosion and sediment control), traffic management controls, vegetation clearing, earthworks, demolition of structures, building temporary construction support sites including acoustic sheds and associated access decline acoustic enclosures (where required), construction of minor access roads and the provision of property access, temporary relocation of pedestrian and cycle paths and bus stops, temporary relocation of swing moorings and/or provision of alternative facilities (mooring or marina berth) within Middle Harbour
- Construction of the Beaches Link, with typical activities being excavation of tunnel construction access declines, construction of driven tunnels, cut and cover and trough structures, construction of surface upgrade works, construction of cofferdams, dredging and immersed tube tunnel piled support activities in preparation for the installation of immersed tube tunnels, casting and installation of immersed tube tunnels and civil finishing and tunnel fitout
- Construction of operational facilities comprising:
 - A motorway control centre at the Gore Hill Freeway in Artarmon
 - Tunnel support facilities at the Gore Hill Freeway in Artarmon and at the Wakehurst Parkway in Frenchs Forest
 - Motorway facilities and ventilation outlets at the Warringah Freeway in Cammeray (fitout only of the Beaches Link ventilation outlet at Warringah Freeway (the outlet structure being constructed by Western Harbour Tunnel and Warringah Freeway Upgrade

project)), the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights

- A wastewater treatment plant at the Gore Hill Freeway in Artarmon
- Installation of motorway tolling infrastructure
- Staged construction of the Gore Hill Freeway Connection at Artarmon and upgrade and integration works at Balgowlah and along the Wakehurst Parkway with typical activities being vegetation clearing, earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of road furniture, lighting, signage and noise barriers
- Testing of plant and equipment and commissioning of the project, backfill of access declines, removal of temporary construction support sites, landscaping and rehabilitation of disturbed areas and removal of environmental and traffic controls.

Further details are provided in Chapter 6 (Construction work).

28.2.2 Temporary construction support sites

Temporary construction support sites would be required as part of the project and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. Temporary construction support sites would include:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7)
- Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

A detailed description of construction works for the project is provided in Chapter 6 (Construction work).

28.3 Project uncertainties

As with any project of the nature and scale of this project, the project design presented in this environmental impact statement would continue to be refined during further design development. This design development would be guided by the key principles adopted during the planning and assessment phase of the project. Some flexibility has been provided in the design to:

- Allow for refinement during further design and construction planning phase to consider alternative construction techniques

- Allow for refinement in response to submissions received following the exhibition of this environmental impact statement
- Respond to improved technologies or materials
- Improve value for money.

The final design may vary from that described in Chapter 5 (Project description). If approval is granted, any changes to the project would be reviewed for consistency with the assessment contained in the environmental impact statement including relevant environmental management measures, environmental performance outcomes and any future conditions of approval. If design refinements are not consistent with the approval issued by the Minister for Planning and Public Spaces, approval would be sought from the Minister for any such modifications in accordance with the requirements of Division 5.2 of the *Environmental Planning and Assessment Act 1979*.

Areas where further work would be carried out to optimise the design outcomes and construction planning include refinements to:

- Avoid utilities that present substantial construction difficulties in terms of logistics, time and/or cost
- Reduce the duration of construction
- Avoid areas of environmental sensitivity
- Reduce impacts on the community during construction and/or operation
- Improve operation of the project without increasing the potential environmental impacts.

For any future design refinements, a screening assessment would be carried out to consider whether the refinement would result in:

- Any inconsistency with the conditions of approval
- Any inconsistency with the objectives and operation of the project as described in the environmental impact statement
- A change to the approved project that may require a modification of the approval
- Any potential environmental or social impacts of a greater scale or impact on previously unaffected receivers than that considered by the environmental impact statement or the submissions and preferred infrastructure report.

Table 28-2 outlines key project components that have been identified as requiring resolution during further design development, construction and/or operation of the project and references where these uncertainties are discussed in this environmental impact statement.

Table 28-2 Resolution of project uncertainties

Project uncertainties	Proposed resolution	Timing	Where discussed
Tunnel design and operational facilities	<ul style="list-style-type: none"> Confirmation of the final tunnel alignment would be carried out by the construction contractor, once appointed Future consultation to engage with communities and affected stakeholders about the final alignment of the mainline and ramp tunnels would be carried out to explain any differences between the design presented and assessed in this environmental impact statement and the design refined during further development, as required The final configuration and design requirements for the tunnel electricity supply and substations and mains water connection (if required) would be determined during further design development in consultation with relevant utility providers. 	Design	Chapter 5 (Project description)
New and improved open space and recreation facilities	<ul style="list-style-type: none"> The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to consultation for the Beaches Link environmental impact statement. This process would start after the environmental impact statement public exhibition period and well in advance of construction starting. 	Design	Chapter 5 (Project description)
Local road changes	The need for, design and location of traffic calming measures as part of the surface connections and road works to be provided at the Burnt Bridge Deviation at Balgowlah would be confirmed during further design development in consultation with Northern Beaches Council.	Design	Chapter 5 (Project description)

Project uncertainties	Proposed resolution	Timing	Where discussed
Utilities	Confirmation of the extent of installation, relocation, adjustment and/or protection of utilities would be carried out during further design development and in consultation with the relevant utility providers. To confirm the extent of utility works, additional utility tracing and/or potholing investigations may be required and may result in the need to carry out works outside of the construction footprint, particularly within and around surface connections and road works. As described in Chapter 5 (Project description), Appendix D (Utilities management strategy) provides the framework for how these utility relocations and adjustments would be identified, assessed and managed.	Design	Chapter 5 (Project description) Appendix D (Utilities management strategy)
Temporary construction support sites – location, layout and facilities	The final location and layout of temporary construction support sites would be confirmed during construction planning, with consideration of the final construction methodologies for the project and in accordance with the conditions of approval, once determined.	Design	Chapter 6 (Construction work)
Cofferdams and extent of dredging works in Middle Harbour	<ul style="list-style-type: none"> • The final location and layout of the Middle Harbour cofferdams (BL7 and BL8) would be confirmed during further design development and construction planning, with consideration of geotechnical conditions, the final construction methodologies for the project and in accordance with the conditions of approval • The final extent of dredging works for the construction of the immersed tube tunnels would be confirmed during further design development and construction planning for the project, with consideration of additional geotechnical investigations and the final construction methodologies for the project. 	Design	Chapter 6 (Construction work)

Project uncertainties	Proposed resolution	Timing	Where discussed
<p>Spoil disposal management and encapsulation opportunities for contaminated material encountered on site</p>	<ul style="list-style-type: none"> • Further site investigations during the further design development and construction planning phases would inform contamination management including determining where encapsulation is appropriate • Any material that is not suitable for encapsulation would be loaded into sealed and covered trucks for disposal at a suitably licensed facility that would be confirmed during development of the detailed construction method for the project by the construction contractor, once appointed • A review of encapsulation, spoil transport and disposal options identified in the environmental impact statement would be carried out by the construction contractor, once appointed • Spoil transport options would be adjusted as required and the relevant construction management plans updated, in accordance with the relevant requirements of the conditions of approval • Confirmation of the location for a loadout facility for any dredged material not suitable for offshore disposal would be confirmed during further construction planning, in accordance with the relevant requirements of the conditions of approval • The location, design and configuration for encapsulating contaminated materials encountered on site during earthworks at Flat Rock Drive construction support site (BL2) and surface works associated with Balgowlah and Wakehurst Parkway would be confirmed during further design development and construction planning. 	<p>Design and construction</p>	<p>Chapter 6 (Construction work) Chapter 24 (Resource use and waste management)</p>

Project uncertainties	Proposed resolution	Timing	Where discussed
Construction method and staging	<ul style="list-style-type: none"> Final construction methodologies and staging plans including road possessions would be prepared by the construction contractor, once appointed. The staging plans would be based on further design development and refinement of the construction method. The plans would describe how construction areas associated with road works would be established to safely maintain traffic flows in areas of reduced traffic capacity, and to minimise delays to motorists, public transport, pedestrians and cyclists. 	Construction	Chapter 6 (Construction work) Chapter 8 (Construction traffic and transport)
Final noise mitigation requirements	<ul style="list-style-type: none"> Further noise modelling would be carried out during further design development to confirm the receivers eligible for at-property treatments. The operational noise performance of the project would be reviewed during further design development and operational noise mitigation (ie quieter noise pavement, noise barrier, at-property treatment or a combination) would be confirmed subject to a reasonable and feasible assessment in accordance with the <i>Noise Mitigation Guideline</i> (Roads and Maritime Services, 2015g) Ongoing community and stakeholder consultation to assist in informing and determining appropriate noise mitigation would be carried out during further design development and construction. 	Design	Chapter 11 (Operational noise and vibration)
The boundary and potential impacts to the Frenchs Bullock Track	<ul style="list-style-type: none"> Further detailed survey would be completed to confirm the heritage curtilage of the southern section of Frenchs Bullock Track prior to construction to determine if this section would be directly impacted Where the heritage curtilage of the Frenchs Bullock Track is within the construction footprint or the boundary of proposed permanent infrastructure, the track would be avoided where possible through further design development. 	Design	Chapter 14 (Non-Aboriginal heritage)

