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Volume 1C

November 2015

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16 Soil and water quality

This chapter describes the environmental values relating to soils and water and identifies the potential impacts to these values as a result of the construction and operation of the project. The potential impacts on water quality resulting from the proposed water treatment plant discharge are also considered.

The Technical working paper: Surface water (**Appendix N**) and **Chapter 18** (Flooding and drainage) have been used to inform this chapter.

Other chapters of this environmental impact statement (EIS) that are relevant to soil and water quality include:

- **Chapter 17** (Contamination), which provides an assessment on the potential for the project to generate or disturb contaminated soils (specifically, **Sections 17.3.1** to **17.3.4**)
- **Chapter 19** (Groundwater) which provides an assessment of the existing groundwater environment and the impacts associated with groundwater inflow and drawdown (specifically, **Sections 19.2**, **19.3**, and **19.4**).

Table 16-1 sets out the Secretary's Environmental Assessment Requirements (SEARs) as they relate to soil and water quality and states where in this EIS these have been addressed.

Table 16-1 SEARs – soil, water and hydrology

SEARs	Section addressed
An assessment of construction and operational erosion and sediment and water quality discharge impacts, taking into account impacts from treated discharge, accidents and runoff (i.e. acute and chronic impacts), having consideration to impacts to surface water runoff, soil erosion and sediment transport, mass movement, salinity and iron levels. The assessment must include identification and estimation of the quality and quantity of pollutants that may be introduced into any waterways by source and discharge point;	Potential erosion, sediment and water quality discharge impacts are described in **Sections 16.3.1**, **16.3.2** and mitigation measures in **Section 16.4**. Surface water runoff, sediment transport, mass movement, salinity and iron levels are considered in **Sections 16.3.1** and **16.3.2**.
An assessment of water quality impacts on receiving waterways likely to be affected by the proposal (including Wolli, Cup and Saucer creeks, Cooks River and Alexandra Canal). The assessment must include existing water quality, geomorphology, riparian vegetation and rehabilitation of riparian land, and have reference to the NSW Water Quality Objectives and relevant public health and environmental water quality trigger values and criteria, including those specified in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000), any applicable regional, local or site-specific guidelines and any licensing requirements.	Potential water quality impacts are described in **Sections 16.3.1** and **16.3.2** and mitigation measures in **Section 16.4**. Biodiversity impacts, including impacts on riparian vegetation at Wolli Creek, are described in **Sections 21.3.1** and **21.3.2** (Biodiversity).

SEARs	Section addressed
An assessment of groundwater impacts (including ancillary facilities such as the tunnel control centre and any deluge systems), considering local impacts along the length of the tunnels and impacts on local and regional hydrology including consideration of any Water Sharing Plan and impacts on groundwater flow. The assessment must consider: extent of drawdown; impacts to groundwater quality; volume of groundwater that will be taken (including inflows); discharge requirements; location and details of groundwater management and implications for groundwater-dependent surface flows, groundwater-dependent ecological communities, and groundwater users. The assessment must include details of proposed surface and groundwater monitoring and be prepared having consideration to the requirements of the NSW Aquifer Interference Policy;	Groundwater impacts are described in **Sections 19.3** to **19.4** (Groundwater). Impacts of groundwater treatment and water treatment plan discharge on surface water quality are discussed in **Sections 16.3.1** and **16.3.2**.
Identifying potential impacts of the development on acid sulfate soils in accordance with the relevant guidelines and a description of the mitigation measures proposed to minimise potential impacts.	Refer to **Sections 16.3.1** and **16.4**.

16.1 Assessment methodology

The methodology for the soils assessment involved:

- A review of the geological context, soil landscapes, and acid sulfate soils within the project corridor, including consideration of:
  - Regional geology along the project corridor, as described in the Geological Survey of NSW 1:100,000 scale Sydney Map Sheet (sheet 9130, 1983)
  - The soil landscapes and characteristics within the project corridor, which have been determined based on the Soil Landscapes of the Sydney 1:100,000 Sheet 9130 (1989). Examination of the soil landscape maps and an interpretation of the erosion potential, and other stability issues, has been conducted in order to assess potential impacts
  - Acid sulfate soils mapping, obtained from Australian Soils Resource Information System and NSW Department of Land and Water Conservation to determine areas of higher probability
- Identification and assessment of construction and operational activities that may result in erosion or the exposure of acid sulfate soils
- Identification of environmental management measures, including the type of controls and design criteria required to mitigate potential impacts.

The methodology for the water quality assessment involved:

- Desktop assessment and review of background information
- Identification of the surface water study area
- Field assessment to assess the current state of surface water features and water quality within the surface water study area
- Consultation with relevant government agencies and stakeholders (**Sections 7.3**, **7.4** and **7.5**)
- Identification and assessment of construction and operational activities that may result in erosion and mass movement, the exposure of acid sulfate soils and impacts to the water quality of receiving environments
- Identification of environmental management measures, including the type of controls and design criteria required to mitigate potential impacts.

The methodology for the water quality assessment is presented in further detail in the following sections.

16.1.1 Surface water study area

The project is located within the lower portion of the Cooks River catchment (refer to **Figure 16-1**). The surface water study area includes the sub-catchments of the Cooks River that contain, or would potentially be influenced by, elements of the project as follows:

- The western surface works and Bexley Road surface works would be located within the Wolli Creek sub-catchment
- The St Peters interchange works and the eastern portion of the local road upgrades would be located within the Alexandra Canal catchment
- The north west portion of the local road upgrades (generally north west of the Princes Highway) would be located within the Eastern Channel sub-catchment
- The Arncliffe surface works would be located on land that drains directly to the Cooks River.

The Cup and Saucer Creek was found to be significantly upstream from the lower portion of Cooks River which does fall within vicinity of the project area. As such, while the Cup and Saucer Creek was identified for assessment in the SEARs (refer **Table 16-1**), it was not considered to be part of the overall study area for the project as it is located sufficiently upstream from the project area to not be impacted on by the project.

16.1.2 Desktop assessment

The desktop assessment involved a review of the existing surface water environment across the study area, including:

- Information available in databases relevant to surface water including water quality data sampled as part of previous assessments, flood data and information about the physical conditions of the surface water environment
- Review of information and previous studies conducted for other relevant major developments within the surface water study area, including the M5 East Motorway and other developments along Alexandra Canal. This included geomorphological and water quality studies used to inform the EIS for this project
- Other relevant studies that form part of this EIS, including groundwater, contamination, biodiversity and flood studies.

Given the availability of several existing surface water quality data sets within the study area (refer **Section 16.1.1**), no further surface water quality sampling was considered necessary to characterise the existing surface water quality of the study area.

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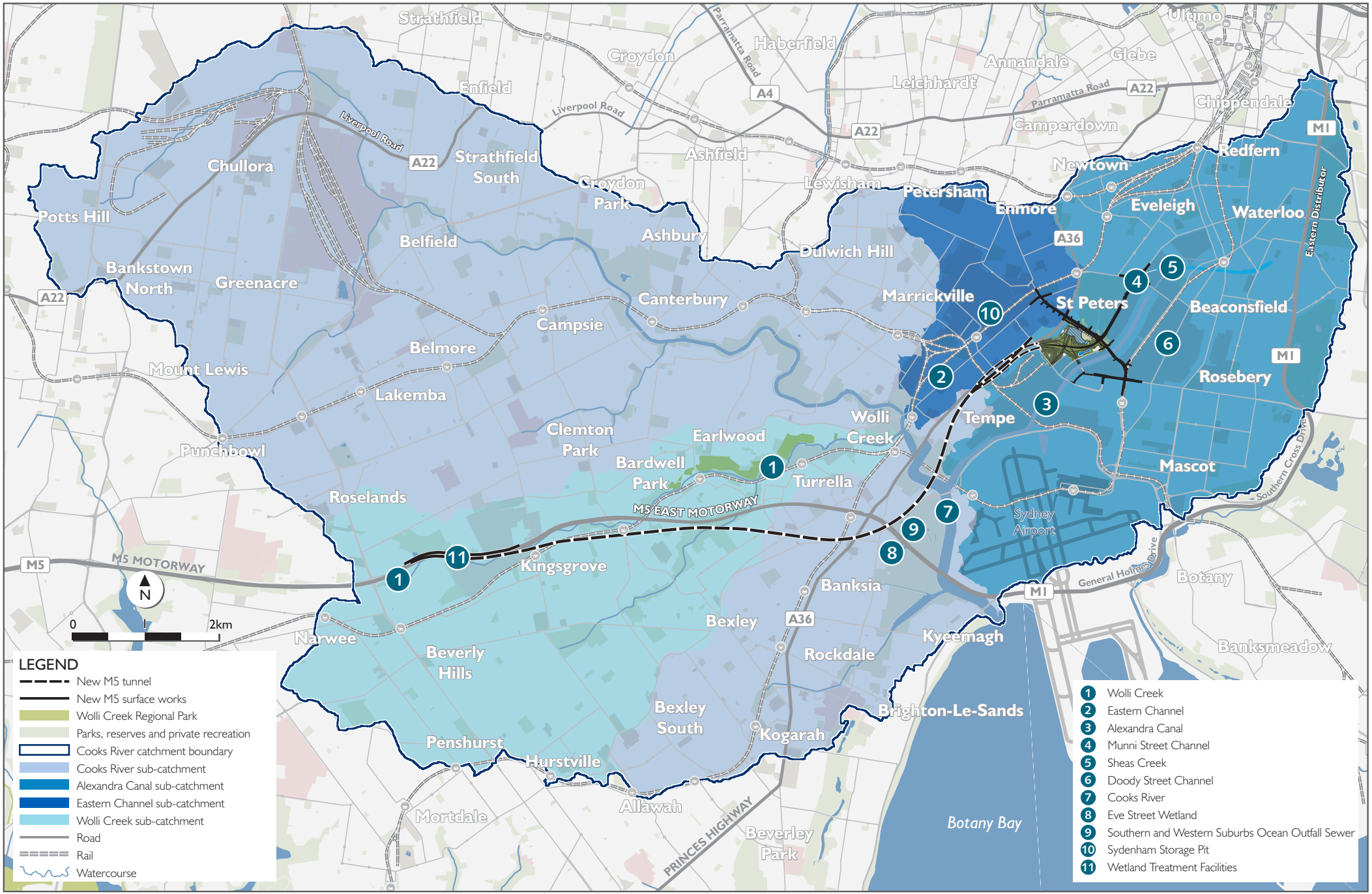


Figure 16-1 Surface water study area

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16.1.3 Field assessment

The objective of the field assessment was to determine the current state of surface water features within the study area that could be impacted on by changes to surface water flooding, hydrology or water quality. The existing flooding regime of the study area is detailed in **Section 18.2.2** in **Chapter 18** (Flooding and drainage).

Field inspections were conducted on 16, 17 and 23 April 2015. Where access was available, inspections were made to relevant sections of:

- Alexandra Canal
- Sheas Creek
- Botany Road / Doody Street Stormwater Channel
- Munni Street Stormwater Channel
- Eastern Channel
- Sydenham Storage Pit
- Lower Cooks River
- Wolli Creek
- Wetland Treatment Facilities (#1-5) along the existing M5 East Motorway alignment (refer to Figure 19 of the Technical working paper: Surface water (**Appendix N**)
- Eve Street Wetland
- South Western Suburbs Ocean Outfall System.

These locations are shown on **Figure 16-1**.

16.1.4 Identification and assessment of potential impacts

The potential impacts of the project on the water quality of receiving waters have been considered in terms of watercourse geomorphology and the potential for erosion, sedimentation and mass movement impacts, as well as uncontrolled spills and the existing water quality within the catchment.

Geomorphology

As a basis of understanding the types of watercourses present within the project corridor a geomorphic categorisation framework called River Styles (Brierley and Fryirs, 2005) was used to classify watercourses based on morphology and behaviour.

A modified version of the framework methodology that was developed for the Sydney Metropolitan Waterways Health Strategy (Earth Tech, 2007) was adopted to allow for the urbanised and modified geomorphology of the watercourses.

The River Styles classification provided the basis for determining the vulnerability of each watercourse to geomorphic impacts such as erosion and mass movement, which in turn influences water quality. The extent of potential impacts was assessed and compared to the vulnerability of the watercourses in order to determine the impacts of the project on geomorphology.

A preliminary erosion and sedimentation assessment was also conducted for the project in accordance with the Erosion and Sedimentation Risk Assessment Procedure – Appendix 1a &1b for Concept Designs (RTA, 2004).

Water quality

Baseline surface water quality data across the study area was obtained from the following previous studies:

- Sydney Water Environmental Indicators Compliance Report Volume 3 (Woodlots, 2004)
- City of Rockdale Water Quality Monitoring Study (Equatica, 2014)
- 2011 Annual Water Quality Study (Cooks River Valley Association, 2010 / 2011)
- Cooks River Stormwater Management Plan. Prepared for the Cooks River Catchment Association of Councils (PPK-WMA, 2009)
- Review of Environmental Factors for the Alexandra Canal (Stormwater Renewal Program) (GHD, 2012).

Surface water monitoring data from these previous studies has been used to characterise water quality in the surface water study area (refer to **Section 16.2.7** for more detail). Data monitoring locations are shown in **Figure 16-2**. The comprehensive nature of existing surface water quality data (in relation to timing, frequency and spatial extent) provided sufficient information to characterise the existing environment. Notwithstanding, the project specific water quality monitoring was also undertaken and the data used in the assessment of the existing environment.

Project specific water quality monitoring of waterways commenced in June 2015, and would continue through construction of the project and for 12 months post-construction or as otherwise required by the conditions of approval. The purpose of the project specific water quality monitoring is to provide a targeted baseline for locations which may be impacted by the project. The baseline would be used to confirm compliance with conditions of consent during construction and operation of the project. Details of the project specific monitoring program are described in **Section 16.3**.

Discharge criteria

The ANZECC Water Quality Guidelines are ambient water quality guidelines that have been used to classify the water quality of watercourses in the study area.

Under the guidelines classification system the watercourses within the study area have been classified as highly disturbed systems. These systems are defined as ecosystems of lower ecological value that include urban streams receiving road and stormwater runoff (ANZECC, 2000).

The NSW Water Quality and River Flow Objectives (DECCW, 2006) are consistent with the ANZECC Water Quality Guidelines and are used to maintain and improve water quality in order to support aquatic ecosystems, recreation activities, aquatic foods and / aquaculture.

The NSW Water Quality and River Flow Objectives have been developed for the Cooks River catchment and are dealt with in this EIS as follows:

- Protect aquatic ecosystems – refer to **Sections 21.2.6, 21.3.1**, **21.3.2** and **21.4**
- Protect visual amenity – refer to **Sections 14.3.1**, **14.3.2** and **14.4**
- Protect irrigation water supply – this was not considered applicable to the project as there is no agriculture within the study area
- Maintain natural flow variability – refer to **Section 16.3.2** and **Sections 21.2.6**, **21.3.1** and **21.3.2**
- Maintain natural rates of change in water levels – refer to **Table 16-12** and **Section 16.3.2**
- Minimise effects of weirs and other structures – refer to **Table 16-12** and **Section 16.3.2**.

In order to promote an improvement in water quality within the receiving environments, a local reference data set for nutrients, dissolved oxygen and pH was developed based on the existing surface water data.

The reference data set has been used to establish the criterion that pollutant concentrations within water treatment plant discharge would not exceed the 80th and / or 20th percentile values of the reference data set. Other controlled discharges in addition to those from water treatment plants are not anticipated, and so were not considered further in this EIS.

Operational Stormwater Pollutant Reduction Targets

To assess the water quality impacts of the surface runoff on the receiving environments, basic assessments incorporating Model for Urban Stormwater Improvement Conceptualisation (MUSIC) modelling was undertaken to estimate the pollutant loads and required treatment levels for stormwater runoff during the project's operation (refer **Section 16.3.2**).

These additional pollutant loads generated by surface runoff would be mitigated in accordance with:

- The project's Water Quality Reference Criteria (refer Appendix A of the Technical working paper: Surface water (**Appendix N**))
- The stormwater pollution reduction targets from the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011).

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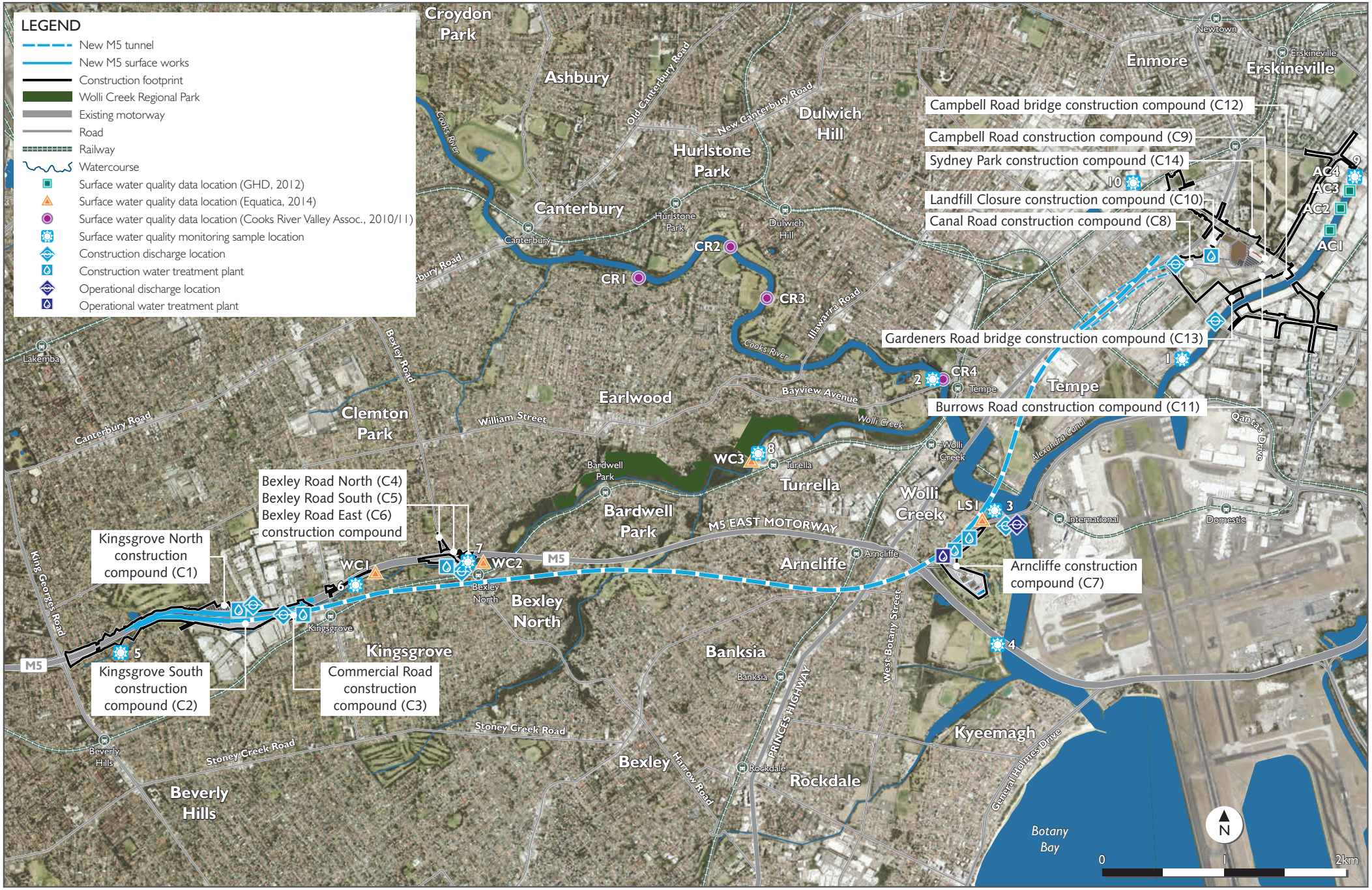


Figure 16-2 Water quality data locations

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16.2 Existing environment

16.2.1 Topography and geology

Topography

The western portion of the project corridor is relatively flat, low lying, with gentle undulating hills ranging between 30 metres Australian height datum (AHD) and 40 metres AHD, characteristic of Ashfield Shale type terrain.

The central portion of the project corridor is characterised by Wolli Creek and Bardwell Creek. These watercourses have incised gullies that pass through a subterranean sandstone and shale plateau.