Project uncertainties	Proposed resolution	Timing	Where discussed
Extent and final design for fauna fencing along the Wakehurst Parkway	The extent and final alignment of fauna fencing along the Wakehurst Parkway would be confirmed during further design development by the construction contractor, once appointed.	Design	Chapter 5 (Project description)
The presence of, and potential impacts on registered Aboriginal Heritage Information Management System (AHIMS) sites and sites containing potential Aboriginal heritage significance	<ul style="list-style-type: none"> • Further consultation with Department of Premier and Cabinet (Heritage), the Metro Local Aboriginal Land Council (LALC) and Registered Aboriginal Parties would be carried out to determine appropriate management measures for previously recorded Aboriginal sites not assessed during archaeological surveys due to site accessibility constraints • Terrestrial Aboriginal site condition surveys would be completed using photogrammetry and 3D capture techniques employed to confirm where vibration monitoring at terrestrial AHIMS sites would be required. 	Design and construction	Chapter 15 (Aboriginal cultural heritage)
The presence of, and potential impacts on maritime heritage	<ul style="list-style-type: none"> • Any pre-dredge clearance of the bed of the harbour to include involvement by a maritime archaeologist to minimise the risk of impact to potential maritime heritage remains such as maritime infrastructure, shipwrecks or submerged heritage sites and items • Complete and review the sidescan sonar survey for areas to be affected by project works to identify any additional potential heritage items requiring investigation and assessment • Carry out high-resolution geophysical survey(s) to further investigate potential submerged cultural heritage material in consultation with a maritime archaeology advisor • Carry out controlled archaeological investigations to recover any artefacts if required and feasible. 	Design and construction	Chapter 14 (Non-Aboriginal heritage) Chapter 15 (Aboriginal cultural heritage)

Project uncertainties	Proposed resolution	Timing	Where discussed
Location and degree of contamination	<ul style="list-style-type: none"> Further investigations of potentially contaminated sites are required to quantify the exposure risk. These investigations would be carried out prior to construction activities so contamination (if present) can be adequately planned for and managed. 	Pre-construction and construction	Chapter 16 (Geology, soils and groundwater)
The potential presence of landfill generated gas which could impact on the construction and/or operation of the project	<ul style="list-style-type: none"> Ground gas investigations would be carried out in Flat Rock Reserve to assess for the potential presence of landfill generated gas which could impact on the construction and/or operation of the project Ground gas investigations would be carried out in accordance (where applicable) with the <i>Guideline for the Assessment and Management of Sites Impacted by Hazardous Ground Gases</i> (NSW EPA, 2012). 	Pre-construction and construction	Chapter 16 (Geology, soils and groundwater)
Groundwater inflow rates and water table drawdown associated with tunnelling in proximity to Middle Harbour	<ul style="list-style-type: none"> A tunnelling procedure that details a methodology to determine when and what type of waterproofing is required to be installed would be implemented during the further design development phase and outcomes monitored Groundwater inflows into the tunnels would be monitored during construction and compared to predictions from the updated groundwater model The groundwater model would be updated based on the results of the monitoring and if required, feasible and reasonable management measures to minimise groundwater inflows would be implemented to ensure that groundwater inflow performance criteria are met. 	Design and construction	Chapter 16 (Geology, soils and groundwater)

Project uncertainties	Proposed resolution	Timing	Where discussed
The locations and extent of potential settlement impacts	<ul style="list-style-type: none"> • Further assessment would be carried out with regards to settlement, including groundwater and geotechnical modelling during further design development to refine the level of predicted settlement, where required • Efforts to minimise impacts in areas where higher ground movement in excess of settlement limits is predicted would be carried out • Building condition surveys and monitoring of settlement during construction would be carried out by the construction contractor. 	Design and construction	Chapter 16 (Geology, soils and groundwater)
Construction and operational water treatment plant design local stormwater discharge capacity	<ul style="list-style-type: none"> • The local stormwater system capacity to receive construction and operational wastewater treatment plant inflows would be confirmed during further design development, and environmental management measures implemented in the event of a capacity issue. 	Design	Chapter 17 (Hydrodynamics and water quality)
Surface water drainage and management infrastructure	<ul style="list-style-type: none"> • The drainage design for the project would be continued to be refined during further design development and would include confirmation of capacity requirements and extent of scour protection • The type and design of the stormwater management system including permanent water quality basins, would continue to be refined and modelled as part of further design development with the aim of meeting or improving the existing water quality of receiving waters. This would also include consideration of best management practice guidelines including Transport for NSW's Water sensitive urban design guideline (Roads and Maritime Services, 2017d). 	Design	Chapter 17 (Hydrodynamics and water quality)

Project uncertainties	Proposed resolution	Timing	Where discussed
Flood behaviour during operation	<ul style="list-style-type: none"> Further flood modelling would be carried out during further design development to confirm the level of predicted impacts and ensure appropriate mitigation measures identified for areas where higher flooding is predicted, eg provision of flood walls and/or increased flood storage capacity. Further flood modelling would also include the consideration of future climate change and a partial blockage of the local stormwater drainage system. 	Design	Chapter 18 (Flooding)
Groundwater drawdown impact on groundwater dependent ecosystems and stream flows	<ul style="list-style-type: none"> A focused study confirming the potential groundwater drawdown and associated baseflow reductions at Burnt Bridge Creek, Flat Rock Creek and Quarry Creek due to tunnelling would be carried out. Where unacceptable ecological impacts are predicted, feasible and reasonable mitigation measures to address the impacts would be identified, incorporated into the detailed design, and implemented during construction. Monitoring of the vegetation within the mapped groundwater dependent ecosystem adjoining Flat Rock Creek and Quarry Creek would be carried out to assess how its health may be impacted by water table drawdown. This would be carried out in conjunction with monitoring of groundwater levels, groundwater quality and surface water flows If monitoring identifies potential long term detrimental effects to groundwater dependent ecosystem health, adaptive management measures would be implemented. 	Design and construction	Chapter 16 (Geology, soils and groundwater) Chapter 19 (Biodiversity)

Project uncertainties	Proposed resolution	Timing	Where discussed
Design details for motorway facilities and ventilation outlets	<ul style="list-style-type: none"> Refinement of the architectural design of the project motorway facilities and ventilation outlets would be confirmed during further design development. A design for the motorway facilities and ventilation outlets would be developed to incorporate the infrastructure component as an integral part of surrounding land use in accordance with the project's strategic urban design framework (refer to Appendix V (Technical working paper: Urban design, landscape character and visual impact) for more information). 	Design	Chapter 22 (Urban design and visual amenity)
Urban design detail of fixed infrastructure (motorway facilities, ventilation outlets, substations, portals, water treatment facilities and bridges) and other key features	<ul style="list-style-type: none"> The urban design for project infrastructure and key features would be refined during further design development in accordance with performance requirements for elements such as the motorway facilities and ventilation outlets, the objectives and principles for urban design and landscaping developed for the project, and the outcomes of consultation An urban design and landscape plan would be prepared during further design development and implemented in line with the strategic urban design framework for the project. The urban design and landscape plan would detail built and landscape features to be implemented during construction and rehabilitation of disturbed areas during construction of the project. 	Design	Chapter 22 (Urban design and visual amenity)

28.4 Summary of project impacts and management measures

This section provides a summary of the impacts of the project that could not be avoided. These impacts are discussed in detail in Chapter 8 (Construction traffic and transport) to Chapter 27 (Cumulative impacts) of this environmental impact statement.

28.4.1 Key impact avoidance

Many potential impacts have been avoided through the project development process which included input from key stakeholders and the community. A number of corridor alternatives were evaluated to identify the most technically, environmentally and socially acceptable alternative with the most efficient transport connections (refer to Chapter 4 (Project development and alternatives) for more information on the alternatives considered).

Following identification of the preferred corridor for the project, further design development and refinement has been carried out which has resulted in the avoidance or minimisation of environmental impacts; these include:

- Selection of roadheaders instead of tunnel boring machines for construction of the land-based tunnels, resulting in lower spoil volumes and fewer heavy vehicle movements
- The selection of precast immersed tube tunnel units on top, or within the top layers, of harbour rock and sediments as the preferred harbour crossing method, rather than the use of driven tunnel, thereby avoiding the need for tunnelling in challenging geology and enabling better grades and journey experience (eg safety, lower emissions)
- Refinements to the location of the Warringah Freeway, Gore Hill Freeway and Balgowlah surface connections, resulting in improved connectivity and network performance, improved constructability and design, and minimising environmental, community and traffic impacts
- Temporary construction support site location and layout alternatives were considered to minimise impacts to sensitive environments and community facilities, while minimising property impacts and acquisitions. Locations were also selected to maximise opportunities for direct access to arterial roads or water transport opportunities for construction traffic, to avoid use of local streets where possible
- Ventilation system design alternatives. A longitudinal system with elevated ventilation outlets was selected as the preferred option as it is able to meet the requirement to avoid portal emissions, most effectively manage smoke in the tunnel in the event of a fire, ensure emissions are dispersed and diluted so there is minimal or no effect on ambient air quality
- Alternatives for the transport of spoil were considered, including the use of rail, barge or truck. A combination of trucks and some barging was selected as the preferred spoil transport option for the project as it reduces the amount of double or triple handling of spoil required (ie transfer spoil to a loading facility) while also providing the ability to move large volumes of spoil, thereby reducing the number of heavy vehicle movements on the wider road network
- Dredged material management alternatives were considered. An application for offshore disposal of suitable dredged material will be submitted to the Australian Government Department of Agriculture, Water and the Environment. It is proposed that suitable dredged material would be transported by barge and disposed of at a designated offshore disposal site (in accordance with legislative requirements). Disposal of suitable dredged material at the designated offshore disposal site would minimise some environmental impacts at sensitive receivers and avoid the creation of a large volume of waste to be disposed on land
- Identification of the potential for residual land at Balgowlah to be repurposed as new and improved open space and recreation facilities in line with the *Northern Beaches Sportsground Strategy* (Northern Beaches Council, 2017a) and addressing the current under supply of sporting grounds available for public use in the local area

- Further refinement of the design including consideration of community issues through the environmental impact statement exhibition process may further reduce and if possible, avoid impacts.

Potential impacts would be further avoided and minimised, where possible, through the implementation of the environmental management measures complying with the performance outcomes identified in Chapter 4 (Project development and alternatives).

28.4.2 Key project impacts

The environmental impact statement has assessed the potential environmental impacts that may occur as a result of the project and recommends measures to manage these impacts. Table 28-3 provides a summary of potential impacts of the project that could not be avoided and the associated environmental management measures. Table 28-3 is not a comprehensive list of all environmental management measures proposed in this environmental impact statement. For further details refer to the individual chapters. Unavoidable impacts would be addressed through design refinements or ongoing management during construction and operation.

Table 28-3 Summary of key project impacts and management measures

Summary of key impact	Timing	Management measure
<p>Traffic and transport</p> <ul style="list-style-type: none"> Increased heavy vehicle movements around work sites during construction Increased traffic volumes and delays for traffic in the North Sydney, Balgowlah and Frenchs Forest areas during construction Temporary, partial closures of the Pacific Highway, Wakehurst Parkway and roads within the Gore Hill Freeway and Artarmon area, for short periods of time to carry out key construction activities which are located within the road corridor Temporary closures and detours of footpaths and shared user paths at Flat Rock Reserve, and within the Gore Hill Freeway, Artarmon, Spit West Reserve, Balgowlah and Wakehurst Parkway areas Temporary impacts on maritime traffic associated with the six closures (likely two full closures and four partial closures) of Middle Harbour for recreational, commercial and government users between Northbridge and Seaforth to enable construction works for the crossing of Middle Harbour. 	<p>Construction</p>	<ul style="list-style-type: none"> Ongoing consultation, as relevant to the location will be carried out with Greater Sydney Operations, the Port Authority of NSW, local councils, emergency services and bus operators to minimise traffic and transport impacts Directional signage, barriers and/or line marking will be used as required to direct and guide motorists, cyclists and pedestrians past construction sites and on the surrounding network. This will be supplemented by Variable Message Signs to advise all road users of potential delays, traffic diversions, speed restrictions, or alternative routes Any adjustments to existing bus stops will be determined in consultation with relevant stakeholders including other divisions of Transport for NSW and advanced notification will be provided to affected bus customers. Relocations will be as close to their existing position where feasible and reasonable Truck marshalling areas will be identified and used where feasible and reasonable to minimise potential queueing and traffic and access disruptions in the vicinity of construction support sites Activities requiring temporary partial road closures will be carried out outside of peak periods and/or during night time to minimise the impact of these activities on the road network where feasible and reasonable Direct impacts to existing pedestrian and cycle facilities will be minimised where reasonable and feasible. Any detours and adjustments will be designed with consideration of user safety and convenience Construction marine traffic activities will be scheduled to avoid times and locations of high recreational marine traffic where feasible and reasonable

Summary of key impact	Timing	Management measure
<p>Noise and vibration</p> <ul style="list-style-type: none"> • Construction noise levels predicted to exceed noise management levels at some sensitive receiver locations • Potential for sleep disturbance impacts during the night • Construction traffic movements has the potential to result in road traffic noise levels above the relevant criteria. 	Construction	<ul style="list-style-type: none"> • Harbour closures scheduling will be carried out in consultation with Port Authority of NSW, other divisions of Transport for NSW and other relevant stakeholders. • Monitoring will be carried out to confirm construction noise and vibration levels in relation to noise and vibration management levels • Where construction activities are predicted to exceed noise management levels at receivers mitigation measures will be implemented where feasible and reasonable including community consultation and engagement, detailed programming and respite protocols and the early implementation of operational noise barriers • An out-of-hours works protocol will be developed for the construction of the project. The protocol will be prepared in consultation with the Department of Planning, Industry and Environment and the NSW Environment Protection Authority. The project protocol will be implemented during the duration of the construction of the project.
<p>Human health and air quality</p> <ul style="list-style-type: none"> • Underwater noise and vibration impacts affecting water-based recreational users • Dust generated during works carried out for demolition, earthworks, construction and track-out • Odours potentially generated during handling and management of harbour sediments and material excavated from a former landfill site • Blast emissions generated by blasting, if required during construction • Potential impacts on ambient air quality due to changes in the distribution of surface traffic and operation of the tunnel ventilation facilities: 	Construction/ operation	<ul style="list-style-type: none"> • Opportunities to coordinate the piling program with the planned activities of key recreational stakeholders to minimise interaction with planned or peak activity periods of these stakeholders, where feasible and reasonable • An underwater noise monitoring program will be carried out during the early stages of impact piling activities at each location to measure underwater noise levels and compare against acoustic thresholds to confirm the extent of areas that need to be managed with respect to underwater noise, and to confirm appropriate management measures (as required). Appropriate management measures will be implemented during impact piling. • Communication and management measures will be implemented during construction to manage potential underwater noise impacts to water-based recreational users during dredging and piling activities in Middle Harbour

Summary of key impact	Timing	Management measure
<ul style="list-style-type: none"> – Generally minor increases in common ambient air quality air pollutants (CO, NO₂, PM₁₀, PM_{2.5}, benzene, polycyclic aromatic hydrocarbons, formaldehyde, 1,3-butadiene and ethylbenzene) predicted, with only a very small proportion of receivers predicted to experience larger increases – Some of the current exceedances of short-term NSW EPA ambient air quality criteria (1-hour NO₂, 24-hour PM_{2.5} and 24-hour PM₁₀ and annual mean PM₁₀ and PM_{2.5}) predicted to continue when the project is in operation, although total numbers of receivers experiencing exceedances predicted to decrease as a result of the project – Exceedances of PM₁₀ and PM_{2.5} air quality criteria predicted at potential future buildings above 30 metres in height within 300 metres of the Gore Hill Freeway ventilation outlet, but would not necessarily preclude such development – Odours generated by vehicle emissions. 		<ul style="list-style-type: none"> • Standard construction air quality mitigation and management measures will be detailed in construction management documents including minimisation and management of dust generation during construction. • Site investigations will be carried out during the detailed design and construction planning phase to determine the potential to encounter odorous gases or materials during the proposed excavations at the Flat Rock Drive construction support site (BL2). If unacceptable off-site impacts are predicted, appropriate mitigation and management measures will be identified to minimise potential impacts, with consideration of the investigation results, proposed site activities and meteorological conditions, and the identified measures will be implemented during relevant site activities • Blasting and associated activities will be carried out in a manner that does not generate unacceptable overpressure and vibration impacts or pose a significant risk impact to structures and sensitive receivers. Prior to any blasting all potentially affected sensitive receivers and features in the vicinity will be identified. The potentially affected community will be kept informed about proposed blasting activities.
<p>Non-Aboriginal heritage</p> <ul style="list-style-type: none"> • Direct and indirect impacts to non-Aboriginal heritage items near of the project including: <ul style="list-style-type: none"> – Moderate and permanent impacts to Cammeray Park (including Golf Course) as a result of the construction activities and the installation of permanent operational infrastructure within the heritage boundary – Major impacts at Balgowlah Golf Course as a result of the temporary establishment and operation of Balgowlah Golf Course construction support site (BL10) and the construction of 	Construction/operation	<ul style="list-style-type: none"> • Non-Aboriginal heritage awareness training will be provided for contractors prior to commencement of construction works to ensure understanding of potential heritage items that may be impacted during the project, and the procedure required to be carried out in the event of discovery of non-Aboriginal heritage materials, features or deposits, or the discovery of human remains • Archival recording will be carried out in accordance with the <i>Photographic Recording of Heritage Items Using Film or Digital Capture guideline</i> for areas/items subject to change • Delineation of restricted zones will be implemented to avoid inadvertent works occurring within the curtilage of heritage items

Summary of key impact	Timing	Management measure
<p>permanent road infrastructure and operational facilities</p> <ul style="list-style-type: none"> - Direct impacts to maritime heritage items near of the project 		<ul style="list-style-type: none"> • A Maritime Heritage Management Plan that details the objectives and methodologies to conserve maritime heritage and mitigate impacts will be prepared in consultation with a qualified and experienced maritime archaeologist and implemented during construction.
<p>Aboriginal heritage</p> <ul style="list-style-type: none"> • Direct and indirect impacts to Aboriginal heritage items near of the project including: <ul style="list-style-type: none"> – Five Aboriginal sites located within 50 metres of surface works including two sites that may be subject to indirect impacts associated with vibration and settlement – Five Aboriginal sites located above or within 50 metres of the tunnel alignment and may be subject to indirect impacts associated with vibration and settlement • Direct impacts from construction activities such as dredging, piling and excavation within the cofferdams to submerged sites • Indirect impacts associated with construction vibration generated by construction activities in proximity to Aboriginal sites. 	Construction	<ul style="list-style-type: none"> • Cultural and historic heritage awareness training will be carried out for personnel engaged in work that may impact heritage items before commencing works for the project. • Vibration monitoring will be carried out where required at terrestrial AHIMS sites. Where monitoring identifies vibration levels exceed 2.5 millimetres per second or following vibration intensive activities, a subsequent condition survey will be carried out to record any changes to the integrity of the site that may have resulted from construction vibration • The effectiveness of using high resolution geophysical survey to identify rock overhangs concealed by marine sediments will be assessed. If determined to be appropriate geophysical survey will be conducted to identify potential rock overhangs concealed by marine sediments.