The topography of the project corridor near the confluence of Wolli Creek and the Cooks River is relatively flat and low-lying (around five to 10 metres AHD) and gradually declining towards Botany Bay.

Various ridgelines have controlled the alignment of drainage features such as the Cooks River. Land within and adjoining the central and north-eastern areas of the project corridor has been substantially modified over time due to land reclamation and industrial activities. The Botany Sands are present in the vicinity of Alexandra Canal.

The eastern portion of the project corridor would include the St Peters interchange, which would be located on the former Alexandria Landfill site. The landfill site is a former brick pit, which has been progressively filled with waste materials over several decades.

Regional geology

Regionally the project area is located within the Permo-Triassic Sydney Basin which is characterised by sandstone and shale sediments. Around the eastern end of the project, the Botany Sands overlie the bedrock.

The main geological layers that are expected to be encountered across the project corridor will comprise the following from youngest to oldest:

- Anthropogenic fill
- Quaternary Alluvium (recent beneath rivers, palaeochannels and Botany Sands)
- Jurassic Intrusions (volcanics)
- Triassic Ashfield Shale (Wianamatta Group)
- Triassic Mittagong Formation
- Triassic Hawkesbury Sandstone Formation.

Figure 16-3 shows the proposed alignment in the regional geology context. A detailed geological long section showing subsurface and geological structures in relation to the vertical alignment of the tunnel is provided in **Appendix C**.

The geology along the project corridor, as described in the Geological Survey of NSW 1:100,000 scale Sydney Map Sheet (sheet 9130, 1983), and confirmed by the project-specific site investigations undertaken between September 2014 and March 2015 (refer to **Section 19.1.2** (Groundwater)), is dominated by the Wianamatta Group rocks and the Hawkesbury Sandstone Formation. These units are separated by the Mittagong Formation across the majority of the Sydney Basin area.

The Wianamatta Group Geological unit comprises Ashfield Shale, which corresponds to the ridgelines around Kingsgrove, and from Sydenham to St Peters. The Ashfield Shale layer typically extends to a depth of three to 10 metres, although has extended to depths in excess of 40 metres. The Ashfield Shale layer comprises siltstone and laminite subgroup units.

Hawkesbury Sandstone is present at depth all the way along the project alignment, at the surface from Bardwell Valley to Wolli Creek, and in areas around Tempe. The Hawkesbury Sandstone is a medium to coarse grained quartz sandstone deposited in beds around one metre to over three metres thick. The beds may be massive, or cross-bedded. Shale breccia is common at the contacts between beds and siltstone interbeds form a minor part of the unit. Siltstone interbeds are prominent within the sandstone below Rockdale and Kogarah.

The Mittagong Formation separates the Ashfield Shale from the underlying Hawkesbury Sandstone. The formation represents the transition from the fluvial or terrestrial environment of the Hawkesbury Sandstone deposition to the marine delta deposition of the Ashfield Shale. The boundary can be variable in composition and thickness. The Mittagong Formation generally comprises an upper, thin, fine grained sandstone unit (typically 0.5 metres to 1.5 metres thick) over a lower unit of fine grained sandstone and siltstone (typically one metre to three metres thick, but can be in the order of 10 metres thick).

Igneous dykes and breccia diatremes (volcanic vents filled with breccia, formed by volcanic eruptions) of Jurassic Age are sparsely distributed throughout the Sydney Region.

The Geological Survey of NSW 1:100,000 scale Sydney Map Sheet 9130 indicates the presence of 25 diatremes and over 100 dykes. Three dykes were identified during site investigations for the project, around Bexley Road, and on the north and south side of the Cooks River. The dykes in the Sydney region generally consist of linear basaltic rock bodies intruded into the surrounding country rock. The dykes are typically extremely weathered and altered to a kaolinitic clay to a depth of some 10 to 20 metres below ground level.

No faults are mapped crossing the project corridor on the Geological Survey of NSW 1:100,000 scale Sydney Map Sheet, but faulted rock and shear zones have been identified during the site investigations for the project at several locations along the alignment, including around Cooks River, Bardwell Valley, St Peters, Banksia and Rockdale. North-east to south-west trending faults have been mapped in the Sydney CBD and these faults may extend south through the project corridor.

The geology of the area was influential in determining the tunnel vertical alignment. Hawkesbury Sandstone is considered an excellent tunnelling and excavation medium and as a result, the main alignment tunnels have been designed to maximise the length of tunnel within this geological unit. The tunnel depth below the Cooks River has also been determined based on the depth of soft sediments within the Cooks River paleo-valley.

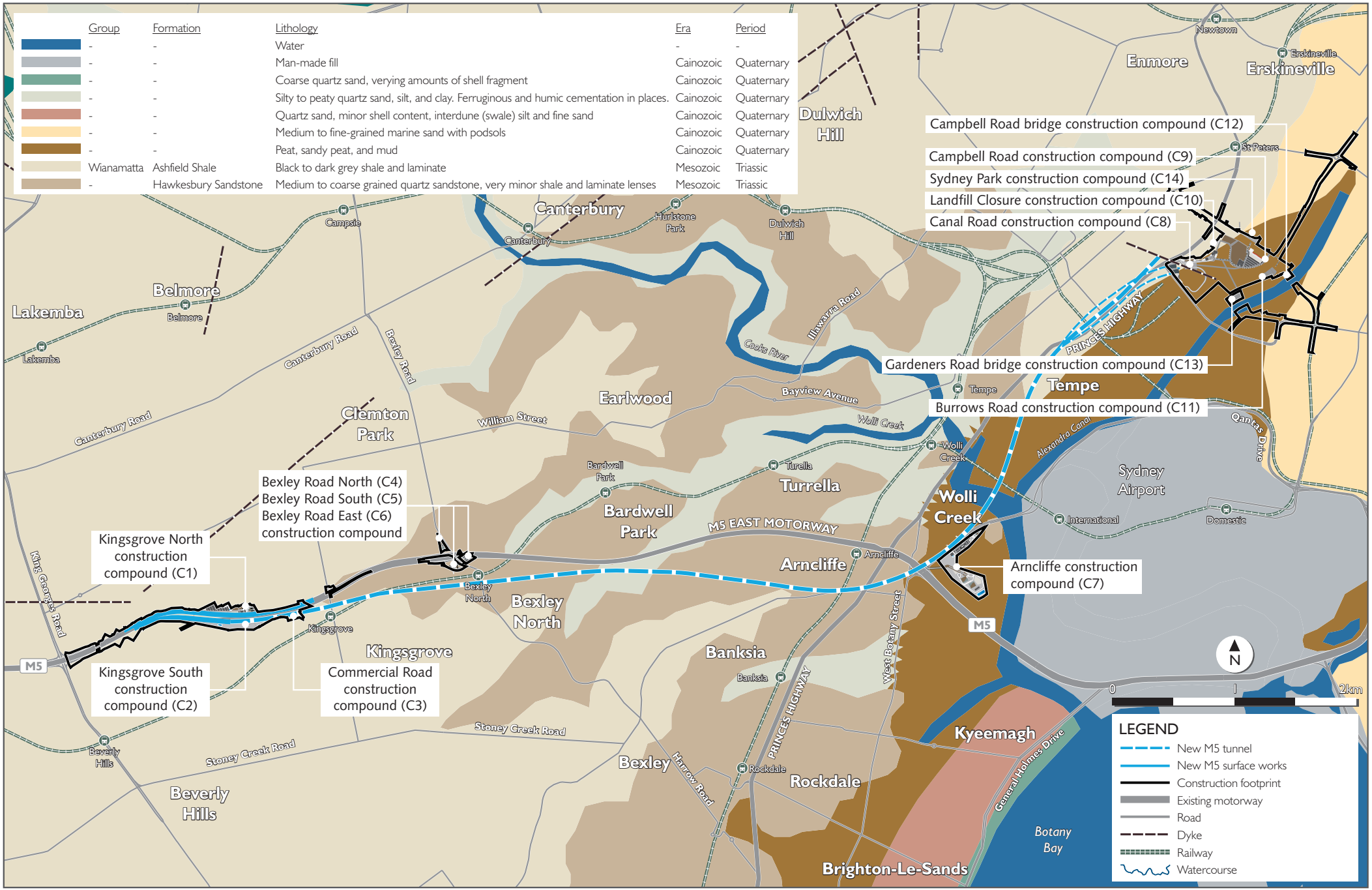


Figure 16-3 Regional geological context

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16.2.2 Soils landscapes

The Soil Landscapes of the Sydney 1:100,000 Sheet 9130 (1989) indicates that the project corridor is underlain by seven soil landscape groupings, within which there are seven soil landscapes. The Gymea soil landscape covers the majority of the project corridor in the west, with smaller areas of the Hawkesbury, Blacktown, Birrong, Warriewood and Oxford Falls soil landscapes. The eastern extent of the project corridor is largely covered by land identified as being disturbed terrain associated with Alexandra Canal and industrial land uses.

Soil landscapes within the study area are shown in **Figure 16-4**, and their key characteristics summarised in **Table 16-2**.

Table 16-2 Soil landscapes

Soil landscape	Characteristics	Erosion/mass movement potential
Residual Blacktown	• Occurs on gently undulating rises on Wianamatta Group Shales • Poorly drained, moderately reactive soil.	No appreciable erosion occurs on this unit as most of the surface is covered by tiles, concrete, bitumen or turf.
Alluvial Birrong	• Occurs on level to gently undulating alluvial flood plan draining the Wianamatta Group Shales • Saline soils, seasonal waterlogging and localised flooding.	Soil landscapes exhibit a high soil erosion hazard. However, most drainage lines have been artificially lined with concrete to prevent ongoing erosion. Minor streambank erosion has occurred along remaining natural drainage lines.
Erosional Gymea	• Occurs on undulating to rolling rises and low hills on Hawkesbury Sandstone • Localised steep slopes • High soil erosion hazard.	Severe sheet erosion occurs following bushfires that destroy or damage stabilising vegetative cover. Minor gully erosion occurs along unpaved roads and fire trails especially those frequented by four wheel drive vehicles and trail bikes.
Colluvial Hawkesbury	• Occurs on rugged, rolling to very steep hills on Hawkesbury Sandstone • Extreme soil erosion and mass movement hazard.	Severe sheet erosions often occur during storms and after ground cover is destroyed by bushfires. Minor gully erosion occurs along unpaved tracks and fire trails, especially those used regularly by four wheel drive vehicles, motorcycles and horses.
Transferral Oxford Falls	• Occurs in hanging valleys on Hawkesbury Sandstone, with occasional broad benches and scarps.	Very high soil erosion hazard perched water tables and swamps, highly permeable soil.
Swamp Warriewood	• Occurs on level to gently undulating swales, depressions and infilled lagoons in Quaternary sands • High water tables and localised flooding, highly permeable soils, compressible soils.	No appreciable erosion occurs where slopes are low and a vigorous ground cover is maintained. Isolated blowouts caused by wind erosion occur in exposed area where cover has been removed.
Disturbed Terrain Disturbed Terrain	• Terrain extensively disturbed by human activity, including complete disturbance, removal or burial of soil • Variable relief and slopes.	Erosion hazard varies markedly according to site characteristics including slope, aspect and exposure. In general, severe sheet and rill erosion often occur at quarries, gravel pits and places where unconsolidated or disturbed material remains without a protective cover of vegetation, asphalt or concrete.

16.2.3 Acid sulfate soils

Acid sulfate soils and potential acid sulfate soils are naturally occurring soils that contain iron sulfides which, on exposure to air, oxidise and create sulfuric acid. This increase in acidity can result in the mobilisation of aluminium, iron and manganese from the soils. Other impacts include the de-oxygenation of water.

A search of the Australian Soils Resource Information System indicated there is a low to extremely low probability of occurrence of acid sulfate soils for the majority of the project corridor. Land adjacent to watercourses, namely the Cooks River, Wolli Creek and Alexandra Canal were identified as having a high probability of being acid sulfate soils.

Areas showing the high and low probability of occurrence of acid sulfate soils extracted from the NSW Department of Land and Water Conservation Acid Sulfate Soil Risk Map for Botany Bay are presented on **Figure 16-5**.

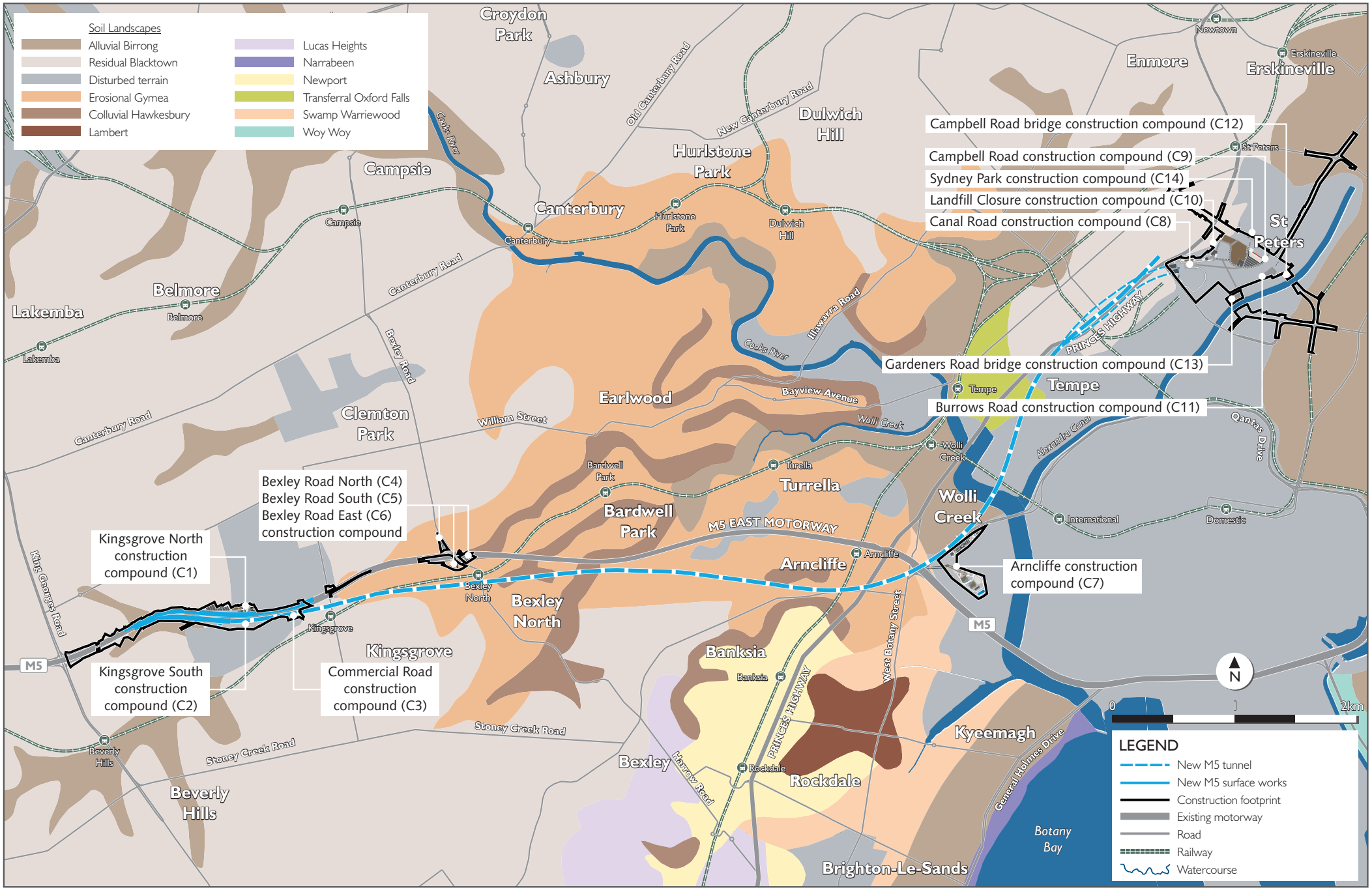


Figure 16-4 Soil landscapes

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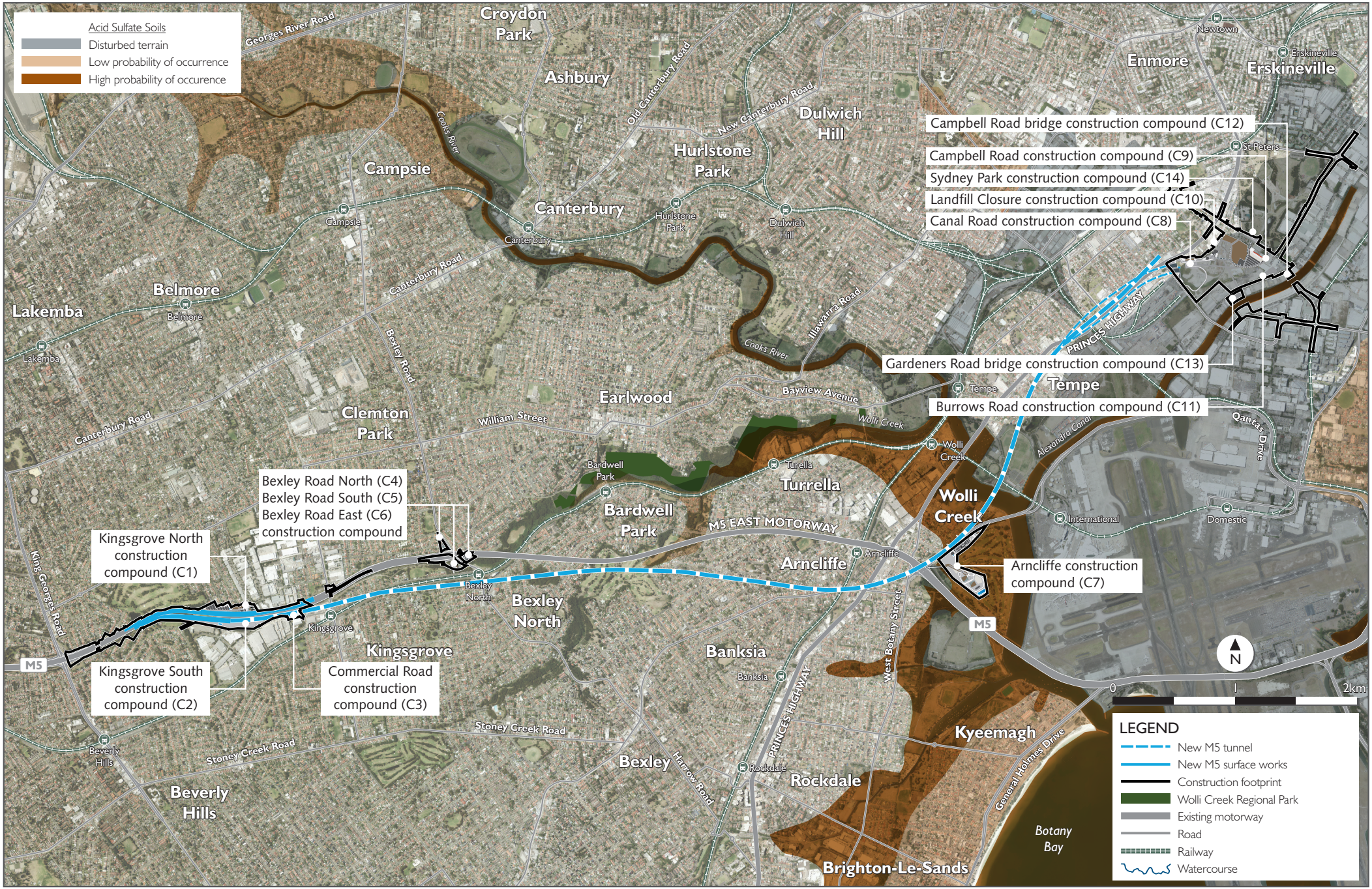


Figure 16-5 Acid sulfate soil risk areas within the study area

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16.2.4 Catchments and watercourses

The project would be constructed within the Cooks River catchment. The Cooks River catchment forms part of the greater Botany Bay Catchment (SMCMA, 2011) and is fed by nine tributaries:

- Greenacre Creek
- Cox's Creek
- Cup and Saucer Creek
- Fresh Water Creek
- Bardwell Creek
- Wolli Creek
- Muddy Creek
- Shea's Creek / Alexandra Canal
- Eastern Channel.

Of these nine tributaries, Wolli Creek, Shea's Creek / Alexandra Canal and the Eastern Channel are located within the surface water study area and are relevant to the project.