Summary of key impact	Timing	Management measure
<p>Hydrodynamics and water quality</p> <ul style="list-style-type: none"> Discharges from construction and operation wastewater treatment facilities affecting fresh and marine water quality. Construction works leading to water quality and sedimentation issues in surrounding waterways. 	<p>Construction/ Operation</p>	<ul style="list-style-type: none"> Construction and operation wastewater treatment plants will be designed to meet the relevant requirements of ANZECC/ARMCANZ (2000) and ANZG (2018) Operational phase monitoring will be described in the operational water quality monitoring program, for both surface water and groundwater as appropriate, and carried out in line with the post construction phases requirements of the <i>Guideline for Construction Water Quality Monitoring</i> (RTA, 2003a). Should any of the discharge criteria be exceeded, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented A freshwater quality monitoring program for the construction of the project will be developed and implemented, with consideration of the freshwater monitoring being carried out for the Western Harbour Tunnel and Warringah Freeway Upgrade project and the completed Northern Beaches Hospital road upgrade project. If exceedances of the criteria established under the freshwater monitoring program are detected, a management response will be triggered and appropriate mitigation measures to address the exceedance will be identified and implemented Erosion and sediment control measures will be implemented at all work sites and surface road upgrades in accordance with the principles and requirements in <i>Managing Urban Stormwater – Soils and Construction, Volume 1</i> (Landcom, 2004), <i>Managing Urban Stormwater: Soils and Construction, Volume 2D Main Road Construction</i> (Department of Environment and Climate Change (DECC), 2008) and relevant guidelines, procedures and specifications of Transport for NSW.

Summary of key impact	Timing	Management measure
<p>Biodiversity</p> <ul style="list-style-type: none"> • Removal of native remnant and planted individuals of Netted Bottle Brush (<i>Callistemon linearifolius</i>) and Magenta Lilly Pilly (<i>Syzygium paniculatum</i>) listed under the <i>Biodiversity Conservation Act 2016</i> and EPBC Act • Removal of about 15.4 hectares of native vegetation and native revegetation • Fragmentation of habitat and removal of hollow-bearing trees due to the realignment and upgrade of the Wakehurst Parkway. The fragmentation of vegetation would potentially adversely affect the movement patterns of a number of threatened terrestrial fauna species known or likely to occur in the area • Potential edge effects to vegetated habitats next to the Wakehurst Parkway • Potential for short-term noise impacts from surface works at Balgowlah to the Grey-headed Flying-fox (<i>Pteropus poliocephalus</i>) camp identified in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the construction footprint • Potential noise and vibration impacts to Large-eared Pied Bat during the realignment and upgrade of the Wakehurst Parkway, particularly during blasting and/or rock hammering • Potential impacts to key fish habitats in Middle Harbour due to the removal of medium/high relief rocky reef habitat, turbidity and sedimentation from dredging, and underwater noise from dredging and piling 	<p>Construction</p>	<ul style="list-style-type: none"> • Vegetation removal including the clearing of native vegetation and fauna habitat will be further minimised during further design development and construction planning, where feasible and reasonable • Credits will be required as part of the biodiversity offsets for the project for the removal of native vegetation and threatened species habitat impacted by the project • Vegetation removal along the Wakehurst Parkway will be timed to avoid the winter breeding period for the Eastern Pygmy-possum (May to July), where possible • Connectivity measures will be designed during further design development in accordance with the <i>Wildlife Connectivity Guidelines: Managing wildlife connectivity of road projects</i> (Draft) (Roads and Maritime Services, 2011c) and consider measures to facilitate the crossing of native fauna species • Adaptive management measures to minimise impacts on Grey-headed Flying-foxes will be developed prior to construction. Where feasible and reasonable, noise intensive works with the potential of impacting the Grey-headed Flying-fox camp (ie demolition involving rock hammering or resurfacing works) should be programmed to avoid September to February. A person experienced in flying-fox behaviour will monitor disturbance levels within the Grey-headed Flying-fox camp at Balgowlah during construction activities • Activity-specific controls will be developed to manage impacts from high noise and vibration generating activities (eg controlled blasting and rock hammering) on Large-eared Pied Bat along the Wakehurst Parkway. The controls will be developed by a suitably qualified and experienced microbat specialist and implemented during surfaced road works as required • Exclusion zones will be implemented to avoid disturbance to sensitive marine habitats not proposed to be directly impacted by the project. Routine inspections and maintenance of exclusion measures will be carried out

Summary of key impact	Timing	Management measure
<ul style="list-style-type: none"> Potential impacts on marine threatened species in Middle Harbour, such as the Black Rockcod and White's seahorse that reside in habitat affected during construction Potential impacts on some marine mammals, turtles and sharks, which may forage or transit through seagrass, rocky reef or deepwater soft sediment habitats Potential underwater noise impacts to marine fauna generated through construction dredging and piling activities. 		<ul style="list-style-type: none"> Silt curtains will be installed around seagrass patches and subtidal rocky reef contained within the Zone of Influence as described in Appendix T (Technical working paper: Marine ecology) Pre-construction surveys of potentially affected marine habitat areas will be carried out as close as practicable to 24 hours prior to commencement of works by suitably qualified and experienced marine ecologists to search for White's seahorses (and other Syngnathids) and relocate to nearby unaffected habitat Salvage of live fish and other native marine organisms (eg large, mobile macroinvertebrates) will occur during cofferdam dewatering and will be carried out by suitably qualified and experienced marine ecologists. All salvaged organisms will be immediately relocated to similar habitat nearby A stop-work procedure will be developed in accordance with the recommendations in Appendix T (Technical working paper: Marine ecology) to mitigate potential impacts to marine mammals and reptiles within the vicinity of impact piling works.
<p>Land use and property</p> <ul style="list-style-type: none"> Temporary leasing of properties and land during construction Temporary land use changes to some areas associated with construction activities or construction support sites Temporary relocation of boat moorings to provide safe access to temporary construction support sites Permanent full or partial acquisition of properties and land Permanent land use changes where permanent project infrastructure is established 	Construction/operation	<ul style="list-style-type: none"> Land subject to temporary use, including areas of public open space, will be rehabilitated as soon as practicable to an appropriate condition, taking into consideration the location, land use characteristics, area and adjacent land uses or in accordance with the urban design and landscape plan where applicable. Rehabilitation will be carried out in consultation with the relevant land owner, the local council and community (where appropriate) Transport for NSW will consult with existing lease holders of properties that will be directly affected by the project regarding any changes to lease arrangements Land acquisition for the project will be carried out in accordance with the <i>Land Acquisition (Just Terms Compensation) Act 1991</i> (NSW), the <i>Roads and Maritime Services Land Acquisition Information Guide</i> (Roads and Maritime Services, 2014b) and

Summary of key impact	Timing	Management measure
<ul style="list-style-type: none"> • Permanent closure of Balgowlah Golf Course and repurposing of the land for new and improved open space and recreation facilities for the community • Permanent land use change for part of Cammeray Golf Course used for operational facilities • Air quality impacts for future elevated receivers above 20 metres in height located within 300 metres of ventilation outlets. 		<p><i>Fact sheet: Property acquisition of subsurface lands</i> (Roads and Maritime Services, 2015b) and in accordance with the land acquisition reforms announced by the NSW Government in 2016</p> <ul style="list-style-type: none"> • Identification of residual land of the project will be confirmed during further design development and construction planning. Appropriate strategies for the ongoing management and/or divestment of the residual land will consider the location, land use characteristics, area and adjacent land uses. • Transport for NSW will assist Northern Beaches Council, North Sydney Council, Willoughby City Council and the Department of Planning, Industry and Environment (as appropriate) in determining relevant land use considerations applicable to future development in the immediate vicinity of ventilation outlets for inclusion in local environmental plans or development control plans, where required, to manage interactions between the project and future development. This may include procedures for identifying the requirement for consultation with Transport for NSW.
<p>Urban design and visual amenity</p> <ul style="list-style-type: none"> • Visual impacts during construction as a result of the presence of construction works, plant and equipment and construction vehicles • Loss of vegetation providing screening and amenity • Temporary increases in exposure to built form. 	Construction	<ul style="list-style-type: none"> • Construction support sites will be developed to minimise visual impacts for adjacent receivers where feasible and reasonable • Existing trees adjacent to the works will be retained and protected where reasonable and feasible to screen construction works • Early planting works will be considered to provide a screening buffer that has time to mature before the project is fully operational. • The urban design and landscape plan will be further developed during further design development and implemented in line with the strategic urban design framework for the project. It will include appropriate operational mitigation measures • All areas disturbed by construction and not required for operation of the project will be restored as soon as practicable to their existing condition or in accordance with the urban design and landscape plan where applicable.