The following field inspections were undertaken:

- 16 April 2015, inspection of geomorphology and waterways
- 17 April 2015, inspection of geomorphology and waterways as well as existing water quality improvement devices
- 23 April 2015, inspection of drainage infrastructure and assessment of waterway capacity following heavy rainfall.

The catchments of these tributaries, and that of the Cooks River, are described below.

Cooks River catchment

The Cooks River catchment measures around 10,000 hectares. The landscape within the catchment has been highly urbanised, with a history of intensive land use ranging from residential to heavy industry.

Residential land use is the predominant zoning within the catchment, covering around 58 per cent of the catchment. Open space represents the smallest land use within the catchment, covering around 11 per cent of the catchment. The catchment has no significant rural lands, eight per cent park land and a small area of bushland surrounding Wolli Creek. Industrial zoned land is concentrated in the Port Botany area, along Alexandra Canal and the southern portion of the Strathfield Council area.

The heavily urbanised nature of the catchment is a likely influencer on the Cooks River catchment being regarded as one of the most polluted catchments in Australia, and the majority of watercourses within the Cooks River catchment are anthropogenically modified channels.

The Cooks River flows for around 23 kilometres from Graf Park in Bankstown into Botany Bay at Kyeemagh (CRA, 2013). The Cooks River is almost uniformly 50 metres wide upstream of Cahill Park, Tempe where it widens to roughly 150 metres until its trained mouth.

The Cooks River is semi-tidal due to its connection with Botany Bay at Mascot. The tidal limit of the Cooks River is estimated to be adjacent to Sando Reserve, Croydon Park (Manly Hydraulics Laboratory, 2005). This is roughly 7.5 kilometres upstream of the confluence of the Eastern Channel, deemed to be the upstream extent of the potential influence of the project.

The Cooks River is highly modified and lined with steel sheet pilings, concrete walls or stone block revetments and with some rehabilitated natural sections. As a result of the channelization and lining works, this lower section of the Cooks River is not susceptible to erosion or mass movement, providing river flows are contained with the channel. During flooding events, there is potential for erosion of the floodplain and slopes adjacent to the Cooks River.

Wolli Creek sub-catchment

The Wolli Creek sub-catchment measures around 2100 hectares. The catchment extends from Narwee in the west, Wolli Creek to the east, Mortdale to the south and Roselands to the north. The catchment has been significantly altered by urbanisation including general residential, industrial and commercial development, as well as the construction of the M5 East Motorway and the East Hills Railway line. Prominent open space areas within the catchment include the Canterbury Golf Course, the M5 Linear Park (part of the M5 East works) and the Wolli Creek Regional Park.

Wolli Creek is the largest tributary of the Cooks River and measures around 3.5 kilometres long. The creek starts in Beverly Hills and flows through the Wolli Creek Valley in a north-easterly direction until joining the Cooks River near Tempe. The creek is tidal to near Hannam Street, Bardwell Park.

The geomorphology of the watercourse is broadly characterised by:

- The western extent of the project corridor downstream to Bexley Road
- Bexley Road downstream to the Wolli Creek confluence with the Cooks River.

The western extent of the project corridor downstream to Bexley Road Bridge crossing is generally anthropogenically modified with hard engineered lining. This section consists of: open concrete-lined trapezoidal channels; underground concrete channels; piped channels; and rock-lined channels.

The section from Bexley Road to the Cooks River has been modified to accommodate the railway line and urban development. The creek flows into a modified natural channel from Bexley Road with alluvial creek banks and densely vegetated weed species within a confined valley setting before transitioning into a partly confined meandering platform controlled setting.

The watercourse travels through the Wolli Creek Regional Park and is joined by Bardwell Creek on the northern side of the passenger rail line at Bardwell Park. A weir and associated fishway at Turrella Park, near Henderson Street regulates flow before it reaches its confluence with the Cooks River adjacent to Wentworth Park, Wolli Creek

Alexandra Canal sub-catchment

The Alexandra Canal sub-catchment measures around 2300 hectares and is a tidal sub-catchment of the Cooks River. The catchment extends from Tempe in the south west to Moore Park in the north east. The catchment is heavily altered, predominantly covered by commercial, industrial and residential development with a small amount of parkland.

The Alexandra Canal is around 3.9 kilometres long and up to 60 metres wide. It is a constructed canal that was originally a natural watercourse named Sheas Creek, flowing into the Cooks River near the north-western corner of Sydney Airport. Sheas Creek is now a shortened concrete-lined channel upstream of Alexandra Canal. The Alexandra Canal is tidally dominated through its connection to the Cooks River. The tidal influence extends up to Huntley Street, St Peters.

Historically, dredging was regularly untaken to remove sediment build up. The canal bank walls were originally constructed using sandstone blocks, the condition of these walls is highly variable. The bottom of the canal is mainly earth except where Sheas Creek enters the canal near Huntley Street, where a base has been laid in sandstone (Department of Public Works and Services, 2004).

The majority of the canal is devoid of geomorphic units, due to the rock-lined banks and dredged canal base. Due to the accretive nature of the Alexandra Canal in its middle reaches, sediments tend to build up and are not protected from scour events. The canal contains a scour hole at the headwaters of the canal and a number of sediment deposition material (slugs), particularly at the extents of the waning flow energy, channel edges, tidal influence, and in-stream structures. These sediment slugs are remobilised when larger events pass through the system, eventually over time entering the Cooks River. The potential for the mobilisation of contaminated sediments is discussed in **Section 5.5.5** and **Section 9.5** of the Technical working paper: Contamination (**Appendix O**). A further study showed that older sediments in the Alexandra Canal are known to be highly contaminated and these are overlain by more recent less contaminated sediments (UoQ, 2002).

Overall, the past investigations have found the following main sources of pollution in the Alexandra Canal to be:

- Stormwater pollution including runoff from roads, industrial, commercial and residential premises
- Seeps and overflows from the sewer system
- Discharges from industry
- Contaminated land within the catchment combined with porous soils allowing leachate to migrate via stormwater or groundwater into the canal
- Release of chemicals from contaminated sediments in the canal into the water column
- Contaminated groundwater input (DPWS, 2004).

Alexandra Canal was declared a remediation site (number 21008) on 25 August 2000 by the EPA due to contaminated bed sediments. A Remediation Order (number 23004) was subsequently issued by the EPA to Sydney Water on 10 May 2004.

The Remediation Order includes a requirement not allowing 'any works or activities on the bed sediments of the site that would result in the disturbance, or further disturbance, of the bed sediments' except as provided by the Remediation Order. The Remediation Order also states that works disturbing the bed sediments require a plan to be submitted to the EPA for approval prior to commencement of the works (refer Section 5.5.5 of **Appendix O**).

Eastern Channel sub-catchment

The Eastern Channel sub-catchment measures around 500 hectares. Within the project corridor the catchment includes the suburbs of Tempe, Sydenham, St Peters and Alexandria. The area is highly urbanised and altered by a relatively even mix of commercial and residential property. The catchment has a very small proportion of open space in the form of recreational parklands.

The Eastern Channel runs along the Sydenham to Tempe railway line. The channel is an open concrete lined channel of varying dimensions and grade (average grade of 0.17 per cent) which carries stormwater. The main open section is around 2.3 kilometres near Murray Street, Marrickville to its confluence with the Cooks River adjacent to Tempe Station. Part of the channel is tidal due to its connectivity with Cooks River.

16.2.5 Catchment land use

The geomorphology and water quality of the watercourses in the surface water study area is closely linked to the land use in each of the catchments. A summary of land uses for each catchment is provided in **Table 16-3**.

Table 16-3 Land use within the Cooks River catchment and sub-catchments within the surface water study area

Land use	Entire Cooks River catchment	Alexandra Canal sub-catchment	Wolli Creek sub-catchment	Eastern Channel sub-catchment
Commercial	3343 ha (31%)	1409 ha (63%)	327 ha (16%)	218 ha (45%)
Residential	6389 ha (58%)	609 ha (27%)	1513 ha (72%)	242 ha (49%)
Open space	1169 ha (11%)	2478 ha (10%)	255 ha (12%)	30 ha (6%)
Total catchment	10881 ha	2230 ha	2094 ha	488 ha

Source: Earth Tech, 2007

16.2.6 Geomorphology

A number of concrete lined and unlined watercourses convey stormwater to the Cooks River. The network of open and partially open channels within the surface water study area, and their geomorphological characteristics, is shown in **Table 16-4**.

Table 16-4 Surface water study area - Riverstyles categorisation

Geomorphic Categorisation	Length within study area (metres)	% of study area
Concrete channel	10230	50
Partly confined channel - Meandering, platform controlled, discontinuous floodplain	2690	13
Occasional pockets - Confined channel with alternating discontinuous floodplain pockets	270	1
Piped channel	220	1
Rock-lined channel	3700	18
Shaped channel	1540	8
Underground concrete channel	1880	9

Source: Earth Tech, 2007

The geomorphological characteristics of the watercourses within the surface water study area are primarily categorised as having no potential for lateral or vertical adjustment (concrete channel, piped channel, rock-lined channel, shaped channel and underground concrete channel). The geomorphic characteristics of the watercourses reflect their urban and anthropogenic nature.

Conversely, slopes in parts of the surface water study area are greater than 10 per cent grade. This combined with an R factor (rainfall erosivity) of 3000-3500 for this area of Sydney presents as a high erosion and mass movement hazard. Soil landscapes with erosion / mass movement potential are identified in **Table 16-2.**

16.2.7 Water quality

The Cooks River catchment is one of the most polluted urban catchments in Australia and its surface water quality is considered to be poor. Water quality of the catchment has been historically affected by stormwater pollution, industrial and domestic wastewater discharge, rubbish dumping and modification of the waterway, and is therefore representative of the water quality to be expected in a highly urbanised catchment.

The Alexandra Canal in particular is a heavily polluted waterway (refer **Table 16-7**). The results of this sampling indicated that metal concentrations in the upper reaches of Alexandra Canal were below the ANZECC Water Quality Guidelines (ANZECC, 2000) for cadmium, chromium, Lead, nickel, and mercury and Ammonia. Copper concentrations were greater than the 95 per cent, though below the 80 per cent protection level at two sites. Zinc concentrations were greater than the 95 per cent trigger value at all test locations, and greater than the 80 per cent protection level at other two test sites.

The following studies concluded that water quality at a number of locations in Wolli Creek, Cooks River and Alexandra Canal is generally poor with frequent occurrences of test results outside the ANZECC Water Quality Guidelines (ANZECC, 2000):

- The City of Rockdale Water Quality Monitoring Study (Equatica, 2014) included four monitoring sites along Wolli Creek. A summary of the parameters analysed during the study is shown in **Table 16-5**
- The 2011 Annual Water Quality Study by the Cooks River Valley Association (2010/2011) reported on a range of water quality parameters measured by Streamwatch at locations in the Cooks River catchment. This sampling gives an indication of water quality in the Cooks River upstream of the project (refer **Figure 16-2**). The results of their reporting are summarised in **Table 16-6**
- In 2012, Sydney Water undertook a Review of Environmental Factors for the Alexandra Canal (6a Huntley Street, Stormwater Renewal Program). The study included water quality testing at four locations in the upper 350 metres of Alexandra Canal. A summary of the parameters analysed during the study in relation to the ANZECC Water Quality Guidelines (ANZECC, 2000) for marine water quality is shown in **Table 16-8**.

A compilation of the water quality data collection points used in these studies is shown in **Figure 16-2**. For detailed information regarding the findings of these studies refer to Section 4.6 of the Technical working paper: Surface water (**Appendix N**).

Where historical data was not available from these existing sources, results from the project specific water quality monitoring program were used to supplement the data set. This included water quality monitoring within the Eastern Channel, the results of which are shown in **Table 16-10**. Water quality monitoring data from the project-specific water quality monitoring program within the Cooks River and Alexandra Canal are presented in **Table 16-7** and **Table 16-9**.

Table 16-5 Water quality in Rockdale LGA - City of Rockdale Water Quality Monitoring Study

Parameter	Wolli Creek				ANZECC (2000) default trigger values*	
	Bonalbo St, Kingsgrove (WC1) (Lowland Freshwater River)	Slade Rd, Bardwell Valley (WC2) (Lowland Freshwater River)	Henderson St, Turrella (WC3) (Estuary/ Marine)	Levey St, Wolli Creek (LS1) (Estuary/Marine)		
	Median				**Lowland rivers**	**Estuaries**
Dissolved oxygen (% Sat)	135.5	75.5	53	17.5	85-110	80-110
Temp (ºC)	21.4	18.8	19.45	21.5	-	-
pH	7.205	6.865	6.65	6.965	6.5-8.0	7.0-8.5
Turbidity (NTU)	8.05	6.7	5.55	110	6-50	0.5-10
Total suspended solids (TSS) mg/L	13	16.5	11	51		
EC (mS/cm)	1340	725	n/a	n/a	125-2200	N/A
NOx (µg/L)	190	420	785	165	40	15
TKN (µg/L)	700	750	1000	1200		
TP (µg/L)	60	70	55	125	50	30
BOD (mg/L)	2.8	4.3	2.95	6.9		
Chl - a (ug/L)	< 0.2	< 0.2	< 0.2	< 0.2	5	4
ANZECC (2000) trigger value for protection of 80% of marine species					**Freshwater**	**Marine Water**
As (µg/L)	2	1	1.5	2	140[#]	ID
Cd (µg/L)	<0.1	<0.1	<0.1	<0.1	0.8	36
Cr (µg/L)	<1	<1	<1	<1	40[#]	85[#]
Cu (µg/L)	5.5	3.5	2	2.5	2.5	8
Pb (µg/L)	1.5	1	2	<1	9.4	12
Ni (µg/L)	1	1	1	2	17	560[3]
Zn (µg/L)	15	23.5	33	51	31	43
Water quality guidelines for recreational waters						
Enterococci (MPN/100 mL)	170	470	114	390	35[1]	230[2]

Source: Equatica, 2014

* ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values for toxicants are for 80 per cent protection of marine species.

1 = Maximum for any one sample for primary contact associated with recreational purposes. 2 = Maximum for any one sample for secondary contact associated with recreational purposes.

3 = Figure may not protect key test species from acute toxicity (and chronic).

ID = Insufficient data. DO = dissolved oxygen, TSS = Total Suspended Solids, EC = Electrical conductivity, NOx = Nitrate + Nitrite, TKN = Total Kjeldahl Nitrogen, TP = Total Phosphorus, FRP = Filterable Reactive Phosphorus, BOD = Biological Oxygen Demand, Chl-a = Chlorophyll a, As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Pb = Lead, Ni = Nickel, Zn = Zinc.

[#] For further indication on how these values were derived, refer to Table 12 of **Appendix N**.

Table 16-6 Water quality in the Cooks River

Parameter	Cooks River				ANZECC (2000) default trigger values*
	Younger Ave, Earlwood (CR1)	Wardell Rd, Marrickville (CR2)	Bruce St, Marrickville (CR3)	Richardsons Cr Marrickville (CR4)	
	Median				
DO %	40	32	55	56	80-110
Temp (ºC)	19	19	20	21	-
pH	8.5	8	8.5	8	7.0-8.5
TURB (NTU)	18	10	15	15	0.5-10
FRP (µg P-1)	180	160	130	140	30
E.coli	2500	2000	400	<100	1000*

Source: Cooks River Valley Association, 2010/2011
*ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems (estuaries)
DO = dissolved oxygen, TURB = Turbidity, FRP = Filterable Reactive Phosphorus, EC = Electrical conductivity.

Table 16-7 Water quality in the Cooks River

Parameter	Site 3 – Cooks River – Levey Street, Wolli Creek		Site 4 – Cooks River – Riverine Park, Arncliffe		ANZECC (2000) default trigger values*
	Range	Median	Range	Median	Estuaries
NOx (µg/L)	130-290	155	90-870	125	15
TN (µg/L)	500-1300	800	300-1400	700	300
TP (µg/L)	60-90	75	40-140	70	30
Parameter	**ANZECC (2000) trigger value for protection of 80% of marine species for marine water**				
As (µg/L)	10-28	10	1-10	10	ID
Cd (µg/L)	1-5.5	1	0.1-1	1	36
Cr (µg/L)	10-22	10	1-10	10	85[#]
Cu (µg/L)	10-107	10	7-10	10	8
Pb (µg/L)	10-36	10	4-10	10	12
Ni (µg/L)	10-16	10	1-10	10	560[3]
Zn (µg/L)	50-120	50	21-52	50	43
Mn (µg/L)	10-49	19.5	10-49	11.5	N/A
Fe (µg/L)	440-470	500	240-640	500	N/A

Source: AECOM, 2015
* ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values for toxicants are for 80 per cent protection of marine species
3 = Figure may not protect key test species from acute toxicity (and chronic)
ID = Insufficient data. NOx = Nitrate + Nitrite, TN = Total Nitrogen, TP = Total Phosphorus, As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Pb = Lead, Ni = Nickel, Zn = Zinc, Mn=Manganese, Fe = Iron.
# For further indication on how this value was derived, refer to Table 14 of **Appendix N**.

Table 16-8 Water sampling results in upper Alexandra Canal

Parameter	Alexandra Canal				ANZECC (2000) default trigger values*
	Site AC1	Site AC2	Site AC3	Site AC4	
As (µg L-1)	3	3	2	2	ID
Cd (µg L-1)	0.2	0.1	<0.1	<0.1	36
Cr (µg L-1)	<1	<1	<1	<1	85
Cu (µg L-1)	1	3	3	<1	8
Pb (µg L-1)	<1	<1	<1	<1	12
Ni (µg L-1)	28	<1	<1	1	560
Zn (µg L-1)	36	43	50	68	43
Hg (µg L-1)	<0.1	<0.1	<0.1	0.2	1.4
Ammonia as N (µg/L)	540	470	410	-	1700

Source: GHD, 2012

* ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values for toxicants are for 80 per cent protection of marine species.

ID = Insufficient data. As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Pb = Lead, Ni = Nickel, Zn = Zinc, Hg = Mercury.

Table 16-9 Water quality in Alexandra Canal

Parameter	Site 1- Alexandra Canal- Via Alexandra Cycleway, near Coward St		ANZECC (2000) default trigger values*
	Range	Median	Estuaries
Dissolved oxygen (% Sat)	34-53	45.5	80-110
Temp (ºC)	9.5-19.8	14.6	-
pH	7.27-7.92	7.41	7.0-8.5
Turbidity (NTU)	2.3-256	9.6	0.5-10
EC (µS/cm)	11483-39060	24714	N/A
NOx (µg/L)	270-4710	1285	15
TN (µg/L).	900-5400	2600	300
TP (µg/L)	10-110	55	30

* ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values for toxicants are for 80% protection of marine species.

DO = dissolved oxygen, EC = Electrical conductivity, NOx = Nitrate + Nitrite, TN = Total Nitrogen, TP = Total Phosphorus

Table 16-10 Water quality in the Eastern Channel

Parameter	Site 10- Eastern Channel- Murray St, Marrickville		ANZECC (2000) default trigger values*
	Range	Median	Estuaries
Dissolved oxygen (% Sat)	63-133	75	80-110
Temp (ºC)	13.5-19	16.7	-
pH	8-8.8	8.3	7.0-8.5
Turbidity (NTU)	20-249	93.5	0.5-10
EC (µS/cm)	291-765	529	N/A
NOx (µg/L)	150-1580	1070	15
TN (µg/L)	1200-3200	2100	300
TP (µg/L)	30-140	80	30
ANZECC (2000) trigger value for protection of 80% of marine species in marine water			
As (µg/L)	1-5	3	ID
Cd (µg/L)	0.1-1	<0.1	36
Cr (µg/L)	0.001-0.002	0.0015	85[#]
Cu (µg/L)	5-20	14	8
Pb (µg/L)	2-13	7.5	12
Ni (µg/L)	2-4	2.5	560[3]
Zn (µg/L)	30-61	42.5	43
Mn (µg/L)	53-64	56	N/A
Fe (µg/L)	600-1950	630	N/A

Source: AECOM, 2015

* ANZECC (2000) default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values for toxicants are for 80% protection of marine species.

3 = Figure may not protect key test species from acute toxicity (and chronic).

ID = Insufficient data. DO = dissolved oxygen, EC = Electrical conductivity, NOx = Nitrate + Nitrite, TN = Total Nitrogen, TP = Total Phosphorus, As = Arsenic, Cd = Cadmium, Cr = Chromium, Cu = Copper, Pb = Lead, Ni = Nickel, Zn = Zinc, Mn=Manganese, Fe = Iron.