Summary of key impact	Timing	Management measure
<p>Geology, soils and groundwater</p> <ul style="list-style-type: none"> • Ground movement may occur as a result of the construction of the project or from settlement induced by groundwater drawdown • The project is situated adjacent to areas that are considered to have a ‘moderate’ or ‘high’ risk rating of containing contaminated material • Disturbance of sediments in Middle Harbour during dredging activities which could potentially pose a contamination risk due to the contamination associated with historical industrial use of the harbour. 	Construction	<ul style="list-style-type: none"> • Detailed predictive settlement models will be developed for areas of concern to guide tunnel design and construction methodology, including the selection of options to minimise settlement where required • Pre-construction building structure condition surveys will be offered and prepared for properties (and heritage assets) within the zone of influence of tunnel settlement where the degree of severity has been assessed as ‘slight’ or above and within the minimum working distances for cosmetic and structural damage due to vibration • Potentially contaminated areas directly affected by the project will be investigated and managed in accordance with the requirements of guidance endorsed under section 105 of the <i>Contaminated Land Management Act 2008</i> • The dredging methodology has been designed to minimise impacts on the marine environment and would include the use of a backhoe dredge with closed environmental bucket.
<p>Resource use and waste management</p> <ul style="list-style-type: none"> • About three million cubic metres of spoil would be produced from land-based construction activities (terrestrial spoil) during construction. In addition, marine construction works for the project within Middle Harbour would produce around 163,000 cubic metres of dredged and excavated material. 	Construction	<ul style="list-style-type: none"> • The resource management hierarchy principles established under the <i>Waste Avoidance and Recovery Act 2001</i> of avoid/reduce/reuse/recycle/dispose will be applied • Wastes will be appropriately transported, stored and handled according to their waste classification and in a manner that prevents pollution of the surrounding environment.

Summary of key impact	Timing	Management measure
<p>Socio-economic</p> <ul style="list-style-type: none"> Loss of open space, parks and recreational facilities, due to use for temporary construction support sites and permanent project facilities Property impacts and acquisitions affecting residential properties and businesses Potential reduction in amenity at social infrastructure due to reduced visual amenity and increased air-borne construction noise, dust and traffic Potential impacts on community cohesion due to temporarily restricting access to some social infrastructure and meetings places, which may reduce opportunities for social and community interaction Changes in passing trade to business, employee and customer access, servicing and deliveries, business visibility, demand for services, displacement of business and potential impacts on maritime businesses and freight and efficiency. 	Construction/operation	<ul style="list-style-type: none"> Ongoing engagement will be carried out with representatives of user groups and managers of social infrastructure located near to surface construction works/construction support sites and sensitive social infrastructure above the tunnel alignment about the timing and duration of construction works and management of potential impacts Where businesses are affected by property acquisition, or lease cessation, the acquisition and compensation process will be implemented in line with the <i>Determination of compensation following the acquisition of a business guideline</i>. Compensation for a business conducted on land that is acquired should be determined in accordance with the <i>Land Acquisition (Just Terms Compensation) Act 1991</i> as relevant Where feasible and reasonable, the extent of permanent impact on public open space areas will be minimised during further design development Specific consultation will be carried out with businesses potentially impacted during construction. Consultation will aim to identify specific potential construction impacts for individual businesses.
<p>Cumulative impacts</p> <ul style="list-style-type: none"> There is the potential for construction fatigue and complaint fatigue to be experienced by surrounding receivers as a result of concurrent and consecutive construction programs. 	Construction	<ul style="list-style-type: none"> Multi-party engagement and cooperation will be established prior to construction to coordinate with the following projects to manage construction fatigue impacts where possible: <ul style="list-style-type: none"> Western Harbour Tunnel and Warringah Freeway Upgrade project Sydney Metro City & Southwest Channel 9 site staged residential redevelopment Complaint fatigue will be managed in accordance with Appendix E (Community consultation framework).

28.4.3 Residual impacts

An environmental risk analysis for the project has been carried out and is detailed in Appendix C (Environmental risk analysis). The risk analysis identifies an initial risk rating for each of the environmental issues and the residual risk rating derived after the application of environmental management measures developed and recommended by this environmental impact statement. It involved:

- Rating the risk of each identified potential impact by identifying the consequences of the impact and likelihood of each impact occurring
- Considering the probable effectiveness of the proposed environmental management measures to determine the likely residual risk of each impact.

The risk analysis outlined in Appendix C (Environmental risk analysis) has identified several 'medium' level residual risks. No potential impacts with a residual risk rating of 'high' were identified for the project. During further design development, opportunities would be identified for 'medium' level residual risks to:

- Resolve residual impacts and risks through further design refinement
- Develop suitable construction methodologies and carry out construction planning with the construction contractor to ensure that environmental management measures can be implemented effectively
- Implement a process of review, correction and audit for the management measures that were identified in this environmental impact statement and summarised in Appendix Y (Compilation of environmental management measures). This would be a process of continuous improvement that would form part of the construction environmental management plan and operational environmental management plan and would allow for environmental management measures to be updated or improved during the construction and operational phases, where practical.

Where 'medium' level residual risks are considered to still be likely after further design development, additional refined environmental management measures would be developed, where appropriate, to ensure those risks are suitably mitigated.

Where 'low' level residual risks are identified, an appropriate process of continuous improvement would be applied to address these potential impacts during construction and operation as far as is reasonable and feasible.

28.5 Environmental management plan framework

The implementation of environmental management measures during further design development, construction and operation of the project would minimise potential adverse impacts arising from the proposed work on the surrounding environment.

28.5.1 Construction environmental management

The environmental management framework provides a whole-of-construction life-cycle approach to construction environmental management and sets out the environmental requirements for construction. Construction environmental management documentation that would be prepared in accordance with the planning approval documents includes:

- Construction environmental management plan
- Construction environmental management plan sub-plans
- Performance and compliance reports.

This approach is illustrated in Figure 28.5 and has been developed to be consistent with legislative and regulatory requirements, including those described in Chapter 2 (Assessment process).

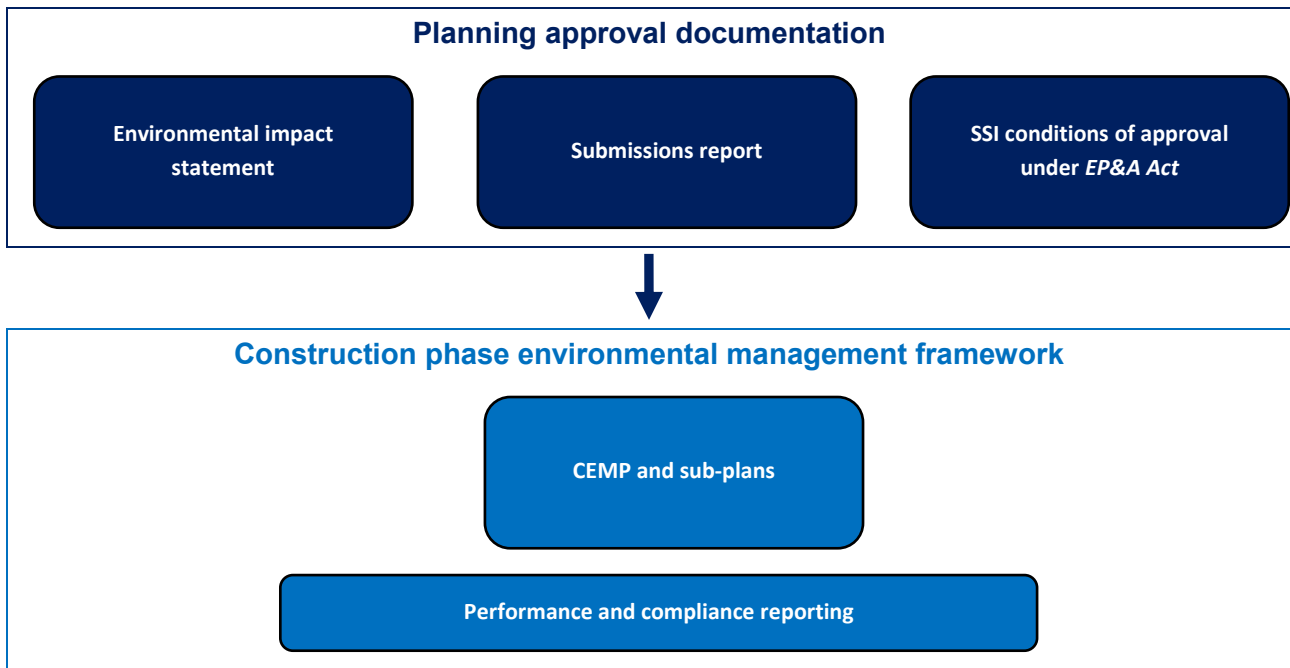


Figure 28.5 Construction environmental management approach

Construction environmental management plan

A construction environmental management plan would be prepared for the project in accordance with *QA Specification G36: Environmental Protection* (Transport for NSW, 2020h) prior to construction of the project and would be reviewed and approved by Transport for NSW and the Department of Planning, Industry and Environment, prior to the commencement of main construction work. It would provide the overarching framework for construction environmental management and would include the following:

- A description of applicable activities to be carried out during construction
- Construction methodologies and incorporation of relevant environmental management measures for applicable activities during construction
- An environmental risk and opportunities methodology
- A matrix of the relevant conditions of approval, as well as project specific commitments including environmental management measures, referencing where each requirement is addressed
- Outline the objectives and targets, in defined performance outcomes
- Environmental accountabilities or responsibilities
- Induction and training requirements
- Management strategies for reviewing the effectiveness of environmental management measures
- Processes and methodologies for surveillance and monitoring, auditing and reviewing and reporting on environmental and sustainability performance including compliance tracking
- Procedures for emergency and incident management, non-compliance management and corrective and preventative action
- Procedures for the control of environmental documents and records
- Environmental management measures table.

The construction environmental management plan would be a working document, subject to ongoing change and updated as necessary to respond to specific requirements.

Construction environmental management sub-plans

The construction environmental management plan would provide the overarching framework for construction environmental management. The following sub-plans which would likely be required to manage specific environmental impacts during construction:

- Traffic and transport management plan
- Marine works and marine traffic management plans
- Noise and vibration management plan
- Heritage management plan
- Air quality management plan
- Waste and resource management plan
- Soil and water management plan
- Groundwater management plan
- Flora and fauna management plan
- Dredge management plan.

The sub-plan structure identified above may be modified slightly during detailed construction planning to respond more effectively to particular contractor or stakeholder requirements.

In addition, a number of other management plans and strategies are likely to be required separate to the construction environmental management plan. These may include, but are not limited to:

- Site establishment management plan
- Utilities management strategy which would be prepared in accordance with Appendix D (Utilities management strategy)
- Blasting management strategy
- Sustainability management plan
- Community communication strategy which would be prepared in accordance with Appendix E (Community consultation framework).

28.5.2 Operational environmental management

Maintenance of the project and its environmental performance during operation would be managed under the existing Transport for NSW environmental management system for asset maintenance (or similar) prepared in accordance with the *AS/NZS ISO 14000 Environmental Management System* series and developed to be consistent with the broad environmental objectives and policies set out in the Transport for NSW environmental management system. Transport for NSW is committed to managing its impacts on the environment and carrying out its activities so as to avoid, minimise or mitigate environmental impacts. Accordingly, any project-specific operational environmental management practices and procedures would be incorporated into the existing environmental management system.

28.6 Performance outcomes

The project's performance outcome as measured against those identified for key issues in the Secretary's environmental assessment requirements is provided in Table 28-4, along with a summary of how each performance outcome would be achieved by the project.

Table 28-4 Design performance outcomes and project outcome

Desired performance outcome	How performance outcomes would be achieved
<p>Environmental impacts assessment process</p> <ul style="list-style-type: none"> The process for assessment of the proposal is transparent, balanced, well focussed and legal. 	<ul style="list-style-type: none"> This environmental impact statement has been prepared in accordance with Part 3 of Schedule 2 of the Environmental Planning and Assessment Regulation 2000 Based on the results of the environmental investigations carried out for this environmental impact statement, it is considered that matters of national environmental significance set out in the <i>Environment Protection Biodiversity Conservation Act 1999</i> are not likely to be significantly impacted by the project. Accordingly, Transport for NSW has decided a referral to the Commonwealth is not required at this stage.
<p>Environmental impact statement</p> <ul style="list-style-type: none"> The project is described in sufficient detail to enable clear understanding that the project has been developed through an iterative process of impact identification and assessment and project refinement to avoid, minimise or offset impacts so the project, on balance, has the least adverse environmental, social and economic impact, including its cumulative impacts. 	<ul style="list-style-type: none"> The project has been described in detail in Chapter 5 (Project description) The merits of the project, and the design options were considered in the context of a range of alternatives based on how well they performed with reference to transport, environmental, engineering, social and economic factors (refer to Chapter 4 (Strategic context and project need)). The preferred design provides a combination of benefits compared with other options assessed, including improved access, minimised impacts on properties and on future development potential.
<p>Assessment of key issues</p> <ul style="list-style-type: none"> Key issue impacts are assessed objectively and thoroughly to provide confidence the project would be constructed and operated within acceptable levels of impact. 	<ul style="list-style-type: none"> The assessment of key issues has been conducted objectively and thoroughly. The implementation of environmental management measures would ensure the project is constructed and operated within acceptable levels of impact. Refer to Chapter 8 (Construction traffic and transport) to Chapter 26 (Climate change risk and greenhouse gas) for further details.
<p>Consultation</p> <ul style="list-style-type: none"> The project is developed with meaningful and effective engagement during project design and delivery. 	<ul style="list-style-type: none"> Consultation has been carried out to inform the design process and project development (refer to Chapter 7 (Stakeholder and community engagement)) The construction contractor would respond to complaints in a timely and appropriate manner, to ensure all stakeholders' concerns are addressed effectively and promptly.

Desired performance outcome	How performance outcomes would be achieved
<p>Transport and traffic</p> <ul style="list-style-type: none"> • Network connectivity, safety and efficiency of the transport system near of the project are managed to minimise impacts • The safety of transport system customers is maintained • Impacts on network capacity and the level of service are effectively managed • Works are compatible with existing infrastructure and future transport corridors. 	<p>With respect to transport and traffic, the project has been developed such that it would:</p> <ul style="list-style-type: none"> • Minimise impacts to local streets from loss of parking, road closures and heavy vehicle movements during construction • Minimise impacts to road network efficiency during construction • Enable access to properties to be maintained during construction and operation • Improve the performance and capacity of Sydney’s road network • Provide an efficient motorway link which improves traffic flow on Sydney’s motorway network • Relocate a substantial volume of through traffic underground • Improve traffic conditions, and ease future congestion on the road network • Provide functional connectivity between the subsurface and surface road network • Provide future motorway connections to support a growing Sydney • Maintain pedestrian and cyclist safety along surface roads near the project • Provide considerable travel time savings for motorists and freight vehicles using Sydney’s motorway network • Provide opportunity to develop faster and more reliable express bus services to connect the Northern Beaches to strategic centres such as North Sydney, St Leonards, Sydney CBD and Macquarie Park, with the potential for links to strategic stations on the rail network • Improved travel times and reliability for buses travelling along existing key corridors including Warringah Freeway, Warringah Road, Eastern Valley Way and Military Road due to a reduction in traffic • Enable long-term development of Sydney’s motorway network, including connections to and from the Northern Beaches.
<p>Air quality</p> <ul style="list-style-type: none"> • The project is designed, constructed and operated in a manner that minimises air quality impacts (including nuisance dust and odour) to minimise risks to human health and the environment to the greatest extent 	<p>With respect to air quality, the project has been developed that it would:</p> <ul style="list-style-type: none"> • Provide effective management of dust, odour and other emissions during construction • Result in zero portal emissions during normal operations • Provide effective dispersion of emissions from the tunnels to ensure negligible contributions to air quality at ground level. <p>Tunnel ventilation design would be developed to maintain in-tunnel air quality in accordance with relevant criteria.</p>

Desired performance outcome	How performance outcomes would be achieved
<p>Health and safety</p> <ul style="list-style-type: none"> The project avoids or minimises any adverse health impacts arising from the project The project avoids, to the greatest extent possible, risk to public safety. 	<p>With respect to health and safety, the project has been developed that:</p> <ul style="list-style-type: none"> Incidents, crashes and risks to public safety would be minimised during construction The motorway design would achieve safe and efficient road user movements including diverting many heavy vehicles into the tunnels and off the surface road network Establishment and operation of temporary construction support sites and ancillary infrastructure would ensure the protection of road users and the public The project avoids, to the greatest extent possible, risk to public safety Hazardous materials within project areas would be managed to protect human health.
<p>Noise and vibration – Amenity</p> <ul style="list-style-type: none"> Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity Increases in noise emissions and vibration affecting nearby properties and other sensitive receivers during operation of the project are effectively managed to protect the amenity and well-being of the community. 	<p>With respect to noise and vibration (amenity), the project has been developed that it would:</p> <ul style="list-style-type: none"> Relocate a considerable volume of through traffic on surface arterial roads underground, improving surface road noise Divert many heavy vehicles into the tunnels and off the surface road network Comply with the relevant criteria from the <i>NSW Industrial Noise Policy</i> Minimise increases in road traffic noise, where possible Include effective implementation of noise management measures during operation Include effective management of construction noise and vibration in accordance with relevant guidelines, for example through the use of acoustic sheds Minimise surface activity and associated noise at tunneling sites, as once tunneling starts the majority of the work at these sites would be underground Minimise impacts to the local community by: <ul style="list-style-type: none"> Controlling noise and vibration at the source Controlling noise and vibration on the source to receiver transmission path Controlling noise and vibration at the receiver Implementing practicable and reasonable measures to minimise the noise and vibration impacts of construction activities on local sensitive receivers.