The Sydney Water Environmental Indicators Compliance Report Volume 3 (Woodlots, 2004) provided a comparison between Wolli Creek, Alexandra Canal and Cooks River, classifying them as highly disturbed systems in relation to the ANZECC Water Quality Guidelines (ANZECC, 2000).

Results indicated poor water quality overall with a number of parameters failing to comply with respective guidelines. The study indicated that:

- Faecal coliforms including Escherichia coli and enterococci failed to meet guidelines at all watercourses during wet-weather flows
- Phosphorus and nitrogen failed to meet guidelines at all watercourses during both wet and dry weather flows
- Chlorophyll failed to meet guidelines during dry weather flows, but was not detectable during wet weather flows
- Dissolved oxygen fell within the guideline range except at Wolli Creek during both wet and dry weather flows and at Cooks River during dry weather flows
- pH levels were recorded at acceptable levels across all tests.

The City of Rockdale Water Quality Monitoring Study concluded that water quality at a number of locations at Cooks River is poor with frequent exceedances of Water Quality Guidelines (ANZECC, 2000). Further, sediment sampling between 2008 and 2011 by local councils and the University of New South Wales showed that highly contaminated river sediments were present. Surface sediments were less contaminated than at depth. It was cited that heavy metal mobilisation would be associated with remediation activities (RCC, 2011).

The City of Rockdale Water Quality Monitoring Study sampled four locations along the Wolli Creek. Findings concluded that pH and turbidity was generally acceptable with elevated levels of nutrients, Copper and Zinc. Faecal coliforms (enterococci) exceeded the guidelines for secondary recreational contact.

The Review of Environmental Factors for the Alexandra Canal (Stormwater Renewal Program) (GHD, 2012) concluded that metal concentration in upper reaches of Alexandra Canal were below the ANZECC guidelines. Zinc and copper were found in parts to exceed respective guideline values. Alexandra Canal is a heavily polluted waterway with older sediments known to be highly contaminated, and overlain by more recent less contaminated sediments (University of Queensland (UoQ), 2002).

16.2.8 Sensitive receiving environments

A sensitive receiving environment is defined as one that has a high conservation or community value, or one that supports ecosystems or humans uses of water that are particularly sensitive to pollution of degradation of water quality.

Sensitive receiving environments include:

- Nationally Important Wetlands and State Environmental Planning Policy No 14 (SEPP 14) wetlands (actual or potential groundwater dependent ecosystems)
- National parks, marine parks, nature reserves and State conservation areas
- Threatened ecological communities associated with aquatic ecosystems
- Known and potential habitats for threatened fish
- Key fish habitats as identified by the NSW Department of Primary Industries (DPI)
- Recreational swimming areas
- Areas that contribute to drinking water catchments
- Areas that are available or used for aquaculture and commercial fishing
- Green and Golden Bell Frog RTA Ponds at Arncliffe (refer Table 18 of the Technical working paper: Surface water (**Appendix N**)).

Changes to water quality may have the potential to impact a number of sensitive receiving environments, including:

- Wolli Creek
- Botany Bay
- Towra Point Wetlands
- Saltmarsh and other wetlands around Sydney Airport
- Seagrass in Botany Bay.

Potential impacts on groundwater dependent ecosystems and other sites of ecological significance area provided in **Sections 19.2.5** and **19.4.5** (Groundwater) and **Sections 21.2.7** and **21.3.1** (Biodiversity).

16.3 Assessment of potential impacts

16.3.1 Construction

Soils

Removal of vegetation and soil exposure during construction may weaken surface soil structure. This could lead to erosion (i.e. mobilisation and deposition of sediments), sedimentation and mass movement within and around watercourses and slopes in the surface water study area, particularly during periods of high wind or rainfall.

Sediments can fill and smoother in-stream geomorphic units and habitat features such as pools and riffles. Furthermore, sediments can accumulate at in-stream barriers and constrictions, which may result in localised flooding and / or channel avulsion (a new altered flow path around an in-stream barrier).

Erosion and sediment loads would gradually diminish after construction as the disturbed areas are stabilised and the vegetation starts to establish and hold the soils in place.

During construction and operation, the key objective is to minimise erosion of areas disturbed by earthworks and to contain any sediments on-site before they enter the riparian zone at Wolli Creek, or other watercourse / drainage system.

There is a risk that any runoff within the Alexandria Landfill site would be contaminated leachate. Therefore, any runoff from the Alexandria Landfill would be directed to a leachate treatment plant and discharged to sewer under a trade waste agreement with Sydney Water. Further details about water management within the Alexandria Landfill site during construction are provided in **Section 17.3.4** (Contamination).

Acid sulfate soils

Most of the study area has a low probability of acid sulfate soils occurrence, except land adjacent to watercourses that have the presence of alluvial deposits. These areas have a high probability of being potential acid sulfate soils, including Cooks River, Alexandra Canal and Muddy Creek (refer **Figure 16-5**). Where acid sulfate soils are encountered during excavation, potential impacts may include:

- Weakening of concrete and steel infrastructure, resulting in increased maintenance and replacement costs
- Damage to aquatic environments (surface water and groundwater) due to the liberation of acids generated from oxidised acid sulfate soils
- Mobilisation of aluminium, iron and manganese from soils as a result of increased acidity from disturbance of acid sulfate soils.

In relation to excavation, the alignment of tunnels around land adjacent to watercourses is deep below the ground surface, within Hawkesbury Sandstone. Alluvial deposits are unlikely to be encountered at this depth and in this geology.

There is a high potential for acid sulfate soils at the Arncliffe construction compound (C7), as well as in sediments in the Alexandra Canal. Further contamination investigation would be conducted in areas with medium or high acid sulfate soils potential during the detailed design stage as part of early works.

Acid sulfate soils could be excavated during earth moving works and/or acidic groundwater could be pumped during construction dewatering. **Section 17.3.2** outlines the potential for contamination in the project area to come into contact with human or environmental receivers through source-pathway-receiver link during construction works. Where acid sulfate soils are disturbed and not managed appropriately, the potential affects to human health may include:

- Exposure to contaminated water, eg during recreational activities
- Ingestion of contaminated water or animal / plant products with an uptake of contaminated water
- Increase in acidic dust causing eye, nose and throat irritation
- Increase in presence of acid-tolerant mosquitos and mosquito-borne diseases.

If and where acid sulfate soils are disturbed, the potential impacts are considered manageable. The material would be stored temporarily in a bunded area, treated and disposed of off-site at a licensed facility. Management of acid sulfate soils would be in accordance with the Guideline for the Management of Acid Sulfate Materials (RTA, 2005c).

The Construction Environment Management Plan and Acid Sulfate Soil Management Plan would also outline the measures and monitoring required where potential acid sulfate soils are expected. The plan would also outline the type of treatment required for acid sulfate soils, bunding and requirement for treatment ponds.

Water uses and balance

Section 6.10.2 provides estimates for the volumes and potential supplies of water for each site, based on the construction program and the anticipated demand and supply sources at varying times during construction.

Preference would be given to the use of non-potable water sources during construction over potable sources where appropriate. The volume of water required would depend on a number of factors including rainfall, wind direction and intensity, soil type, area of ground disturbance at any one time, and the storage space required to collect runoff water for reuse purposes.

Water treatment plants

During construction, tunnelling works would result in significant volumes of groundwater ingress requiring treatment. Other sources of wastewater during construction would include water used in dust suppression, wash down runoff, and sewage / grey water from construction compound sites. Water captured from both surface flows and groundwater ingress during construction works would be collected in sumps and pumped to holding tanks, from where it would be pumped to one of the temporary construction water treatment plants at the following locations:

- Kingsgrove North construction compound (C1)
- Commercial Road construction compound (C3)
- Bexley Road South construction compound (C5)
- Arncliffe construction compound (C7)
- Canal Road construction compound (C8).

The water treatment plants would treat tunnel groundwater, including runoff and inflows during construction. They would be capable of treating the maximum required discharge rates and to meet the minimum water treatment requirements during construction.

Each treatment plant would comprise a series of modular water-tight tanks with automated probes and dosing units designed to test and treat the water to the required standard. Based on the existing groundwater quality (refer to **Section 16.2.7**), water treatment would typically involve:

- Flocculation to remove total suspended solids
- Reverse osmosis to reduce salinity and dissolved solids
- Correction of pH level through the addition of lime or acid
- Treatment of elevated levels of iron and manganese
- Treatment of salinity and other contaminants such as ammonia.

The treatment train adopted for each plant would vary depending on the origin of water being treated at each plant.

The estimated discharge rates from temporary water treatment plants are identified in **Table 16-11**. Temporary water treatment plants and discharge locations are shown in **Figure 16-6** and **Figure 16-7.**

Table 16-11 Expected water treatment plant rates of discharge

Location	Receiving Watercourse	Average discharge flow L/s (ML/d)*
Kingsgrove North construction compound (C1)	Wolli Creek	2.8 (0.09)
Commercial Road construction compound (C2)	Wolli Creek	2.8 (0.24)
Bexley construction compounds (C4-C6)	Wolli Creek	7.6 (0.66)
Arncliffe construction compound (C7)	Cooks River	11.6 (1.00)
Canal Road construction compound (C8)	Alexandra Canal	7.2 (0.62)

*subject to confirmation during detailed design

Water from the temporary water treatment plants may be used for dust suppression where reasonable and feasible to do so. Excess of water treatment discharge would drain to the existing stormwater drainage systems, eventually discharging into the Cooks River via its tributaries including Wolli Creek. Temporary water treatment plants would therefore be designed to discharge at a minimum standard so as to meet the Water Quality Reference Criteria (refer to Appendix A of the Technical working paper: Surface water (**Appendix N**)). Provided these criteria are met, there would be a low risk of adverse impacts from water treatment plant discharge on the quality of the receiving environment.

As outlined in **Section 16.2.7**, the receiving environments for water treatment plant discharge are highly disturbed ecosystems, which cannot feasibly be returned to a 'slightly to moderately disturbed' condition (ANZECC Water Quality Guidelines, 2000). This is due to the historical catchment land use change from a natural catchment to a highly urbanised one, as well as past engineering works which removed natural ecosystems by replacing natural watercourses with straightened, concrete lined channels.

Based on the design of the project, it is anticipated that water treatment plant discharge would be of a better quality than the current water quality of the receiving environments. The quality and outflow velocities of water treatment plant discharge would be in accordance with the project's Water Quality Reference Criteria (refer to Appendix A of the Technical working paper: Surface water (**Appendix N**)) and the project's Environment Protection Licence.

The proposed water treatment plant at the Canal Road construction compound (C8) would be subject to measures to minimise the disturbance of bed sediments within the Alexandra Canal. Approval from Sydney Water and the NSW EPA would be sought on this matter as per the requirements of the Remediation Order 23004 (refer **Section 17.4**).

Provided these criteria are met, there would be a low risk of adverse impacts of water treatment plant discharges on the water quality of the receiving environment, including the sensitive receiving environments outlined in **Section 16.2.8**.

During landfill closure activities, there is also the potential for overland surface flows to become contaminated through exposure to waste and other contaminants in the absence of appropriate environmental controls. As such, mitigation measures would be required to isolate and capture runoff from these areas and direct these flows to the existing leachate treatment plant.

The Remediation Order 23004 is in place over the Alexandra Canal due to contamination of bed sediments with chlorinated hydrocarbons including organochlorine pesticides, polychlorinated biphenyls and metals in such a way as to present a significant risk of harm to human health and the environment. **Section 17.3.2** outlines the potential for existing contamination in the project area to come into contact with human or environmental receivers through source-pathway-receiver link during construction works. However, construction works would be undertaken in accordance with the requirements of the *Contaminated Land Management Act*, as well as the *Work Health and Safety Regulation 2011*. Following these regulatory requirements, including relevant exposure standards would effectively break any potential for source-pathway-receiver linkages to be completed, and for health impacts to result (refer **Section 17.4**).



Figure 16-6 Location of construction water treatment plants and discharge locations - Kingsgrove and Bexley Road construction compounds

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Figure 16-7 Location of water treatment plants and discharge locations - Arncliffe and St Peters interchange

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Watercourses and geomorphology

During construction the following activities would have the potential to impact upon the geomorphic condition of watercourses:

- Direct construction activity within or adjacent to the watercourse and / or Wolli Creek riparian zone
- Concentrated discharge from temporary water treatment plants
- Concentrated drainage during upgrade of existing infrastructure
- Sediment deposition in receiving waterways caused by wind or runoff from construction activities
- Increased impermeable areas and / or altered flow paths that may result in increased over bank flows entering the waterway causing erosion
- Tunnelling activities causing bedrock fracturing and /or subsidence / mass movement with the watercourse bed.

A number of construction activities would occur near watercourses, namely Cooks River, Wolli Creek, Alexandra Canal and the Eastern Channel. Watercourse crossings would be designed and constructed in accordance with the Guideline for Controlled Activities on Waterfront Land (DPI, 2012a). A summary of the construction impacts are identified in **Table 16-12**.

For details regarding existing and proposed drainage infrastructure, refer to **Chapter 18** (Flooding and drainage).

Table 16-12 Potential construction impacts on geomorphology

Construction activity	Impacts
Wolli Creek	
Construction activities associated with the western surface works have the potential to impact the geomorphology in Wolli Creek as a result of: • Exposing and weakening terrestrial surface soils, allowing them to be mobilised and deposited into the Creek during wind or rainfall • Clearing a small portion of grassed / vegetated parkland, particularly where this land lies on steep grades (eg Bexley Road South construction compound just upstream of Bexley Road) with the potential for scour and bank failure during flood events • Upgrades to existing drainage and construction of new outlets with the potential for localised impacts such as weakened bed and bank soil structure, localised erosion and sediment mobilisation • Temporary waste water treatment plant discharges into the concrete lined reach of the Creek, which could nevertheless be transported to the natural reaches downstream of Bexley Road • Two discharge from the temporary water treatment plants of up to around 2.8 litres per second at Kingsgrove, with an additional discharge of around 7.6 litres per second at Bexley Road. A total of around 13.2 litres per second would therefore enter Wolli Creek during construction.	Discharge to Wolli Creek would be to the concrete lined section upstream of Bexley Road. Between Bexley Road and the fish weir at Turrella – the discharge would contribute up to 13.1 litres per second to a highly altered reach of creek, affected by both upstream lining and downstream hydraulic controls. This small amount of discharge would not have the potential to impact what was the natural flow variability in Wolli Creek. When compared to the one year ARI flow of 58.9 cubic metres per second at Bexley Road, this discharge from the water treatment plant would contribute an increase of 0.02 per cent. This is a relatively insignificant increase in flow that would likely have minimal impact on stream levels and velocities in the creek. As a result, it is not expected to impact the geomorphology of the Creek. Notwithstanding, erosion and sedimentation controls would be in place to control water quality impacts and slow surface water runoff prior to it leaving the construction compound. This would further reduce the impact on watercourses. Drainage and discharge outlet infrastructure during construction would also include energy dissipation and erosion scour protection as appropriate.

Construction activity	Impacts
Alexandra Canal	
Construction of the St Peters interchange and local roads upgrades has the potential to impact the geomorphology in Alexandra Canal as a result of: • Discharge from the temporary water treatment plant of up to around 7.2 litres per second at the Ricketty Street bridge construction works at Campbell Road and Gardeners Road, although no piers would be installed within the Canal • Upgrades to existing drainage outlets and construction of a new outlet adjacent to Campbell Street (a culvert alongside the Burrows Road bridge). These have the potential to cause localised impacts such as weakened bed soil structure, localised erosion and sediment mobilisation.	When compared to the one year annual recurrence interval (ARI) flow of 83.9 cubic metres per second at its confluence with the Cooks River, discharge from the water treatment plant would contribute an increase of 0.02 per cent. This is a relatively insignificant increase in flow that would likely have minimal impact on levels and velocities in the canal. As a result, it is not expected to impact the geomorphology of the Canal. Alexandra Canal is tidal at the location of drainage outlets, with two tidal cycles daily producing relatively small velocities. High energy flows as a result of rainfall events have the potential to create high velocities in the Canal. Peak velocities and the size of sediments likely to be mobilised by various flow scenarios are shown in Section 7.3.3 of the Technical working paper: Surface water (**Appendix N**). New discharges have the potential to cause both a change in direction and velocity of flows in the Canal. Based on grain size distribution, the majority of sediment would likely experience minor mobilisation even under tidal conditions and various flood events would have the potential to uncover a greater volume of sediment. The canal floor is said to be in a state of dynamic equilibrium meaning mobilised sediments would not travel far and the system would tend to return to its preceding state. However there is some potential for impacts associated with sediment disturbance, due to: • Uncertainty regarding sediment distribution in the Canal, including contamination therein • Minimal understanding of three dimensional flow mechanisms within the Canal • Potential increase in point velocities from scouring These impacts would be manageable for the following reasons: • The minor extent of works resulting in new discharge structures within the canal (one culvert, one pipe) • The Alexandra Canal's tendency (based on previous numerical modelling and anecdotal evidence) to return to equilibrium, and accrete sediment in its middle reaches • Modelling would be undertaken prior to design of the outlets to determine velocities. Design would include energy dissipaters where appropriate, and/or sufficient scour protection to minimise the potential for contaminated sediments to be mobilised. Further details on the likelihood of sediments being contaminated are included in Technical working paper: Contamination (**Appendix O**). The potential impacts relating to scour would need to be mitigated as per mitigation measures in **Section 16.4**. These matters are dealt with further in

Construction activity	Impacts
	Section 5.5.5 and Section 9.5 of the Technical working paper: Contamination (**Appendix O**).
Eastern Channel	
Minor construction works at Camdenville Park have the potential to impact the Eastern Channel as a result of uncontrolled surface runoff from construction areas. A small extent of land clearing would create the potential for materials to be transported into the existing stormwater detention basin in Camdenville Park, though not at the location of the Eastern Channel itself. No discharges would be made to the Eastern Channel during construction.	No discharges would be made to the Eastern Channel during construction of the project. Regardless the concrete lined trapezoidal nature of the channel means the potential for geomorphic impact is minimal from any water treatment plant discharges to the head of the channel. Notwithstanding, erosion and sedimentation controls would be in place to control water quality impacts.
Cooks River	
Construction activities associated with the Arncliffe surface works and construction compound have the potential to impact the geomorphology in the Cooks River as a result of: • Stockpiling of soil • Temporary waste water treatment plants discharging up to around 20 litres per second (during peak discharge at any point in time) into the Cooks River adjacent to Kogarah Golf Course. Note that the average daily discharge is predicted to be 11.6 litres per second (refer **Table 16-11**) • The Cooks River receiving flows discharged into Wolli Creek and Alexandra Canal.	When compared to the one year ARI flow of 357.3 cubic metres per second the discharge from this temporary water treatment plant would be a very small (less than 0.01 per cent) increase at its discharge to Botany Bay. At this location the river is almost fully tidal due to its close proximity to Botany Bay. This small inflow would therefore not impact the geomorphology of the Cooks River. At the outlet location, scour resulting from the discharges related to construction activities has the potential to locally impact the floodplain, bank and bed morphology. Erosion and sedimentation controls would be in place to control water quality impacts and slow surface water runoff prior to it leaving the construction compound. This would further reduce the potential impact on watercourses. Drainage and discharge outlet infrastructure during construction would also include energy dissipation and erosion scour protection as appropriate.

Erosion

A preliminary erosion and sedimentation assessment was undertaken for the project in accordance with the Erosion and Sedimentation Risk Assessment Procedure (RTA, 2004) – Appendix 1a &1b for Concept Designs. The assessment identified the project works to be high risk to erosion and mass movement due to slopes in parts of the surface water study area being greater than ten per cent grade. This combined with an R factor (rainfall erosivity) of between 3000 and 3500 for this area of Sydney presents as a high erosion hazard.

A soil conservation specialist would therefore be engaged before and during construction to assist in the design of controls, carry out site inspections and develop progressive erosion and sediment control plans, in accordance with the Erosion and Sedimentation Management Procedure (RTA, 2008c). An Erosion and Sedimentation Management Plan would also be prepared as outlined in Erosion and Sedimentation Risk Assessment Procedure (RTA, 2004).

Water quality

The assessment of the potential impacts from water treatment plant discharge is based on a comparison of discharge quality with relevant environmental water quality criteria, including the ANZECC Water Quality Guidelines (ANZECC, 2000) for highly disturbed systems. Provided these criteria are met, there would be a low risk of water treatment plant discharge causing adverse impacts on the water quality of the receiving environment, particularly given the relatively poor quality of the existing waterways (refer to **Section 16.2.7**). The water treatment plant would be designed to meet the discharge water quality criteria outlined in the Water Quality Reference Criteria (refer to Appendix A of the Technical working paper: Surface water (**Appendix N**)).

During construction the following activities would have the potential to impact upon surface water quality:

- Earthworks and exposed soil, followed by wind or rain has the potential to mobilise sediments that could be discharged to local watercourses
- Accidental leaks or spills of chemicals, fuels and oils from construction plant or construction materials during the construction phase
- Construction activities within the Alexandra Canal (ie stormwater infrastructure and discharge points), as well as construction activities adjacent to the canal could introduce foreign contaminants such as oil or greases, and disturb contaminated sediments, potentially having an adverse impact on water quality
- The project would increase the impervious surfaces in the road corridor. Consequently, pollutant loads building up on the road surfaces would increase, and greater loads of pollutants may be washed off and discharged to receiving environments
- Discharge of inadequately treated water from the temporary water treatment plants.

The specific risk level associated with each construction compound would be subject to site specific factors including:

- Extent of soil disturbance and susceptibility of the soil to erosion and mass movement
- Proximity to local watercourses and drains
- Stockpiling activities and locations
- Potential for dust generation
- Land rehabilitation on completion of construction.

These surface water quality impacts due to soil erosion would be effectively managed through the application of the proposed mitigation and management measures as detailed in **Section 16.4**. Additional measures for managing surface water quality include:

- The management of dust is discussed in **Section 10.5.1** (Air quality)
- The management of dangerous goods and hazardous substances is discussed in **Section 26.1.1** and **Section 26.1.2** (Hazards and risk)

- The management of waste (**Section 24.1.1** and **Section 24.1.2** (Construction resource use and waste minimisation))
- Appropriate management of runoff and temporary water treatment plants (as detailed earlier in this section).

Wolli Creek

The extent of works located within the Wolli Creek catchment includes the western surface works, the Kingsgrove surface works and Bexley Road surface works, and includes construction compounds. A summary of potential impacts to surface water quality within the Wolli Creek catchment is as follows:

- Stockpiling of spoil and construction materials could present a risk to water quality. However, this would predominantly occur within the stockpile sheds. The sheds would minimise the potential for transport of spoil sediments by both wind and rain
- Runoff from these construction compounds would drain to the concrete lined tributary of Wolli Creek and the main arm of Wolli Creek. Runoff could impact these environments by delivering sediments and pollutants to Wolli Creek. Mitigation measures would be required to reduce the potential for environmental impacts arising during construction. Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality
- During construction, an existing water quality wetland would be removed due to the construction of a replacement wet basin. The basin currently treats pavement runoff from a catchment of 2.21 hectares of the existing M5 East Motorway. The time between removal and construction opens the potential for a reduction in the water quality treatment provided for the M5 East Motorway pavement drainage discharge, if not treated by some other means, such as the construction water treatment plants.

Cooks River

The Arncliffe surface works would include the establishment and use of the Arncliffe construction compound (C7). Runoff from these construction compounds would drain to the Cooks River, which is a heavily polluted waterway with poor water quality and contaminated sediments (refer to Section 4.6 of the Technical working paper: Surface water (**Appendix N**)). The location of this compound is very close to the mouth of the Cooks River and Botany Bay. Botany Bay and its estuaries are associated with significant biodiversity and other environmental values as well as significant community and social values.

Runoff from construction areas could impact this environment by delivering sediments and pollutants to the river. Spoil and other construction materials would also be stockpiled at the site. As discussed earlier, there is also a high risk of acid sulfate soils. Unmitigated runoff from the project during the construction phase would place increasing pressure on the already-stressed Cooks River, and could endanger the ecological health of Botany Bay. Mitigation measures would be required to reduce the potential for environmental impacts arising during construction.

Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality.

Alexandra Canal

Construction of the project would involve works within the Alexandra Canal catchment. These activities have the potential to impact surface water in the surface water study area. A summary of potential impacts to surface water quality within the Alexandra Canal catchment are as follows:

- Stockpiling of spoil and construction materials could present a risk to water quality. In some instances, stockpiling would be within sheds. Mitigation and management measures would be implemented to manage risks to water quality
- Runoff from these construction compounds would drain to Alexandra Canal. Runoff from construction areas could impact these environments by delivering sediments and pollutants to the canal. Alexandra Canal is a heavily polluted waterway with poor water quality and contaminated sediments. There is also a high risk of acid sulfate soil at the canal. Unmitigated

runoff from the project during the construction phase would place increasing pressure on this already stressed environment

- Mitigation measures (as described in **Section 16.4**) would be required to reduce the potential for environmental impacts arising during construction. Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality
- Construction of the two bridges over Alexandra Canal would not involve installation of any piers within the canal. However, works would occur in close proximity to the canal. Runoff from these activities would be managed to minimise potential impacts to water quality within the canal.

Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality.

Eastern Channel

Construction activities in the Eastern Channel catchment would occur as a result of upgrades to road and drainage structures and works at the existing water quality basin in Camdenville.

Runoff from construction areas could impact the receiving environment by delivering sediments and pollutants to the channel. Water quality within the Eastern Channel is not yet known, but due to its direct connection to the Cooks River, and proximity with similar land use to Alexandra Canal, it is expected that the water quality would be similar to these other watercourses, characterised by high turbidity, high nutrients, pathogens and toxicants (refer Section 4.6 of the Technical working paper: Surface water (**Appendix N**)). The Eastern Channel, being concrete-lined, has little habitat value but is an efficient conveyance for water that would impact upon the ecosystem health of the Cooks River. Therefore, unmitigated runoff from the project during the construction phase would place increasing pressure on the already stressed environment of the Cooks River and would undermine attempts by the surrounding community and stakeholders to improve the ecosystem health.

Provided that appropriate controls are implemented during construction, short term impacts are expected to be manageable and expected to have no material impact on receiving water quality.

Water quality monitoring

Water quality monitoring commenced in June 2015. Monitoring would continue until either 12 months of data is collected or until the commencement of construction (whichever is sooner) to represent pre-construction conditions for the project. Monitoring would continue during construction of the project. This would include monitoring at upstream (control) and downstream measurement locations. Samples would be taken twice a month, once in dry and once in wet conditions where possible. Parameters to be tested for and locations of monitoring sites are shown in Appendix B of the Technical working paper: Surface water (**Appendix N**). Water quality monitoring locations have been suitably established so that the place and methodology of capture is consistent both pre-construction and during construction. The data obtained during this program would be used to ascertain any potential water quality impacts of the construction of the project, as opposed to placing reliance on the previously obtained water quality monitoring data outlined in **Section 16.2.7**, for which sampling locations and methodologies would have varied.

Riparian ecosystems

The construction impacts of the project on riparian ecosystems are set out in more detail within **Section 21.3.2**, and are summarised as follows:

- Aquatic habitats may be impacted by:
  - Groundwater discharge
  - Weed invasion
  - Polluted surface water runoff
  - Erosion, sedimentation and increases in turbidity

- While impacts to aquatic fauna in the upper reaches of watercourses which traverse the biodiversity study area are unlikely, given the already degraded condition of these environments and the lack of available habitat, higher quality environments downstream could be affected during construction by:
  - Increased surface water volumes and velocities, which may contribute to bank erosions and sedimentation
  - Transport of weeds and nutrients, which may increase the potential for algal blooms to occur.

It is noted that impacts to aquatic habitat may also reduce the availability or desirability of habitat for macroinvertebrates.

Overall, impacts to aquatic habitats during construction would be avoided by reducing the speed of discharge flows into watercourses, removing sediment and nutrients prior to the discharge of water into watercourses and stabilising banks, where necessary (refer **Section 16.4** and **Section 21.4**). The impacts to riparian vegetation are therefore considered to be negligible.

Green and Golden Bell Frog Habitat

One sensitive environment in proximity to construction is the breeding ponds for Green and Golden Bell Frog near Marsh Street, Arncliffe. The species also uses parts of the golf course for foraging habitat. Dust generated by construction activity has the potential to impact the water quality of the RTA ponds and frog habitat on the golf course. The presence of the tunnelling shed in addition to targeted mitigation measures for the species, as detailed in the Biodiversity Assessment Report (**Appendix S**), would minimise these potential impacts. The project is not expected to impact the function or quality of the RTA ponds or surrounding habitat. Environmental management measures to be implemented during construction to minimise impacts to the Green and Golden Bell Frog and their habitat would be contained in a Green and Golden Bell Frog Plan of Management. More information regarding the management of impacts to the Green and Golden Bell Frog during construction of the project is provided in **Section 21.4**.

Cumulative impacts

For water quality and geomorphology, the key construction related impacts would be erosion of exposed soil resulting in sedimentation, and water pollution associated with sediment-laden runoff.

Although this might be considered a temporary impact, ongoing re-development within the catchment has the potential to persistently expose receiving environment to these impacts. Such cumulative impacts would be managed through proper implementation of the project's Construction Environmental Management Plans. There is also the risk that uncontrolled spills during construction works (eg of hydrocarbons, cleaning fluids or other liquids) may be released into the surrounding environment, potentially causing soil and groundwater contamination, as well as adverse water quality impacts. However with the mitigation measures outlined in **Table 16-14**, the risk of this occurring is low.

Further information on the project's potential cumulative impacts is provided in **Sections 27.4** and **27.5** (Cumulative impacts).

16.3.2 Operation

Water treatment plant

Operation of the project would include collecting, managing and pumping groundwater seepage from the main alignment tunnels to a collection tank for treatment and discharge. An operational water treatment plant would therefore be built at Arncliffe as part of the Arncliffe motorway operations complex (MOC3). This operational water treatment plant would be designed to receive and treat two separate streams:

- Contaminated groundwater from the eastern section of the project
- Non-contaminated groundwater from the western section of the project, stormwater, wash down, fire testing, hydrant and deluge water.

The proposed operational water treatment plant location is shown on **Figure 16-7** and would include:

- A main sump at the tunnel low point, which would have the capacity to store around 50,000 litres in case of a spill within the tunnel, with a separate sump to capture potentially contaminated groundwater from the eastern portion of the project area
- A holding tank at Arncliffe motorway operations complex which would receive water from the tunnel sumps. Water would then be directed to the water treatment plant or removed for alternative disposal, eg in case of a spill
- The water treatment, which would comprise a water treatment plant itself, as well as a wetland system
- In the case of higher flows (eg from washdown or deluge), overflow from the holding tank would be directed to the deluge holding tank. These flows would be discharged to the Cooks River via the existing stormwater drainage network.

Groundwater from the eastern section of the project may have elevated levels of ammonia or other contaminants. Groundwater collected from this portion of the project area would be treated through sedimentation / flocculation to remove iron, suspended solids, hydrocarbons and other settle-able compounds.

Following initial treatment, water would be drained to a wetland to remove nitrogen (organic nitrogen, ammonia, nitrate and nitrite) and then to a polishing tertiary treatment system (ozone and biologically activated carbon or membrane filtration and reverse osmosis) to remove additional heavy metals (if required). The wetland system would have a surface area of around 1000 square metres, with floating treatment media to allow plant growth.

Groundwater from the western section of the project area, which is not expected to have elevated levels of ammonia or contaminants, would be treated to remove suspended solids and iron using the same water treatment process as outline above, without the need to be transferred to a wetland system.

Once the two streams of water have been treated they would be blended downstream of the wetland and would be discharged into the Cooks River. The outfall would consist of a submerged diffuser system such that the effluent stream is dispersed into the Cooks River. The operational water treatment plant would discharge at a predicted maximum rate of around 20.1 litres per second into the Cooks River at the Marsh Street Bridge.

The receiving environments for operational water treatment plant discharge are ‘highly disturbed’ ecosystems, which cannot feasibly be returned to a ‘slightly to moderately disturbed’ condition (ANZECC Water Quality Guidelines – Section 2.2, 2000). In such cases, ANZECC (2000) recommends suitable guidelines for water quality trigger values. The operational water treatment plant would be designed to ensure that discharge water quality would meet the Water Quality Reference Criteria (refer to Appendix A of the Technical working paper: Surface water (**Appendix N**)). Monitoring of the Cooks River would be undertaken in accordance with the water quality program (as provided in Appendix B of **Appendix N**) for 12 months post-construction or as otherwise required by the conditions of approval to ensure discharge is meeting these criteria.

Water extraction and use

Water use for various operational activities such as building use, emergency deluge and cleaning would be sourced from Sydney Water mains. Alternative sources to portable water (such as rainwater and treated wastewater) would be investigated during detailed design.

Opportunities for reuse of treated water generated at the Arncliffe motorway operations complex would be considered during detailed design in preference to discharge to the stormwater system, including irrigation of landscaped areas within the project area, and / or local parks and reserves.

Watercourses and geomorphology

During operation, the project has the potential to impact the geomorphology of receiving watercourses. Impacts on watercourses could result from:

- Discharge of groundwater

- Discharge of drainage at new locations
- Increased discharges at existing locations due to drainage upgrades
- New overland flow paths construction in the floodplain.

The increase of impervious surfaces, drainage discharges from new and upgraded pipes and the operational water treatment plant would result in a relatively insignificant increase in water flow to each of the receiving watercourses (Wolli Creek, Alexandra Canal and Cooks River). Further, the geomorphological characteristics of the watercourses within the study area are primarily categorised as having no potential for lateral or vertical adjustment (concrete channel, piped channel, rock-lined channel, shaped channel and underground concrete channel). Therefore, the relatively insignificant increase in stream levels and velocities would not impact the geomorphology of the watercourses.

Drainage and discharge outlet infrastructure during operation would include energy dissipation and erosion scour protection as appropriate in order to further reduce impacts to geomorphology at the discharge location.

In terms of the Alexandra Canal, two new discharge outlets would convey stormwater into the Canal as follows:

- A 3300 x 2400 millimetre open channel discharging immediately to the south west of Gardeners Road Bridge
- A 525 millimetre reinforced concrete pipe discharging immediately to the south east of Gardeners Road Bridge.

The detail of these outlets, including discharge velocities and scour protection measures, would be confirmed during detailed design.

There is some potential for operational impacts associated with sediment disturbance at the discharge location of these proposed outlets, due to:

- Uncertainty regarding sediment distribution in the Alexandra Canal , including contamination therein
- Minimal understanding of three dimensional flow mechanisms within the Alexandra Canal
- Potential increase in point velocities from scouring.

As outlined in **Table 16-12**, the Alexandra Canal has a tendency to return to equilibrium, and accrete sediment in its middle reaches, meaning these impacts are not likely to occur.

Modelling would also be undertaken prior to stormwater outlet design at the Alexandra Canal to clarify velocities. Outlet designs would include energy dissipaters where appropriate, and/ or sufficient scour protection to minimise the potential for contaminated sediments to mobilise. These matters are dealt with further in Section 5.5.5 and Section 9.5 of the Technical working paper: Contamination (**Appendix O**).

The potential for human health impacts as a result of the operation of the project follows the same logic to that outlined in **Section 17.3.2** in terms of source-pathway-receiver links. Newly constructed stormwater outlets along the banks of the Alexandra Canal could cause localised erosion and scour in the vicinity of the stormwater discharge points, which could potentially mobilise contaminated sediments which may already be present within the canal or contributed as discharge through the stormwater drain.

New stormwater infrastructure discharge points would be constructed in the vicinity of an upstream of Ricketty Street bridge, which is located greater than two kilometres from the junction of Alexandra Canal with the Cooks River. As demonstrated in historic studies undertaken for existing stormwater drains within the Alexandra Canal (refer to Section 2.2.11 of **Appendix O**), it is considered unlikely that sediments mobilised as a result of the impact of new operational infrastructure would extend a significant distance from the stormwater discharge points. As such, the risk of mobilised sediment migrating to the Cooks River as a result of discharge from stormwater infrastructure is considered to be low (refer Section 9.5 of **Appendix O**). In addition, mitigation measures would be installed at the

points of discharge to further minimise the potential for sediment disturbance caused by the construction and operation of a new stormwater system (refer **Section 16.4**).

During operation, flooding and drainage impacts could include the following:

- Impacts from the operational water treatment plant
- Localised flooding
- Mainstream flooding.

In terms of managing localised flooding, existing drainage and surface water management infrastructure (identified in **Table 18-2** of **Section 18.2.1**) would continue to manage surface drainage and potential flooding. Additional upgrades would be carried out where parts of the drainage infrastructure would be impacted by the project and / or would require relocation. **Table 18-4** of **Section 18.3.2** provides an overview of the proposed drainage systems as part of the project.

The discharge of treated water during operation would be to the Cooks River. As flow variability in the Cooks River is dominated by tides, the proposed discharges would not impact its natural flow variability.

Water quality

Operation of the project has the potential to cause water quality impacts resulting from the increased impervious surface areas and changes to the total catchment. Surface runoff carries pollutants that have built up on these surfaces. Such runoff would typically contain pollutants such as nutrients, oils, greases, petrochemicals and heavy metals. In a typical year, pollutants are generated from impervious surfaces at a rate of about:

- Total suspended solids - 3130 kilograms per hectare
- Total phosphorus - 5.83 kilograms per hectare
- Total Nitrogen - 25.5 kilograms per hectare.

The above were estimated from MUSIC stormwater quality modelling for a 100 per cent impervious catchment. These additional pollutant loads would be managed through a range of stormwater treatment measures such as gross pollutant traps, constructed wetlands, bioretention systems, water quality basins and proprietary treatment devices. These would be designed with consideration to the pollutant reduction targets of the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011).

Current provisions are sufficient to meet the treatment targets for most catchments, and stormwater treatment in some catchments exceeds the treatment requirements, such that the project overall would result in less pollutants being delivered to Botany Bay. The final design would be would be confirmed during detailed design.

Wolli Creek

The project would result in new permanent infrastructure, as well as increased pavement area within the Wolli Creek catchment. Paved surfaces within the catchment would increase by roughly seven hectares as a result of the project, increasing the overall imperviousness of the catchment. This would create the potential for higher pollutant loads in the receiving Wolli Creek environment.

Existing stormwater treatment would be upgraded or, where existing stormwater treatment devices are impacted by the project, offset by the installation of new stormwater treatment devices. This would be determined during detailed design with a target of meeting the pollutant load reductions outlined in **Table 16-13**.

Stormwater runoff from new impervious surfaces created by the project would be treated by new stormwater treatment systems with a target of meeting the pollutant load reductions outlined in **Table 16-13**. The design of new treatment systems would be confirmed during detailed design.

The performance of the proposed stormwater treatment systems was modelled. For the Wolli Creek catchment, the model indicated that the proposed systems would meet targets set for total

phosphorous and total nitrogen removal. However, the model indicates that removal for total suspended solids would be substantial but that the target would not be met.

The deficit in treatment for total suspended solids would be somewhat compensated for by the high pollutant removals from the Alexandra Canal and Eastern Channel catchments further downstream.

However, it is acknowledged that:

- Sydney Water own and operate a gross pollutant trap in the concrete lined section of Wolli Creek at Kingsgrove. The trap would receive both treated and a relatively small amount of untreated drainage from the project drainage network and would contribute further to total suspended solids reductions in the catchment
- The catchment of the project footprint (around 7.1 hectares) compared to the total Wolli Creek catchment (2,100 hectares) is relatively minor and is unlikely to generate significant impacts to downstream water quality.

Stormwater treatment designs would be defined during detailed design in consultation with the future owners and or operators. Stormwater treatment would be designed in accordance with the recommendations made in **Section 16.4**.

Cooks River

The project would result in a small amount of new permanent infrastructure within the Cooks River catchment, including the operational water treatment plant. The final footprint of these facilities would be roughly 1.7 hectares. The Kogarah Golf Course currently has a very low impervious fraction (assumed zero). The project would include new impervious surfaces of around 1.7 hectares, with an accompanying increase in pollutant loads that would be discharged to the Cooks River (**Table 16-13**).

Although no provision has been made for the treatment of stormwater runoff from the permanent infrastructure located at the Arncliffe motorway operations complex, the modelled increased in pollutants from this site would be offset by the pollutant removal achieved in the Eastern Channel and Alexandra Canal catchments. In those catchments, the pollutant reductions have been modelled as being in excess of the required load reductions, and these more than account for the additional pollutants created by the project at the Arncliffe motorway operations complex (**Table 16-13**). Therefore the project's net environmental impact immediately downstream of the golf course is a substantial reduction in pollutant loads.