Desired performance outcome	How performance outcomes would be achieved
<p>Noise and vibration – Structural</p> <ul style="list-style-type: none"> Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on the structural integrity of buildings and items including Aboriginal places and environmental heritage Increases in noise emissions and vibration affecting environmental heritage as defined in the <i>Heritage Act 1977</i> during operation of the project are effectively managed. 	<p>With respect to noise and vibration (structural), the project would minimise impacts to structures by:</p> <ul style="list-style-type: none"> Controlling vibration at the source Controlling vibration on the source to receiver transmission path Implementing practicable and reasonable measures to minimise vibration impacts of construction activities on structures Carrying out building/structure condition surveys for properties (and heritage assets) within the zone of influence of tunnel settlement prior to the commencement of construction.
<p>Biodiversity</p> <ul style="list-style-type: none"> The project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity Offsets and/or supplementary measures are assured which are equivalent to any remaining impacts of project construction and operation. 	<p>With respect to biodiversity, the project has been developed that:</p> <ul style="list-style-type: none"> It would minimise impacts on biodiversity Where practicable, the design minimises the need to clear vegetation Potential impacts on biodiversity would be managed in accordance with relevant legislation, including the <i>Environmental Planning and Assessment Act 1979</i> and the <i>Biodiversity Conservation Act 2016</i> and relevant guidelines Offsets would be provided for the project in accordance with NSW Biodiversity Offsets Scheme, established under Part 6 of the <i>Biodiversity Conservation Act 2016</i> and the <i>Policy and guidelines for fish habitat conservation and management</i> (NSW Department of Primary Industries (DPI), 2013).
<p>Place Making and Urban Design</p> <ul style="list-style-type: none"> The project design complements the visual amenity, character and quality of the surrounding environment The project contributes to the accessibility and connectivity of communities. 	<p>With respect to place making and urban design, the project has been developed that:</p> <ul style="list-style-type: none"> It would connect disconnected communities A substantial volume of through traffic on surface arterial roads would be diverted underground, improving urban amenity Sympathetic urban design would integrate with adjacent and historical land uses It would establish and operate ancillary infrastructure to minimise adverse impacts on the visual amenity of the local community It would provide for new and improved active transport links It would provide for new and improved open space and recreation facilities at Balgowlah.

Desired performance outcome	How performance outcomes would be achieved
<p>Socio-economic, land use and property</p> <ul style="list-style-type: none"> • The project minimises adverse social and economic impacts and capitalises on opportunities potentially available to affected communities • The project minimises impacts to property and business and achieves appropriate integration with adjoining land uses, including maintenance of appropriate access to properties and community facilities, and minimisation of displacement of existing land use activities, dwellings and infrastructure. 	<p>With respect to socio-economics, land use and property, the project has been developed to:</p> <ul style="list-style-type: none"> • Minimise property acquisition • Manage the property acquisition process to minimise impacts to community and businesses • Minimise impacts to businesses during construction • Make provision for social infrastructure • Reduce congestion on the road network, supporting future urban regeneration • Avoid barriers and division of the community through the tunnel solution.
<p>Water – Hydrology</p> <ul style="list-style-type: none"> • Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised • The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved) • Sustainable use of water resources. 	<p>With respect to water (hydrology), the project has been developed that:</p> <ul style="list-style-type: none"> • Design and construction of the tunnels minimises groundwater inflow • Opportunities for reuse of treated water during construction have been considered throughout project development • The environmental values of nearby, connected and affected water sources would be improved and/or maintained.
<p>Water – Quality</p> <ul style="list-style-type: none"> • The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable). 	<p>With respect to water (quality), the project has been developed to:</p> <ul style="list-style-type: none"> • Operate under water quality discharge criteria with consideration of the NSW Water Quality Objectives • Effectively treat water to meet water quality discharge criteria.

Desired performance outcome	How performance outcomes would be achieved
<p>Flooding</p> <ul style="list-style-type: none"> The project minimises adverse impacts on existing flooding characteristics Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, or dam failure. 	<p>With respect to flooding, the project has been developed that:</p> <ul style="list-style-type: none"> Construction would be carried out in a manner that minimises the potential for adverse flooding impacts, through staging of works and the implementation of mitigation measures Temporary construction support sites and construction sites would be laid out so flows are not substantially impeded Flood levels would be maintained or reduced at residential, commercial and industrial properties adjacent to the alignment during a 1% AEP event.
<p>Soils</p> <ul style="list-style-type: none"> The environmental values of land, including soils, subsoils and landforms, are protected Risks arising from the disturbance and excavation of land and disposal of soil are minimised, including disturbance to acid sulfate soils and site contamination. 	<p>With respect to soils, the project has been developed that:</p> <ul style="list-style-type: none"> Erosion and sediment controls would be implemented in accordance with <i>Managing Urban Stormwater – Soils and Construction, Volume 1</i> (Landcom 2004) and <i>Managing Urban Stormwater: Soils and Construction, Volume 2D: Main Roads</i> (DECC 2008), commonly referred to as the ‘Blue Book’ Acid sulfate soils would be managed in accordance with good practice measures Contamination would be managed to protect environmental values and human health.
<p>Heritage</p> <ul style="list-style-type: none"> The design, construction and operation of the project facilitates, to the greatest extent possible, the long term protection, conservation and management of the heritage significance of items of environmental heritage and Aboriginal objects and places. 	<p>With respect to heritage, the project has been developed that it would:</p> <ul style="list-style-type: none"> Establish archival recording of items of heritage significance that would be subject to change Minimise impacts on heritage items during construction Incorporate key heritage values and stories into the final urban design and landscaping outcome Minimise impacts to features of heritage conservation significance from vibration. <p>The design would be sympathetic to the heritage significance of surrounding listed heritage items, and where practicable, avoid and minimise impacts to heritage.</p> <p>Impacts on heritage would be managed in accordance with relevant legislation, including the <i>Environmental Planning and Assessment Act 1979</i>, the <i>Heritage Act 1977</i>, and relevant guidelines.</p>

Desired performance outcome	How performance outcomes would be achieved
<p>Sustainability</p> <ul style="list-style-type: none"> The project reduces the NSW Government's operating costs and ensures the effective and efficient use of resources Conservation of natural resources is maximised. 	<p>With respect to sustainability, the project has been developed that:</p> <ul style="list-style-type: none"> Sustainability considerations would be integrated throughout design, construction, and operation The project would seek to achieve an 'Excellent' Design and 'As Built' Infrastructure Sustainability rating The project would be carried out in accordance with the Sustainability Framework developed for the project Activities to implement the sustainability framework, including requirements from the Infrastructure Sustainability rating scheme, would be implemented through a Sustainability Management Plan.
<p>Waste</p> <ul style="list-style-type: none"> All wastes generated during the construction and operation of the project are effectively stored, handled, treated, reused, recycled and/or disposed of lawfully and in a manner that protects environmental values. 	<p>With respect to waste, the project has been developed that:</p> <ul style="list-style-type: none"> Where feasible and reasonable, the project would recycle or reuse clean spoil either on site or off site Disturbed contaminated material would be encapsulated on site where appropriate and in accordance with relevant regulatory requirements. Off-site waste reuse would be managed in accordance with relevant NSW Environment Protection Authority resource recovery exemptions and requirements Waste would be disposed of at appropriately licensed facilities.
<p>Climate change risk</p> <ul style="list-style-type: none"> The project is designed, constructed and operated to be resilient to the future impacts of climate change. 	<p>With respect to climate change risk, the project has been developed that it:</p> <ul style="list-style-type: none"> Would incorporate climate change and sea level rise adaptation measures into the further design development and construction planning for the project.

28.7 Project justification and conclusion

28.7.1 Biophysical, economic and social considerations

The environmental impact statement has been prepared with regard to the key issues associated with the project and the integration of biophysical, economic and social considerations.

While the development of the project would have some unavoidable impacts (associated with, for example, construction impacts from heavy vehicle traffic, noise, vibration and dust, access disruptions and visual impacts) overall, the project would deliver a large number of benefits and opportunities including:

- Reducing pressure on congested road corridors, leading to faster and more reliable journeys to, from and around the Northern Beaches and North Shore
- Improving public transport journey times, travel time reliability and connectivity between the Northern Beaches and strategic centres, enabling new express bus service routes
- Improving access for local businesses to Greater Sydney, making it easier and safer to move goods and provide services
- Increasing the resilience of the Northern Beaches road network to traffic incidents by providing a new alternate underground bypass route of existing congested arterial road corridors

- Improving the amenity of local streets and local town centres by freeing up local streets for local traffic
- Creating opportunities to enhance local communities by improving active transport links and providing new and improved public open space.

28.7.2 Sustainable development

Facilitating ecologically sustainable development is adopted as an object of the *Environmental Planning and Assessment Act 1979*. This object requires the integration of "relevant economic, environmental and social considerations in decision making about environmental planning and assessment".