Alexandra Canal

The project would result in new permanent infrastructure within the Alexandra Canal catchment, including new roads and bridges. Additional pavement associated with this infrastructure would increase the imperviousness of the pavement drainage catchment area. The future impervious area attributable to the project is estimated to be about 45.74 hectares. This creates the potential for higher pollutant loads to be discharged to the receiving environment of Alexandra Canal.

The Alexandra Canal catchment is made up of multiple sub-catchments. Within some of these sub-catchments there is minimal or no available space in the road reserve for the installation of stormwater treatment devices such as bioretention systems or constructed wetlands. Further, as the project connects directly into the existing stormwater drainage network, there are no treatment opportunities further downstream within these sub-catchments. However, there are opportunities within other sub-catchments that could be used to offset the impacts of the project on the untreatable sub-catchments.

As a result, some of the sub-catchments impacted by the project would not be able to accommodate full stormwater treatment. By reducing pollutant loads in the other sub-catchments, there is the opportunity to offset the treatment deficit from the untreated sub-catchments and provide a net overall environmental benefit. This is because the treatable sub-catchments are larger than the untreatable sub-catchments. Refer to the Technical working paper: Surface water (**Appendix N**) for further details.

Further, the untreatable sub-catchments discharge to Alexandra Canal, which has very little habitat value. As a result, the environmental benefit of treating stormwater that is discharged to this canal is only realised as water is discharged into the Cooks River and the downstream natural environment at

Botany Bay. Consequently, untreated stormwater runoff from small urban catchments is unlikely to impact the habitat value of Alexandra Canal, but if total pollutant loads to Botany Bay can be reduced, this would be of direct benefit to that receiving environment. To determine the likely impact and adequacy of mitigation measures, the pollutant loads from all catchments that discharge to Alexandra Canal have been considered together.

Stormwater treatment devices have been proposed for the Alexandra Canal catchment. Further, provisions would be made, where space is available, for the treating of stormwater runoff from new impervious surfaces created by the project, including the operation of new stormwater treatment systems.

For the Alexandra Canal catchment, the treatment targets for total suspended solids, total phosphorous and total nitrogen would be easily met by the proposed stormwater treatment. The pollutant removal capability of the proposed treatment devices exceeded 100 per cent because these removals would include pollutants from the existing catchment that are over and above the impacts of the project. The designs would be refined during detailed design in consultation with the future owners and or operators, and designed in accordance with the recommendations made in **Section 16.4**.

Eastern Channel

Parts of project (ie some of the local road upgrades) are located in the Eastern Channel catchment. The local road upgrades, specifically the widening of Campbell Street and adjoining streets, would result in additional pavement areas.

These works would result in a relatively large increase in stormwater runoff within the catchment draining to Camdenville Park. It is proposed that the increase in runoff potential be offset through the provision of additional detention storage within and adjacent to Camdenville Park. This would limit increases in peak flow rates discharged to the downstream trunk drainage system. The proposed drainage strategy would be determined during detailed design and would be based on not increasing flows into the Eastern Channel for all events up to and including the 100 year ARI flood (refer Section 7.3.3 of the Technical working paper: Surface water (**Appendix N**)). Matters relating to the disturbance of sediments within Camdenville Park have been further considered in Technical working paper: Contamination (**Appendix O**).

Treatment devices are proposed to reduce pollutant loads in line with the targets in **Table 16-13**. The combined treatment performance of the treatment devices was evaluated by comparing the total pollutant load reduction required, with the reduction achieved. For the Eastern Channel catchment, the treatment targets for total suspended solids, total phosphorous and total nitrogen would be easily met with the proposed provisions. The modelled pollutant removal exceeded 100 per cent because these removals would include pollutants from the existing catchment that are over and above the impacts of the project. The designs would be refined during detailed design in consultation with Marrickville Council, and designed in accordance with the recommendations made in **Section 16.4**.

Table 16-13 Increases in imperviousness and resultant pollutant loads in surface water runoff, and required pollutant load reduction targets*

Criteria	TSS	TP	TN
Wolli Creek – western surface works			
Increase in pollutant loads resulting from the project (kilograms per year)	17,700	31	118
Target pollutant load reduction (SMCMA,2011)	85	60	45
Target pollutant load reduction (kilograms per year)	15,045	18.6	53.1
Kogarah Golf Course			
Increase in pollutant loads resulting from the project (kilograms per year)	4,100	7	27
Target pollutant load reduction (SMCMA,2011)	85	60	45
Target pollutant load reduction (kilograms per year)	3,485	4.2	12.2
Alexandra Canal and Eastern Channel –local road upgrades			
Increase in pollutant loads resulting from the project (kilograms per year)	2,000	4	10
Target pollutant load reduction (per cent) (SMCMA,2011)	85	60	45
Target pollutant load reduction (kilograms per year)	1700	2.4	4.5
Eastern Channel			
Increase in pollutant loads resulting from the project (kilograms per year)	1,000	2	7
Target pollutant load reduction (SMCMA,2011)	85	60	45
Target pollutant load reduction (kilograms per year)	850	1.1	3.2

* Note that these load reductions are indicative and would need to be updated based on the catchment areas used in detailed design.

Discharges from the operational water treatment plant could also impact on the water quality of receiving waterway, depending on the discharge volumes and degree of prior treatment. Appropriate management and treatment of water during operation is discussed above in this **Section 16.3.2** in relation to the operational water treatment plant.

Drainage systems would be designed and implemented to minimise potential impacts on receiving watercourses. Drainage infrastructure is discussed in **Section 18.3.2**.

Water quality monitoring

Operational water quality monitoring would be conducted for 12 months post-construction or as otherwise required by the conditions of approval. This would include upstream (control) and downstream measurement locations. Samples would be taken twice a month, once in dry and once in wet conditions where possible. This would include upstream (control) and downstream measurement locations. Parameters to be tested for and locations of monitoring sites are shown in Appendix B of the Technical working paper: Surface water (**Appendix N**).

Baseline water quality data would not be required for the Eve St Wetlands (separated from the project disturbance footprint by the M5 East and SWOOS) and Green and Golden Bell Frog breeding ponds (fed by Marsh Street stormwater and actively manipulated / managed) as the project would not discharge water to these locations.

Riparian ecosystems

As set out in **Section 21.3.3**, the operation of the project would not result in significant impacts for riparian ecosystems.

With specific reference to the Cooks River, the watercourse itself is currently degraded with limited fish habitat present. As such, the operation of the project is unlikely to have a significant impact on aquatic ecology as a result of the discharge of tunnel groundwater and deluge water.

The potential impacts on aquatic and riparian ecology at Wolli Creek associated with the increased flow in receiving watercourses are described in **Sections 21.3.1** and **21.3.2**. No significant impacts are anticipated for riparian ecosystems, as the project has been designed to avoid impacting such sensitive ecosystems.

Cumulative impacts

The project area is within a continually altering urban environment. Further developments are likely to occur in or around the project area during and after construction of the project.

The project would involve the construction of the St Peters interchange, which would include drainage and pavements associated with future connections road infrastructure. Significant works are currently underway directly to the west of the project as part of the King Georges Road Upgrade which would connect directly to the project.

The cumulative impacts of future infrastructure at this location are considered in Appendix A of the Technical working paper: Surface water (**Appendix N**). In regards to flooding, where other construction activities are not in close proximity to the project, cumulative temporary flood impacts and cumulative operational flooding impacts are not likely. Operational surface water quality would be maintained through the routine application of stormwater treatment devices to new infrastructure and new developments to ensure discharges to the surrounding catchments comply with legislative requirements.

Potential flooding and geomorphological impacts associated with new developments would be mitigated through detailed design so that no unacceptable increases in velocities, discharges, flood levels or flood extents occur. Ongoing maintenance works in the project area have the potential to lead to uncontrolled spills (eg of hydrocarbons, cleaning fluids or other liquids) being released into the surrounding environment, potentially causing soil and groundwater contamination, as well as adverse water quality impacts. However, with the mitigation measures outlined in **Table 16-14**, the risk of this occurring is low.

Due to insufficient information regarding the impacts, design and management of surface water flows and infrastructure associated with other development proposals, cumulative surface water impacts cannot be fully understood at this stage. However, if mitigation requirements are applied consistently to all projects, adverse cumulative surface water impacts are not anticipated. Residual risks to the environment would therefore be low.

Where legislative requirements are applied consistently across the catchment, there is the potential for overall improvement in water quality and / or reduction in flood risk.

16.4 Environmental management measures

Environmental management measures relating to soils and water quality for the construction and operation of the project are provided in **Table 16-14**.

Table 16-14 Environmental management measures – Soils, surface water and flooding

Impact	No.	Environmental management measures	Timing
Construction			
Water quality	SW01	The control and mitigation of potential surface water quality impacts during construction would be defined in a Soil and Water Management Plan prepared as part of the overall Construction Environmental Management Plan.	Pre-construction/ construction
Water quality	SW02	The Soil and Water Management Plan would be developed to incorporate controls and measures in accordance with The Blue Book. The plan would be continually updated to suit the changing needs as the project works progress. The plan would be developed in consultation with the Environment Protection	Pre-construction/ construction

Impact	No.	Environmental management measures	Timing
		Authority and DPI - Water and document the types of measures that would be put in place to minimise the risk of soil erosion or polluted discharges reaching the receiving environments.	
Water quality	SW03	An Erosion and Sedimentation Management Plan would be prepared as outlined in the Erosion and Sedimentation Risk Assessment Procedure (RTA, 2004).	Pre-construction/ construction
Water quality	SW04	The Soil and Water Management Plan would include: • Construction traffic restricted to delineated access tracks, and maintained until construction complete • Appropriate sediment and erosion controls to be implemented prior to soil disturbance • Stormwater management to avoid flow over exposed soils which may result in erosion and impacts to water quality • Stockpiles located outside the 20 year ARI flood extent where feasible. Otherwise, appropriate management control measures such as bunding would be implemented • Staging of surface works to minimise area of exposed surfaces, with re-vegetation and / or stabilisation of disturbed areas to occur as soon as feasible • Site compounds sealed or hard stand to minimise erosion where possible • Wheel wash or rumble grid systems installed at exit points to minimise dirt on roads • A soil conservation specialist would be contracted to supervise construction in high risk areas in accordance with the Erosion and Sedimentation Management Procedure (RTA, 2008c) • All water generated during construction would be captured, tested (and treated if required) prior to reuse or discharge under a site specific arrangement, depending on the quality of water generated. This would target compliance with the Water Quality Reference Criteria. At the St Peters interchange site this would include transfer of some water to the leachate treatment plant. Varying levels of groundwater quality would also require a variation to treatment approaches • Contaminated sediments and potential acid sulfate soils would be segregated and disposed of (with or without prior treatment as appropriate) at a licensed facility or treated onsite • Stockpiles would be located outside of riparian corridors.	Pre-construction/ construction
Water quality	SW05	The water quality and outflow velocities of the water treatment plants at the following compounds would be in accordance with the project's Water Quality	Construction

Impact	No.	Environmental management measures	Timing
		Reference Criteria and the project's Environment Protection Licence: Kingsgrove North construction compound (C1), Commercial Road construction compound (C3), Bexley Road South construction compound (C5), Arncliffe construction compound (C7), Canal Road construction compound (C8).	
Water quality	SW06	The project specific water quality monitoring program would continue to collect to at least 12 months of data or to the commencement of construction (whichever is sooner) to represent pre-construction conditions for the project. Monitoring would continue during construction of the project as identified in Appendix A of the Technical working paper: Surface water (**Appendix N**). The details of this monitoring program would be contained in the Soil and Water Management Plan, and would include the following: • Sampling locations to include upstream (control) and downstream measurement locations • Samples taken twice a month, once in dry conditions and once in wet conditions where possible • In-situ monitoring of: – pH – Reduction Oxidation Potential – Dissolved Oxygen – Temperature – Conductivity – Turbidity – Colour – Odour • Analytical sampling of the following potential constituents of concern: – Total Recoverable Hydrocarbons – Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene – Nutrients including: Total Nitrogen, Total Kjeldahl Nitrogen, Nitrogen Oxide, Nitrite, Nitrate, Total Phosphorous and Reactive Phosphorous – Heavy metals (Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel, Zinc) – Manganese – Ferrous Iron and Total Iron.	Pre-construction/ construction
Water quality	SW07	Water quality monitoring of the breeding ponds for Green and Golden Bell Frog near Marsh Street, Arncliffe would occur during construction by a suitably qualified scientist as part of the Green and Golden Bell Frog Plan of Management.	Construction
Water reuse	SW08	Opportunities for reuse of treated water generated at the Arncliffe motorway operations complex would be considered during detailed design.	Detailed design
Acid sulfate soils	SW09	An Acid Sulfate Soil Management Plan would be prepared as a sub-plan to the Construction	Pre-construction/

Impact	No.	Environmental management measures	Timing
		Environment Management Plan to outline the requirements for the management of potential acid sulfate soils.	construction
Acid sulfate soils	SW10	Further contamination investigation would be conducted in areas with medium or high acid sulfate soils potential during the detailed design stage as part of early works. Management of acid sulphate soils during the project would be undertaken as per the management measures outlined in **Section 17.4**.	Detailed design / pre-construction
Contamination	SW11	During landfill closure activities, surface water management measures would be implemented in accordance with The Blue Book to isolate and capture potentially contaminated water. Any such water would be transferred to the leachate treatment plant for treatment prior to discharge to sewer under a trade waste agreement with Sydney Water.	Construction
Contaminated runoff and spills	SW12	The following measures would be in place to manage spills of contaminated fluids: • Areas would be allocated for the storage of fuels, chemicals and other hazardous materials • Facilities would be secured and bunded to levels dictated by Environment Protection Authority guidelines • Spills or contaminated runoff would be captured and treated and / or disposed of at a licensed facility • Re-fuelling, wash down and preparation of construction materials would be undertaken in bunded areas to mitigate risks in relation to spills or leaks of fuels / oils or other hazardous onsite construction material • The application of good practice in the storage and handling of dangerous and hazardous goods would provide appropriate practical responses to manage impacts on occupational health and safety and minimise the risk of a spill occurring • Potential discharges from construction sites would be managed through the installation of basins (primarily designed for sediment capture but with capacity to contain the nominated spill volume) constructed in accordance with The Blue Book • Captured contaminants resulting from spills or leaks would be treated and disposed of at a licensed facility • Any soil which has been contaminated with fuel, oils or other chemicals would be disposed as contaminated soil by a waste subcontractor.	Construction
Geomorphology	SW13	Construction work activities within and / or adjacent to waterways would be minimised as much as feasibly possible to minimise disturbance to those waterways and waterfront land.	Construction

Impact	No.	Environmental management measures	Timing
Geomorphology	SW14	Alignment of drainage and discharge outlet infrastructure would direct flows downstream to minimise alterations and erosion of the channel beds and banks.	Detailed design/ construction
Geomorphology	SW15	Drainage and discharge outlet infrastructure would include energy dissipation and erosion scour protection as appropriate.	Detailed design/ construction
Geomorphology	SW16	Disturbed floodplain environments adjacent to watercourses (including waterfront land) and / or along overland drainage lines would be stabilised and vegetation managed in accordance with the *Guidelines for Controlled Activities on Waterfront Land* (DPI, 2012a).	Construction
Operation			
Surface runoff	OpSW01	Suitable stormwater treatment devices would be identified during detailed design, including an operational water treatment plant, with the aim of meeting the targets of the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011). Where space is available, water quality basins would be installed. In the case where space is unavailable, treatment would include the use of proprietary stormwater treatment devices. The design of treatment trains would be informed by an assessment of the sensitivity of the receiving environments and supported by MUSIC modelling.	Detailed design/ operation
Surface runoff	OpSW02	The treatment capacity lost in decommissioning pond WQP – 3 would be provided by new or upgraded stormwater treatment devices.	Detailed design/ operation
Water quality monitoring	OpSW03	Operational water quality monitoring would be conducted for 12 months post-construction or as otherwise required by the conditions of approval. This would include upstream (control) and downstream monitoring locations. The details of this monitoring program would be contained in the Soil and Water Management Plan, and would include the following: • Sampling locations to include upstream (control) and downstream measurement locations • Samples taken twice a month, once in dry conditions and once in wet conditions where possible • In-situ monitoring of: – pH – Reduction Oxidation Potential – Dissolved Oxygen – Temperature – Conductivity – Turbidity – Colour – Odour • Analytical sampling of the following potential constituents of concern:	Operation

Impact	No.	Environmental management measures	Timing
		– Total Recoverable Hydrocarbons – Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene – Nutrients including: Total Nitrogen, Total Kjeldahl Nitrogen, Nitrogen Oxide, Nitrite, Nitrate, Total Phosphorous and Reactive Phosphorous – Heavy metals (Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel, Zinc) – Manganese – Ferrous Iron and Total Iron.	
New discharge outlets	OpSW04	New discharge outlets into Alexandra Canal would be designed with sufficient energy dissipation or scour protection to limit the impact on contaminated sediments and reduce the possibilities of contaminated sediments being subject to scour or resuspension.	Detailed design/ operation
Existing drainage outlets	OpSW05	Where existing drainage lines are to be subject to increased inflow, an assessment of their discharge characteristics would be made. If necessary, energy dissipation or scour protection would be added to prevent contaminated sediments from being subject to scour or resuspended. This would be undertaken during detailed design.	Detailed design/ operation
Mitigation for spills	OpSW06	The assessment of risk of spills on the motorway would be undertaken during detailed design. If warranted, spill containment would be provided.	Detailed design/ operation
Operational water treatment plant	OpSW07	The operational water treatment plant would be designed to meet the Water Quality Reference Criteria outlined in Appendix A of the Technical working paper: Surface water (**Appendix N**). Monitoring of the Cooks River would be undertaken during initial operation of the project to ensure discharge meets these criteria.	Detailed design/ operation
Geomorphology	OpSW08	Suitably designed scour and erosion control measures would be included in the detailed design.	Detailed design/ operation
Geomorphology	OpSW09	Drainage and discharge infrastructure where space is available would incorporate measures, as appropriate, to trap and remove sediments in line with the outcomes of the stormwater pollution reduction targets from the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011). This would reduce the risk of any impacts to the geomorphic condition of receiving waters.	Detailed design/ operation

17 Contamination

This chapter provides a summary of the Technical working paper: Contamination (**Appendix O**), which was prepared to inform this environmental impact statement (EIS) and address the Secretary's Environmental Assessment Requirements (SEARs) for the project as they relate to contamination.

The Technical working paper: Contamination (**Appendix O**):

- Identified potential areas and contaminants of concern
- Provided a preliminary and qualitative assessment of contamination risk posed to the environment, construction work and proposed future land use
- Assessed where further investigation should be undertaken or appropriate management procedures should be put in place for the project
- Incorporated the findings of a number of environmental site assessments that have been prepared for the project.

Table 17-1 sets out the SEARs that relate to contamination and lists where in the EIS they have been addressed.

Table 17-1 SEARs – contamination

SEAR	Section Addressed
An assessment of contaminated sites in accordance with the guidelines made or approved under section 105 of the *Contaminated Land Management Act 1997.* The assessment must include details of proposed remediation measures and justification for the proposed measures in terms of the proposed final use of that land;	An assessment of contaminated sites is included in the Technical working paper (Contamination) (**Appendix O**) and summarised in **Section 17.2**. Proposed remediation measures and other mitigation measures are presented in **Section 17.4**.
Status of site contamination and suitability of the site for the proposal, including the suitability of the Alexandria landfill site for the St Peters interchange;	The status and suitability of the land affected by the project, including the Alexandria Landfill, is addressed in **Section 17.2**and **Section 17.3**
An assessment of the potential disturbance of contaminated bed sediments in the Alexandra Canal, and interception of contaminated water from the Botany Sand Beds aquifer; and	The potential disturbance of contaminated bed sediments in the Alexandra Canal is discussed in **Section 17.3**. The potential for the project to intercept contaminated water from the Botany Sand beds aquifer is discussed in **Section 17.3.2.**
Having reference to the assessments conducted in satisfaction of the above, consideration of whether or not a site auditor, accredited under the *Contaminated Land Management Act 1997,* has or will be engaged to issue a site audit statement to certify on the suitability of the current or proposed uses.	Consideration of whether or not a site auditor is required to certify the suitability of land use is discussed in **Section 17.3**.

17.1 Assessment methodology

The Technical working paper: Contamination (**Appendix O**) has been completed in the form of a Phase 1 Environmental Site Assessment (Phase 1 ESA). The purpose of the Phase 1 ESA was to provide a preliminary assessment of contamination risks associated with the surface disturbance areas of the project. Potential areas of contamination that may pose a potential risk to the environment, construction work and proposed future land use were identified.

The Phase 1 ESA considered the following key guidelines applicable to contamination identification, assessment and management:

- *Contaminated Sites: Guidelines for the NSW Site Auditor Scheme* (2nd Edition) (DEC, 2006b)
- *Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites* (OEH, 2011)
- *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC, 2013).

The assessment methodology for the Phase 1 ESA included:

- Defining the study area for the Phase 1 ESA based on the project footprint
- A preliminary screening assessment and data review based on historical records to identify potential areas of contamination concern
- A field inspection in order to confirm the outcomes of the preliminary screening assessment
- A secondary data review and preliminary assessment of identified areas of contamination concern to further evaluate the potential for contamination to be present.

Details of these assessment stages are outlined between **Section 17.1.1**and **Section 17.1.4**.

17.1.1 Phase 1 ESA study area

The Phase 1 ESA targeted project surface disturbance areas associated with tunnel entry and exit points, ventilation facility locations, construction compounds and potential disturbance areas within the Alexandra Canal. These areas are identified in **Figure 17-1** and included:

- Western surface works (Project area 1), extending west of King Georges Road, Beverly Hills to Kingsgrove Road, Kingsgrove
- Kingsgrove Road surface works (Project area 2)
- Bexley road surface works (Project area 3), located near the Bexley Road / M5 East Motorway interchange
- Arncliffe surface works (Project area 4) at Kogarah Golf Course
- St Peters interchange and local road upgrades (Project area 5) in St Peters, Alexandria and Mascot.

Areas where the main alignment tunnels are proposed to be located at depth within the bedrock have not been assessed due to the low likelihood of contamination being encountered. Given the depth, location of the tunnels in relation to contaminant sources, and low inflow rates, the risk of encountering contamination along the tunnel alignment would be low. Groundwater details across the project are detailed in **Chapter 19** (Groundwater).

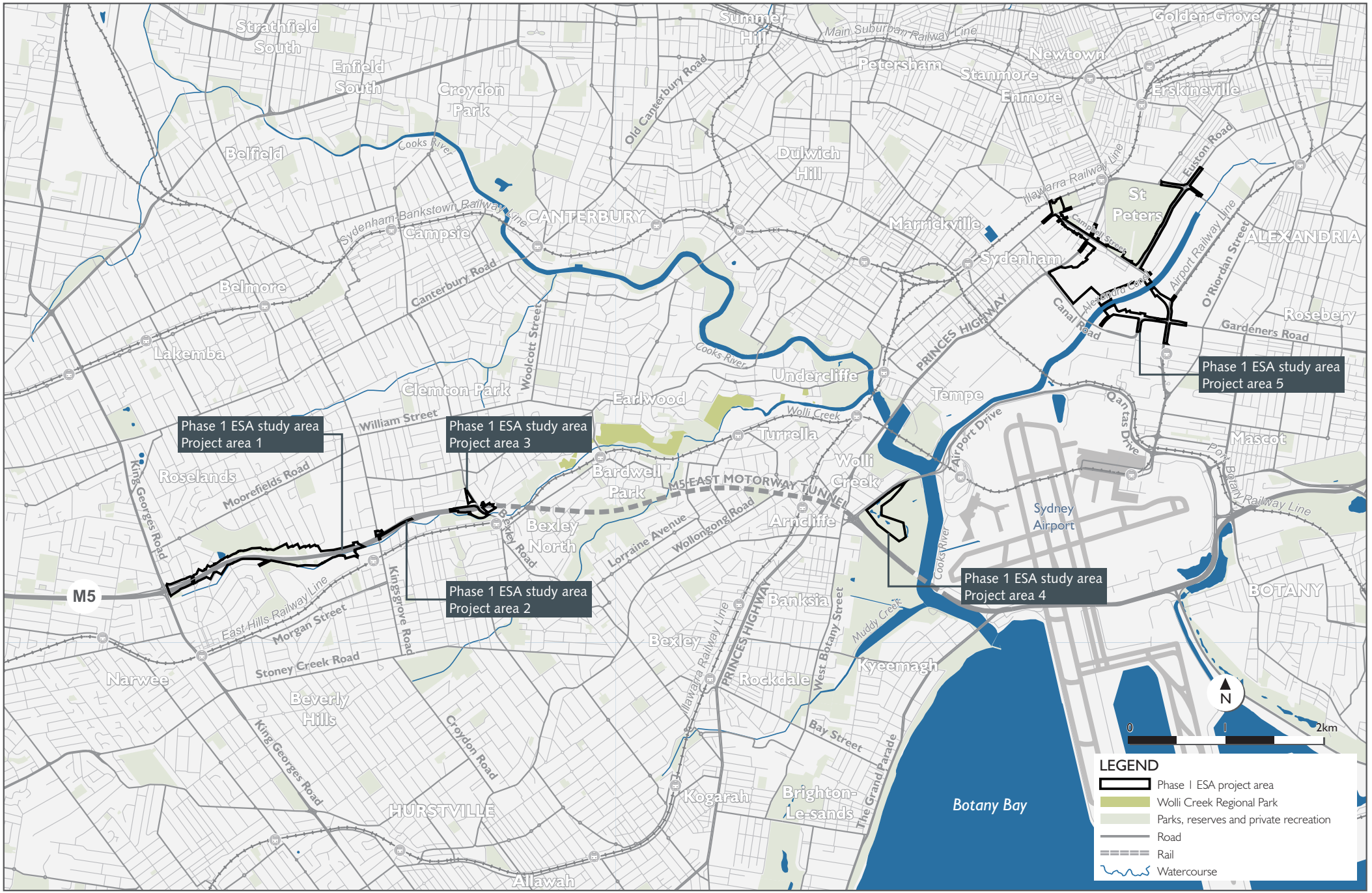


Figure 17-1 Phase 1 environmental site assessment study area

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17.1.2 Preliminary screening assessment and data review

A preliminary screening assessment and data review was undertaken to identify areas of potential contamination concern that may pose a risk during construction of the project. The preliminary screening assessment and data review included:

- A review of previous environmental reports relevant to the Phase 1 ESA study area, including:
  - *Phase 1 Environmental Site Assessment Alexandria Landfill Site Acquisition Area* (AECOM, 2014d)
  - *Phase 1 Environmental Site Assessment, Local Road Upgrades, St Peters, Mascot and Alexandria, NSW* (AECOM, 2015c)
  - *Phase 2 Environmental Site Assessment Alexandria Landfill, 5 Canal Road, St Peters, NSW* (AECOM, 2015d)
  - *Phase 2 Environmental Site Assessment Alexandria Landfill, 10-16 Albert Street, NSW* (AECOM, 2015e)
  - *WestConnex Stage 2: M5 KGRIU Noise Mound Stockpile, Factual Stockpile Contamination Characterisation Report* (AECOM, 2015f)
  - *WestConnex Stage 2: M5 Factual Contamination Assessment* (AECOM, 2015g)
  - *Alexandria Landfill Closure Hydrogeological Assessment, Alexandria Landfill, 10-16 Albert Street, St Peters, NSW* (AECOM, 2015k)
  - *Preliminary Waste Classification: Stockpile 21* (AECOM, 2015i)
  - *Phase 2 Area Preliminary Stockpile Characterisation* (ENVIRON, 2015)
  - *Sediment-Water Column Interactions in Alexandra Canal Sydney. University of Queensland, Centre for Marine Studies. Prepared for Woodward-Clyde* (University of Queensland, 2002b)
  - *Final Report - Upper Alexandra Canal Sediment Management Study* (Woodward-Clyde, 1998)
  - *Sediment Remediation Options Study* (URS, 2003)
  - *Marrickville Council, Camdenville Park, May Street, St Peters, NSW. Remedial and Construction Environmental Management Action Plan* (GHD, 2013)
  - *Advice Regarding the Contamination Status of the Property at 6A Huntley Street, Alexandria, NSW* (SMEC, 2012).
- A review of current and former potentially contaminating land uses along and adjacent to the project and in proximity to surface disturbance areas
- Database searches, including identification of contaminated sites listed under:
  - Either section 58 or 60 of the *Contaminated Land Management Act 1997* (CLM Act)
  - *Protection of the Environment Operations Act 1997* (POEO Act) licence register
  - Australian Government Department of the Environment National Pollutant Inventory (NPI).

The NSW Environment Protection Authority (NSW EPA) contaminated sites register lists both former and current contaminated sites which have had regulatory involvement (listed under section 58 of the CLM Act). The register identifies the location of these sites and specifies the contaminants of concern and their nature of harm to the environment and human health. A search of the register identified 12 properties with current or former notices located within one kilometre of the project surface disturbance areas.

When a 'notice' has been issued by the NSW EPA, it indicates that a site is known to be contaminated to an extent that warrants regulation. A 'notified site' indicates that the landowner or person whose activities have contaminated land has informed the NSW EPA that a site may be contaminated at a level triggering regulatory action. Notified sites may or may not be contaminated to an extent to warrant regulation by the NSW EPA.

A search of properties within a one kilometre radius of the project surface areas was also conducted to identify properties that have been previously notified to the NSW EPA under section 60 (duty to report) of the CLM Act. Twelve 'notified sites' were identified within one kilometre of the project surface areas. The majority of sites reported have been determined by the NSW EPA as not requiring regulation under the CLM Act.

The POEO Act licence register identifies premises that are licenced for certain activities under the POEO Act. The register provides information in regard to location, activity type, clean up notices and non-compliance information. Ten sites within or near the surface disturbance areas were identified.

17.1.3 Field inspection

A field inspection was undertaken on 30 April 2015 at and in the vicinity of the project surface areas (refer to **Figure 17-1**) to visually identify any potentially contaminated areas identified during the preliminary screening assessment and data review (a full list is provided in the Technical working paper: Contamination **(Appendix O**)). During the inspection, digital photographs, GPS coordinates of potentially contaminating / contaminated features, and observations were recorded and marked against the corresponding property Lot and deposited plans (DP).

Areas of contamination concern were inspected for typical evidence of contamination including features such as:

- Contaminating businesses / activities
- Areas of stressed vegetation
- Evidence of filling such as unnatural landforms and subsidence
- Stockpiled waste
- Disturbed soil
- Discolouration
- Sheen on water
- Odours
- Proximity to suspected contamination source areas
- Sign of old infrastructure and asbestos buildings.

17.1.4 Secondary data review

Potential areas of contamination concern identified during the preliminary screening assessment were subject to a secondary data review which allowed for further investigation to confirm the likelihood that contaminated materials may be present.

The secondary data review involved additional desktop investigations and database searches, including:

- Identification of properties which are listed on the NSW Government Land and Property Information central register of restrictions
- Review of historical aerial photographs for the surface disturbance areas and historical certificates of title
- Sourcing and review of Section 149 and Section 149(5) certificates for identified properties of concern within surface disturbance areas
- Review of published maps of the area to gain an understanding of surface and subsurface conditions (e.g. geology, hydrogeology, soil and topography)
- Search and review of information readily available through the internet (e.g. historical parish maps and NSW Department of Primary Industries: Water registered groundwater bore database)
- WorkCover NSW records for licensed dangerous goods of selected properties
- Search of Australian Department of Defence unexploded ordnance contamination database.

17.2 Existing environment

The predominant land uses within the project corridor are mixed commercial / industrial, residential and open space. Some areas within the project corridor have a long history of heavy industrial land use, particularly in the vicinity of Tempe, Alexandria and St Peters.

Potential sources of contamination that might have resulted from land uses (current and historical) within and in the vicinity of the project corridor include:

- Landfilling operations (waste disposal)
- Use of fill material of unknown origin
- Fuel and chemical spills associated with traffic accidents, use and storage.

Discussion of surface water pathways and management is provided in **Chapter 16** (Soil and water quality) and asbestos management is provided in **Chapter 24** (Resource use and waste minimisation).

This section provides an overview of the existing environment and potential contamination, with particular reference to the following surface disturbance areas:

- Western surface works (Project area 1)
- Kingsgrove Road surface works (Project area 2)
- Bexley road surface works (Project area 3)
- Arncliffe surface works (Project area 4)
- St Peters interchange and local roads upgrades (Project area 5).

17.2.1 Western surface works (Project area 1) and Kingsgrove Road surface works (Project area 2)

Four areas of potential contamination concern are located within the western surface works. These properties consist of sites that may have historically been the subject of uncontrolled filling, various commercial / industrial land uses, including brick works and fertiliser manufacturing and storage for supply, market gardening, laundering and various public utility and/or council works sites. More recently, these sites have been subject to various warehousing and commercial/industrial uses.

The areas of potential contamination concern are shown on **Figure 17-2** and include:

- M5 Linear Park (noise mounds). The site potentially contains asbestos and other contaminants commonly associated with uncontrolled fill. Recent investigations (AECOM, 2015f and 2015g) detected friable asbestos in soil within a soil noise mound on the southern side of the existing M5 Motorway near Kirrang Street and within M5 Linear Park near Tallawalla Street
- 27-31 Garema Circuit, Kingsgrove. Potential sources of contamination relate to historical fertiliser manufacturing and storage for supply, brick and pipe work manufacturing, uncontrolled filling and various commercial / industrial land uses
- 30A and 32 Commercial Road, Kingsgrove (two areas). Potential sources of contamination relate to historical land use activities including laundering, market gardens, public and council works sites and various other commercial / industrial land uses.

Table 17-2 details potential contaminants for each individual area of contamination concern located within the western surface works.

No areas of potential contamination concern were identified in association with Kingsgrove Road surface works.

Table 17-2 Western surface works: identified potential areas of contamination concern

Item name and / or address	Surface disturbance area	Potential source of contamination	Potential contaminants
M5 Linear Park	Western surface works	Fill material used for noise mound creation along the M5 Motorway	Asbestos
27-31 Garema Circuit, Kingsgrove	Western surface works	Former fertiliser manufacture and/or storage, brick and pipe works, and potential uncontrolled filling and various other commercial/industrial land use including warehousing	Calcium phosphate, calcium sulphate, copper chloride, sulphur, sulphuric acid, metals (boron, cadmium, copper, magnesium, molybdenum), herbicides, fungicides, asbestos, hydrocarbons, pesticides and PCBs
30A and 32 Commercial Road, Kingsgrove	Western surface works	Laundering, market gardens, public and council works site, various commercial / industrial land uses including bus storage	Hydrocarbons, pesticides and heavy metals



Figure 17-2 Potential contamination at Western surface works

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17.2.2 Bexley Road surface works (Project area 3)

Three areas of potential contamination concern are located within or immediately adjacent to the Bexley Road surface works (**Figure 17-3**). The potential contaminants of concern relate to a former ammunition storage site for World War II, a vacant Roads and Maritime owned site (part of M5 Linear Park) and Kingsgrove Avenue Reserve.

A review of historical aerial photographs identified a potential ammunition storage site that may have been associated with an anti-aircraft battery located near Homer Street and Bexley Road during World War II. It appears that most of the site would have been excavated for the construction of the M5 East Motorway in the late 1990s and remaining parts developed as residential housing, M5 Linear Park or road reserve. The vacant Roads and Maritime site and Kingsgrove Avenue Reserve have been identified as a result of potential historical uncontrolled fill activities.

Table 17-3 details potential contaminants on these sites.

Table 17-3 Bexley surface works: identified potential areas of contamination concern

Item name and / or address	Surface disturbance area	Potential source of contamination	Potential contaminants
Former ammunition storage	Bexley Road surface works	Former ammunition storage for World War II Anti-Aircraft Battery unit located between Flatrock Road, Bexley Road and Wolli Creek	Unexploded ordnance and heavy metals
Vacant Roads and Maritime owned site, west of Bexley Road (part of M5 Linear Park)	Bexley Road surface works	Uncontrolled fill material	Asbestos, heavy metals and hydrocarbons
Kingsgrove Avenue Reserve	Bexley Road surface works	Open space with potential uncontrolled filling	Asbestos, heavy metals and hydrocarbons

17.2.3 Arncliffe surface works (Project area 4)

The Kogarah Golf Course was identified as an area of potential contamination concern (**Figure 17-4**) relevant to the Arncliffe surface works due to:

- Historical land use activities at and around the site including:
  - Market gardens
  - Sewerage board works
  - Potential uncontrolled filling for golf course creation
- Current pesticide and herbicide use
- The proximity of the site to the Cooks River and Alexandra Canal, both of which drain industrialised catchments
- The likelihood of acid sulfate soils being present. Acid sulfate soils are further discussed in **Chapter 16** (Soil and water quality).

The Kogarah Golf Course also contains Green and Golden Bell Frog habitat including breeding pond, foraging, sheltering and dispersal habitat. Potential impacts and management measures relating to this habitat are discussed in **Chapter 21** (Biodiversity).

Table 17-4 details the potential contaminants associated with the Kogarah Golf Course.

Table 17-4 Arncliffe surface works: identified potential areas of contamination concern

Item name and / or address	Surface disturbance area	Potential source of contamination	Potential contaminants
19 Marsh Street, Arncliffe	Arncliffe surface works	Market gardens, public works including sewerage board. Potential uncontrolled filling for golf course creation, current pesticide and herbicide use. Cooks River and Alexandra Canal also lie within the immediate vicinity of the study area	Hydrocarbons, pesticides, heavy metals, PCBs, herbicides, fungicides, acid sulfate soils and asbestos



Figure 17-3 Potential contamination at Bexley surface works

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Figure 17-4 Potential contamination at Arncliffe surface works

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17.2.4 St Peters interchange and local roads upgrades (Project area 5)

Areas of potential contamination concern identified within and immediately surrounding the St Peters interchange and local road upgrades can be divided into three general geographies, namely:

- Alexandria Landfill including Bradshaw Mountain (10-16 Albert Street, St Peters) and 5/5A Canal Road, St Peters which have been assessed by Phase 2 ESAs (AECOM, 2015d and AECOM, 2015e respectively)
- Alexandra Canal, which is listed under section 58 of the CLM Act and regulated by the NSW EPA due to sediment contamination and has been subject to previous intrusive investigations
- 'Other Lands', referring to areas within and immediately surrounding the St Peters interchange and local roads area footprint which have not been subject to a Phase 2 ESA.

Areas of contamination concern have been split into categories and described in **Table 17-5**.

Discussion on asbestos management and acid sulfate soils is provided in **Chapter 24** (Resource use and waste minimisation) and **Chapter 16** (Soils and water quality) respectively.