Ecologically sustainable development is defined under the *Protection of the Environment Administration Act 1991* (NSW) and Environmental Planning and Assessment Regulation 2000 and includes four principles. The project is consistent with these principles of ecologically sustainable development:

- **Precautionary principle:** The environmental impact statement was prepared adopting a conservative approach, which includes an assessment of the worst case impacts and scenario and using the best available technical information and has adopted best practice environmental standards, goals and measures. The design and development of the project included consideration of potential environmental impacts associated with the project alternatives and options analysis, and opportunities were identified to avoid and minimise surface disturbance. In addition, sustainability workshops and meetings were held during design development with planning and design teams to develop draft sustainability targets and objectives for the project
- **Intergenerational equity:** The project is designed to meet the needs of both current and future generations with a design life of about 100 years and would contribute to an increase in the resilience and capacity of the Sydney transport network. During construction and operation of the project, opportunities would be taken to reduce resource and material use and maximise the use of materials with low embodied environmental impact, where feasible
- **Conservation of biological diversity and ecological integrity:** The design and assessment of the project has been carried out with the aim of identifying, avoiding, minimising and mitigating impacts to biodiversity and ecological integrity. Consistent with the *Biodiversity Conservation Act 2016* and the Secretary's environmental assessment requirements, a biodiversity offset strategy has been developed to compensate for the unavoidable loss of ecological values as a result of the project
- **Improved valuation and pricing and incentive mechanisms:** The value placed on avoiding and minimising environmental impacts is demonstrated in the design features incorporated into the project (for example identifying opportunities to improve local amenity, improve public transport access and active transport connections, and create additional green spaces). The costs of planning, design and implementation of avoidance and environmental management measures have been incorporated into the project cost.

28.7.3 Objects of the *Environmental Planning and Assessment Act 1979* (NSW)

A consideration of the project against the objects of the *Environmental Planning and Assessment Act 1979* is outlined in Table 28-5.

Table 28-5 Objects of the *Environmental Planning and Assessment Act 1979* (NSW)

Objects of the <i>Environmental Planning and Assessment Act 1979</i>	Project attributes
<p>(a) To promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources,</p>	<p>The project would provide benefits for local businesses and commuters by enabling better and more efficient access between the Northern Beaches region and major centres across Greater Sydney. By connecting the Northern Beaches to the Sydney motorway network, the project would provide faster connections to strategic commercial and industrial centres across Greater Sydney including Chatswood, St Leonards and Macquarie Park, as well as the international gateways of Sydney Airport and Port Botany.</p> <p>Increased network capacity and connectivity as a result of the project would result in travel time savings for freight movements, further servicing the growth of Sydney's Eastern Economic Corridor. The combination of freight and business travel time savings would be integral to the economic growth of Sydney's Eastern Economic Corridor, enabling sustained growth and productivity.</p> <p>During construction and operation, the following opportunities would be taken to reduce material use and maximise the use of materials with low embodied environmental impact, where practical:</p> <ul style="list-style-type: none"> • Water efficiency measures would be implemented where possible, with the reuse of non-potable water from stormwater harvesting and on-site reuse of treated water from groundwater inflows, where water quality and volume requirements are met • The design of the project has included careful consideration of the construction methodology and selection of materials and resources to minimise resource consumption • Consistent with the resource management hierarchy under the <i>Waste Avoidance and Resource Recovery Act 2001</i>, solid wastes would be reused and recycled where feasible and reasonable. <p>Where possible, the project has been designed to avoid impacts on the natural environment and to minimise the need for land acquisition, as well as impacts on existing development and local communities.</p>
<p>(b) to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment,</p>	<p>The project is consistent with the principles of ecologically sustainable development as outlined in Section 28.7.2.</p>

Objects of the <i>Environmental Planning and Assessment Act 1979</i>	Project attributes
(c) to promote the orderly and economic use and development of land,	<p>The project has been designed to:</p> <ul style="list-style-type: none"> • Provide improved efficiency of the road network, in particular for freight and commercial users, resulting in economic benefits for NSW • Provide an additional underground motorway alternative, enhancing the resilience of the road network, supporting wider network improvements • Minimise impacts to the surrounding natural and built environments where possible, for example by integrating design features such as tunnel portals and motorway facilities and ventilation outlets into the existing road corridors as far as practical • Integrate with, and thereby minimise disruption to, existing development and other projects.
(d) to promote the delivery and maintenance of affordable housing,	<p>Not applicable to this project.</p> <p>The residual land created as a result of the project would largely continue to remain suitable for future development in accordance with the relevant land use zonings and applicable development standards. Land use considerations would be required to manage any interaction between the project and future development for buildings with habitable structures above 20 metres and within 300 metres of ventilation outlets.</p>
(e) to protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats,	<p>Construction would result in the clearing of native vegetation, and some areas of planted vegetation would also be removed. Management measures have been proposed to minimise the potential for direct and indirect impacts.</p> <p>Some terrestrial fauna species would be impacted by the project. Management measures including pre-clearing surveys and monitoring to minimise the risk of impacts to native species.</p> <p>Mitigation and rehabilitation works would be carried out to protect and restore subtidal rocky reef and intertidal rocky shore habitat removed along the shoreline.</p> <p>In accordance with the Secretary's environmental assessment requirements and the requirements of the <i>Biodiversity Conservation Act 2016</i>, a biodiversity offset strategy has been developed to compensate for the loss of ecological values as a result of the project.</p>
(f) to promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage),	<p>Impacts on heritage items would be minimised during construction where possible, and works would be carried out in accordance with relevant management strategies where impacts are unavoidable.</p> <p>Possible indirect impacts associated with vibration and settlement from tunnelling works or surface works beneath or near to Aboriginal sites would be managed in accordance with relevant management measures.</p>

Objects of the <i>Environmental Planning and Assessment Act 1979</i>	Project attributes
(g) to promote good design and amenity of the built environment,	<p>The project would provide:</p> <ul style="list-style-type: none"> • New and upgraded active transport infrastructure (pedestrian and cyclist facilities) • Reduction in traffic noise at receivers surrounding the project surface road works, due to the redistribution of traffic. The project is expected to lead to an overall improvement in noise levels within the community (compared with the existing situation). Noise mitigation (such as at-property treatment) would be implemented where required • Improved access and connectivity through improved travel time and improved travel time reliability, including to local and regional infrastructure within and near the project • New and improved open space and recreation facilities at Balgowlah.
(h) to promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants,	<p>The construction of the project, including motorway facilities, ventilation outlets and tunnel portals would be completed in line with the applicable Australian and international safety standard as well as any applicable Transport for NSW Safety in Design guidelines.</p>
(i) to promote the sharing of the responsibility for environmental planning and assessment between the different levels of government in the State,	<p>Consultation has been carried out with the relevant local councils and government agencies throughout the development of the project and the preparation of this environmental impact statement. All levels of government have been encouraged to be actively involved in and to contribute to the evolution of the project through consultation to date and continuing consultation activities.</p>
(j) to provide increased opportunity for community participation in environmental planning and assessment.	<p>Consultation has been carried out through all stages of the project development, with targeted community consultation periods carried out in 2017 and 2018, consultation with key community and interest groups, and a business survey carried out in November 2017 across ten local centres potentially affected by the project.</p> <p>Community feedback has been considered at each stage of the project development to inform the selection of the preferred corridor alignment and subsequent design development and refinements. Community consultation would continue through public exhibition of this environmental impact statement and during further design development and construction, should the project be approved, in accordance with the Community consultation framework.</p> <p>A dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input to the final layout of the new and improved open space and recreation facilities at Balgowlah.</p>

28.7.4 Cumulative impacts

Once operational, the Western Harbour Tunnel and Beaches Link program of works is expected to deliver beneficial cumulative impacts including substantial increases in travel speeds through sections of the surface road network, increased reliability, and a reduction in average travel times.

Adverse cumulative impacts could occur when impacts from the project interact or overlap with impacts from other projects and potentially result in a larger overall impact. Cumulative impacts may also occur when there are projects that are constructed consecutively, resulting in construction fatigue for local receivers. Cumulative impacts for the project are presented in Chapter 27 (Cumulative impacts).

The implementation of environmental management measures for the project would avoid, to the greatest extent possible, cumulative impacts with surrounding development. In particular, the design of the project has carefully considered minimising construction fatigue as far as practical. The intent is to reduce the overall cumulative or consecutive impacts on the community over a longer period.

28.7.5 Conclusion

This environmental impact statement addresses the key issues identified in the Secretary's environmental assessment requirements issued under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* and the relevant provisions of Schedule 2 of the Environmental Planning and Assessment Regulation 2000.

The project is part of the NSW Government's commitment to investing in and delivering efficient and effective transport systems including road infrastructure that would relieve congestion, improve travel times, improve road safety and enhance and expand capacity on key road corridors. In particular, the project would provide additional capacity across Middle Harbour, relieving congestion on existing key routes and providing connections including via planned new express bus services within the tunnels to other key existing and future proposed transport projects.

The merits of the project were considered in the context of a range of other alternatives including do-nothing, based on the extent to which they could meet the project objectives and how well they performed with reference to other transport, environmental, engineering, social and economic factors. No other alternative would satisfy the need and objectives as effectively as the project.

As for any major infrastructure project to be constructed through the middle of a major urban area, there are expected to be impacts. Designing and constructing the project mainly underground has considerably reduced impacts and largely confined these to the construction stage. The design and construction method would continue to be developed with the objective of further minimising potential impacts taking into account the input of stakeholders and the local community.

Notwithstanding there would be a range of residual impacts. With the implementation of the proposed environmental management measures, the potential residual environmental impacts of the project are considered manageable and the project would be in the public interest.



Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Chapter 29

References

29 References

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