Table 17-5 St Peters interchange and local roads upgrades: identified potential areas of contamination concern

Item name and / or address	Surface disturbance area	Potential contaminants
Landfills and uncontrolled filled quarries		
Alexandria Landfill (including Boiling Pty Ltd and Bradshaw Mountain), 10-16 Albert Street St Peters (listed under POEO Act) (Phase 2 ESA completed)	St Peters interchange and local roads upgrades	Landfill gases (including methane, carbon dioxide, carbon monoxide, hydrogen sulphide, VOCs), hydrocarbons, semi-volatile organic compounds (SVOCs), VOCs, nutrients, heavy metals, herbicides, fungicides, asbestos and biological hazards.
Sydney Park	St Peters interchange and local roads upgrades	
Camdenville Park (listed under CLM Act section 60)	St Peters interchange and local roads upgrades	
3-7 Unwin's Bridge Road	St Peters interchange and local roads upgrades	
Metal smelter sites		
5/5A Canal Road, St Peters (Phase 2 ESA completed)	St Peters interchange and local roads upgrades	Heavy metals, hydrocarbons, asbestos and dioxins/furans
34 Burrows Road, St Peters	St Peters interchange and local roads upgrades	
Manufacturing sites		
Dial a Dump Industries, 1 Holland Street, St Peters	St Peters interchange and local roads upgrades	Heavy metals, hydrocarbons, SVOCs, PCBs, dioxins and total cyanide
Burrows Industrial Estate, 1-3 Burrows Road, St Peters	St Peters interchange and local roads upgrades	
Pioneer Plating Works, 25-29 Ricketty Street, Mascot (listed under CLM Act Section 60)	St Peters interchange and local roads upgrades	
Fuel storage and dispensing		
Dynamo Workshop, 318 Princes Highway, St Peters	St Peters interchange and local roads upgrades	Lead and hydrocarbons
City of Sydney, Material Recycling Depot 19-25 Burrows Road, St Peters (listed under POEO Act)	St Peters interchange and local roads upgrades	

Item name and / or address	Surface disturbance area	Potential contaminants
Greyhound Bus Depot (also former metal smelter), 34 Burrows Road, St Peters	St Peters interchange and local roads upgrades	
Shipping Container Logistics, 12-18 Burrows Road, St Peters	St Peters interchange and local roads upgrades	
Car rental outlet, 532-536 Gardeners Road, Mascot	St Peters interchange and local roads upgrades	
Waste facilities		
SIMS Metal and Taxi Depot, 33 Burrows Road, St Peters	St Peters interchange and local roads upgrades	Heavy metals, hydrocarbons, SVOCs, PCBs, pesticides, dioxins and asbestos.
Good River Properties Pty Ltd, 33 Burrows Road, St Peters (listed under POEO Act)	St Peters interchange and local roads upgrades	
SITA Alexandria Pty Ltd, 33 Burrows Road, St Peters (listed under POEO Act)	St Peters interchange and local roads upgrades	
Former Drum Reconditioning Facility, 53 Barwon Park Road, St Peters (listed under CLM Act section 58)	St Peters interchange and local roads upgrades	
Australian Refined Alloys, 202-212 Euston Rd, Alexandria (listed under CLM Act section 60 and on National Pollutant Inventory register)	St Peters interchange and local roads upgrades	
Visy Paper Pty Ltd and SPRC Pty Ltd, 6-10 Burrows Road South, St Peters (listed under POEO Act)	St Peters interchange and local roads upgrades	
Other		
Alexandra Canal (listed under section 58 of the CLM Act)	St Peters interchange and local roads upgrades	OCPs, PCBs, Metals,
Cooks River Rail Terminal, 20 Canal Road, St Peters (listed under CLM Act section 60)	St Peters interchange and local roads upgrades	Hydrocarbons, asbestos, heavy metals, pesticides and PCBs.
Uncontrolled filling for land reclamation and levelling	St Peters interchange and local roads upgrades	Heavy metals, hydrocarbons, pesticides, PCBs, asbestos
Acid sulfate soils	St Peters interchange and local roads upgrades	Due to the presence of Holocene sediments within the area, potential acid sulfate soils are likely to be present. The potential presence and implications of acid sulfate soils across the project is discussed in **Chapter 16** (Soils and water quality).

Alexandria Landfill

The main known source of contamination within the footprint of the proposed St Peters interchange is the Alexandria Landfill. The Alexandria Landfill site was acquired by the NSW Government in December 2014 and the operations of the previous landowner ceased at that time. Activities consistent with the existing planning approvals are continuing on site. However, the site no longer operates commercially as a landfill.

Alexandria Landfill is licensed by the NSW EPA under the POEO Act for the following scheduled activities:

- Environment Protection Licence No. 4627: Waste Disposal (Application to Land)
- Environment Protection Licence No. 12594: Recovery of General Waste and Waste Storage.

Roads and Maritime is presently operating Alexandria Landfill in accordance with the provisions of these Environment Protection Licences and the conditions of consent previously provided for the premises by City of Sydney Council and Marrickville Council. Typical operations include:

- Sorting through the various stockpiles of waste and materials stored for resource recovery
- Evaluating opportunities to recycle and / or recover materials for reuse
- Processing of materials scheduled for reuse
- Removing and disposing of waste materials assessed as being unsuitable for recycling / reuse to the landfill, or to another suitably licensed landfill facility in accordance with EPA requirements
- Stabilisation of a cliff face landslip.

The activities do not involve any excavation of the land and / or landfilled waste and involve dealing with the stockpiles of materials stored across the premises.

Where asbestos waste is identified within the stockpiled materials, Roads and Maritime's contractors manage and remove the materials in accordance with the *Work Health and Safety Act 2011*, an Asbestos Management Plan and an Asbestos Removal Control Plan.

Since this acquisition, in order to meet the requirements of the existing trade waste agreement with Sydney Water, temporary upgrade works have commenced on the existing leachate treatment plant.

Current and past land uses have resulted in contamination at the site. In the past, the Alexandria Landfill:

- Was a brickworks quarry between 1908 and 1962
- Was a solid waste landfill owned and operated by the City of Sydney Council from 1988 to 2002
- Continued to operate as a solid waste landfill and resource recovery facility run by Dial a Dump Industries from 2002 until acquisition by the NSW Government in December 2014
- A Phase 2 ESA was completed for the Alexandria Landfill in 2015 (AECOM, 2015e) which included soil, groundwater, leachate and ground gas sampling and analysis.

The Phase 2 ESA identified the following:

- The main contaminants of concern included lead, polycyclic aromatic hydrocarbons (PAH), total recoverable hydrocarbons (TRH), dioxins and asbestos. Contamination was mainly confined to the fill and appeared to be randomly distributed both laterally and throughout the full depth of the landfill.
- The analytical results indicated that natural soils may contain potential acid sulfate soils
- Landfill gases including methane, hydrogen sulphide and carbon dioxide were detected within the subsurface monitoring wells at concentrations that could potentially pose a risk to surrounding receptors. Landfill gases could migrate through preferential pathways such as unconsolidated sediments, bedrock factures and underground service trenches into surrounding land
- Groundwater and leachate monitoring detected elevated concentrations of ammonia, heavy metals, TRH and phenols, which appeared mainly confined to the leachate, due to an inward hydraulic gradient into the landfill from leachate extraction
- The base of the landfill is not lined and, as such, fractures and joints within the underling Ashfield Shale formation may provide migration pathways for leachate to enter the aquifer within the Ashfield Shale aquifer. If an inward gradient is not maintained by leachate extraction, the leachate could also migrate into the Botany Sands Aquifer.

Leachate generated from the infiltration of groundwater and surface water into the Alexandria Landfill is currently pumped out of the main leachate extraction riser. The extracted leachate is initially treated at a leachate treatment plant before being discharged to sewer under a trade waste agreement with Sydney Water. To protect surrounding groundwater and the Alexandra Canal from leachate, the leachate management system is required to operate continuously to keep the leachate level within the shale pit (i.e. intercept groundwater and reduce the volume of leachate being generated due to groundwater inflow). Details of the groundwater assessment and mitigation measures to be implemented are discussed in **Chapter 19** (Groundwater).

The current landfill gas mitigation measure is limited to a small (~50 m) cut off trench located at the northwest boundary of the site and the existing temporary landfill cap. Further ground gas measures would be implemented in accordance with the Landfill Closure Management Plan (refer **Section 17.3.4**).

5/5A Canal Road

The land at 5/5A Canal Road, St Peters is located on the southern boundary of the Alexandria Landfill. The land was formerly used as a metal smelter, waste recycle facility and has since been filled with uncontrolled fill. A Phase 2 ESA was completed (AECOM, 2015d) which included soil, groundwater and ground gas sampling and analysis. The fill was found to be contaminated with heavy metals, asbestos, PAHs, PCBs, TRH and dioxins.

Asbestos was identified and is likely to be randomly present throughout the fill and potentially concentrated in pockets of fill with high proportions of demolition waste. The management and removal of asbestos as part of the project is discussed in **Chapter 24** (Resource use and waste minimisation).

Alexandra Canal

As identified in the NSW EPA contaminated sites register, Alexandra Canal has been declared a remediation site due to the contamination of bed sediments resulting from a history of industrial activities in the local area. Primary contaminants of concern that have previously been identified in the Alexandra Canal sediments include organochlorine pesticides (chlordane, total DDT and dieldrin), PCBs and metals.

Due to the type and levels of these contaminants, the NSW EPA has determined that the bed sediments have the potential to present a significant risk of harm to human health and the environment if disturbed. The NSW EPA consequently issued Sydney Water (the landowner) with a Remediation Order under the CLM Act to facilitate the prevention of sediment disturbance.

Other lands

Other potentially contaminated land within and in the vicinity of the St Peters interchange and local road upgrades area includes commercial and industrial land uses, such as filled quarries, metal smelter sites, manufacturing sites and fuel storage sites. The industrial nature of the area as well as wide spread uncontrolled filling has resulted in the potential for a range of contaminants to be present.

The *M5 Factual Contamination Assessment* (AECOM, 2015g) was completed within parts of the St Peters interchange and local road upgrade area, and provides an indication of the potential contamination. Specific findings included the presence of petroleum hydrocarbon soil and potential groundwater contamination at a borehole completed at 34 Burrows Road, St Peters (Lot 13 DP 32332) and asbestos containing materials in boreholes completed in Sydney Park near Campbell Road and Barwon Park Road.

The Phase 1 ESA identified a number of properties, including (and in association with) areas of contamination concern (**Table 17-5** and **Figure 17-5**), where additional intrusive investigations were recommended. These properties are discussed in greater detail in the Technical working paper: Contamination (**Appendix O**).

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Figure 17-5 Potential contamination at St Peters interchange and local road upgrades

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17.3 Assessment of potential impacts

The project has the potential to generate contamination during construction and operation, including the potential to disturb existing contaminated lands at each of the surface works locations.

17.3.1 Potential to generate contamination

Various activities undertaken at and around the surface disturbance areas would have the potential to generate contamination including:

- Earthworks
- Demolition of buildings containing hazardous materials
- Vehicle, plant and / or equipment maintenance
- Accidents, spills of fuels, oils and chemicals during construction or operation.

The potential to cause contamination through earthworks, demolition of hazardous building materials and maintenance activities would be mitigated through further investigations of identified areas of contamination concern, and the implementation of appropriate environmental management measures (refer **Section 17.4**).

The potential for contamination to occur as a result of accidents or spills of fuels, oils and chemicals during construction and operation of the project is considered to be low, providing the environmental management measures presented in **Section 17.4** are implemented.

Chapter 26 (Hazard and risk) presents further details on the management of dangerous goods and hazardous substances during construction, operation and transportation.

17.3.2 Potential to disturb contamination and associated risk

The risk of disturbing or encountering contaminated material during construction of the project varies across the project corridor. The risk for localised areas of soil, fill and groundwater contamination to be encountered at locations associated with historically contaminating land uses has been incorporated into the contamination risk assessment.

The contamination risk assessment (without the implementation of appropriate controls or remediation) was undertaken to understand the potential risk of identified areas of contamination concern. The risk assessment was qualitatively undertaken by assessing identified areas of contamination concern based on the likelihood of:

- Encountering soil or groundwater contamination
- The exposure pathway for human or ecological receptors.

Table 17-6 highlights the findings of the contamination risk assessment. Table 20 in the Technical working paper: Contamination (**Appendix O**) provides further details of the preliminary risk evaluation.

The potential for acid sulfate soils to be present is further discussed in **Chapter 16** (Soil and water quality) and discussion of asbestos management is presented in **Chapter 24** (Resource use and waste minimisation).

Table 17-6 Preliminary risk evaluation without the implementation of appropriate controls or remediation

Area of contamination concern	Project area	Preliminary risk evaluation
M5 Linear Park	Project area 1, 2 and 3	High
27-31 Garema Circuit, Kingsgrove	Project area 1	Medium
30A and 32 Commercial Road, Kingsgrove	Project area 1	Medium
Former ammunition storage	Project area 3	Medium
Vacant Roads and Maritime owned site, west of Bexley Road (part of M5 Linear Park)	Project area 3	Low
Kingsgrove Avenue Reserve	Project area 3	Low
19 Marsh Street, Arncliffe	Project area 4	Medium
Alexandria Landfill	Project area 5	High
Sydney Park	Project area 5	High
Camdenville Park	Project area 5	High
3-7 Unwin's Bridge Road	Project area 5	High
5/5A Canal Road, St Peters (Phase 2 ESA completed)	Project area 5	High
34 Burrows Road, St Peters	Project area 5	High
Dial a Dump Industries, 1 Holland Street, St Peters	Project area 5	High
Burrows Industrial Estate, 1-3 Burrows Road, St Peters	Project area 5	High
Pioneer Plating Works, 25-29 Ricketty Street, Mascot (listed under CLM Act section 60)	Project area 5	High
Dynamo Workshop, 318 Princes Highway, St Peters	Project area 5	High
City of Sydney, Material Recycling Depot 19-25 Burrows Road, St Peters (listed under POEO Act)	Project area 5	High
Greyhound Bus Depot (also former metal smelter), 34 Burrows Road, St Peters	Project area 5	High
Shipping Container Logistics , 12-18 Burrows Road, St Peters	Project area 5	High
Car rental outlet, 532-536 Gardeners Road, Mascot	Project area 5	High
SIMS Metal and Taxi Depot, 33 Burrows Road, St Peters	Project area 5	High
Good River Properties Pty Ltd, 33 Burrows Road, St Peters (listed under POEO Act)	Project area 5	High

Area of contamination concern	Project area	Preliminary risk evaluation
SITA Alexandria Pty Ltd, 33 Burrows Road, St Peters (listed under POEO Act)	Project area 5	High
Former Drum Reconditioning Facility, 53 Barwon Park Road, St Peters (listed under CLM Act section 58)	Project area 5	Medium
Australian Refined Alloys, 202-212 Euston Rd, Alexandria (listed under CLM Act section 60 and on National Pollutant Inventory register)	Project area 5	Medium
Visy Paper Pty Ltd and SPRC Pty Ltd, 6-10 Burrows Road South, St Peters (listed under POEO Act)	Project area 5	Low
Alexandra Canal (listed under section 58 of the CLM Act)	Project area 5	Low
Cooks River Rail Terminal, 20 Canal Road, St Peters (listed under CLM Act section 60)	Project area 5	Low
Uncontrolled filling for land reclamation and levelling	Project area 5	Medium
Acid sulfate soils	Project area 5	High

Potentially contaminated sites identified in **Table 17-6** would be subject to further investigation, remediation and / or management in accordance with the measures described in **Section 17.3.3**and those outlined in **Section 17.4**. These measures would be implemented so that all land used as part of the project is suitable for the proposed land use (ie the development of road infrastructure).

Exposure Pathways

Where construction works would come into contact with contaminated materials, the potential exists for the health of onsite and offsite receivers to be impacted. However, for this potential impact to be realised, a pathway must exist between the contamination source and a sensitive receiver. This is commonly referred to as a source-pathway-receiver link.

Source-pathway-receiver links have the potential to occur when contaminated materials are first released and then transported (eg through mediums such as water and air) to a potential receiver (such as a person, fauna or flora species or an ecosystem), who then has the ability to intake those contaminated materials.

A specific example relevant to the construction of the project would be the potential for asbestos to be disturbed, causing asbestos particles to become airborne and thereby transported to a sensitive receiver (such as an onsite worker, or offsite member of the public). If those asbestos particles are in a form which can be chemically taken in by the receiver (eg friable asbestos), that receiver may be impacted by coming into contact with that substance. Other pathways by which contaminated materials may be transported to human or environmental receivers include vapour, leachate, or groundwater migration offsite.

However, the construction of the project would be undertaken in accordance with the requirements of the CLM Act, as well as the *Work Health and Safety Regulation 2011*, which sets out the requirements for preventing workers and nearby members of the public becoming exposed to airborne contaminants and hazardous materials in general. By following the requirements set out in the *Work Health and Safety Regulation 2011*, such as using appropriately licensed sub-contractors and ensuring persons are not exposed to contaminated materials above and beyond the relevant exposure standards, the construction of the project would effectively break any potential for source-pathway-receiver linkages to be completed, and for any adverse health impacts to result.

Potential disturbance of contaminated bed sediments in the Alexandra Canal

New stormwater infrastructure would be constructed near and upstream of Ricketty Creek Bridge, which is located more than two kilometres from the junction of the Alexandra Canal with the Cooks River.

During periods of high stormwater runoff, sediments within the canal, particularly in proximity to stormwater outlets, may be temporarily mobilised. This has the potential to cause localised erosion and scour in the vicinity of the stormwater discharge point(s) which may mobilise contaminated sediments already present in the canal.

However, it is considered unlikely that sediments mobilised as a result of the impact of the new infrastructure would extend a significant distance from the stormwater discharge point. Details of previous investigations indicating that sediments would not be mobilised a significant distance are provided in the Technical working paper: Contamination (**Appendix O**). These investigations suggest that sediment mobilisation is likely to be localised and would be unlikely to result in an increased risk to human health or the environment.

As such, the risk of mobilised sediment migrating to the Cooks River as a result of discharge from stormwater infrastructure constructed for the purposes of the project is considered to be low. In addition, mitigation measures (that would be detailed in the construction environmental management plan) would be installed at the point of discharge to further minimise the potential for sediment disturbance caused by the construction and operation of a new stormwater system. The construction and operation of the additional discharge points would not conflict with the existing Remediation Order.

Interception of contaminated water from the Botany Sand Beds aquifer

The Botany Sand Beds aquifer is a shallow, unconfined aquifer with a high hydraulic conductivity. In many areas it has been contaminated by industrial activities, most notably in the southern portion of the aquifer near the Botany Industrial Park where groundwater use has been embargoed due to contamination. Further details regarding the botany sand beds aquifer is discussed in **Chapter 19** (Groundwater). The proposed treatment of intercepted contaminated groundwater would be managed through a water treatment plan, a wetland system and a polishing tertiary treatment system. Details of this process are provided in **Chapter 16** (Soils and water quality).

17.3.3 Site assessment and remediation

Both the Alexandria Landfill (including Bradshaw Mountain) and 5/5A Canal Road sites would be managed under the NSW site auditor scheme provided in the CLM Act. Additional areas of contamination concern (**Table 17-5**) may be managed under the NSW site auditor scheme as a result of additional intrusive investigations.

The NSW site auditor scheme is in place to increase the certainty that contaminated sites are assessed and/or remediated to an appropriate level. The scheme is administered by the NSW EPA under the CLM Act, including the relevant guidelines published under section 105 of the CLM Act.

NSW accredited auditors are engaged to undertake an independent review of a consultants work, thereby providing an increased certainty to planning authorities about the suitability of a site for a proposed use or the extent and nature of contamination.

An accredited site auditor has been engaged by Roads and Maritime, and a further site auditor would be engaged by the contractor to certify different stages of the management of these sites under the CLM Act. Initial site assessments have been completed for the Alexandria Landfill and the 5/5A Canal Road sites, and a Landfill Closure Management Plan (LCMP) has been prepared for the Alexandria Landfill. The LCMP would be finalised prior to closure and remediation works commencing at the Alexandria Landfill (refer **Section 17.3.4**).

The accredited site auditor engaged by Roads and Maritime would continue to act as an independent reviewer of further investigations undertaken at these sites under the CLM Act.

To ensure they are suitable for use as part of the project, both the Alexandria Landfill and 5/5A Canal Road sites would ultimately be subject to the following process under the CLM Act:

- Remediation of both sites would take place in accordance with separate Remedial Action Plans. Both Remedial Action Plans would first be certified by the accredited site auditor engaged by the proponent, and would also be approved by the NSW EPA
- After remediation works are complete, the Site Auditor engaged by the contractor would prepare a Site Audit Report and a Site Audit Statement for each site. The purpose of these Site Audit Reports and Site Audit Statements would be to demonstrate how, and confirm that, each site is suitable for its intended use in the operation of the project.

Areas of land identified in this chapter and Technical working paper: Contamination (**Appendix O**) as being of potential contamination concern would be further investigated to assess whether the land is suitable for the proposed land use.

If the land is assessed as not suitable, based on the findings, recommendations would be made to undertake one or all of the following:

- Undertake further investigations
- Development of a remedial action plan to make the site suitable for the proposed land use
- Notify the site to the NSW EPA in accordance with section 60 of the CLM Act if required
- Development and implementation of a site management plan to manage risks to future land uses.

17.3.4 Landfill rehabilitation and management

A Phase 2 ESA was prepared for the former Alexandria Landfill (AECOM, 2015e), with works including intrusive site investigations, comprising the drilling of 93 boreholes, 12 groundwater monitoring wells and 13 landfill gas monitoring wells. The Phase 2 ESA found that the Alexandria Landfill site at the time of the Phase 2 ESA investigations did not meet the proposed land use criteria of motorway interchange and open space parkland; however, the site could be made suitable if appropriate remediation and management actions were adopted and implemented. It was recommended that further delineation and monitoring of landfill gases was required and that a Remedial Action Plan and Landfill Closure Plan be prepared for the site.

The LCMP prepared for the former Alexandria Landfill site (**Appendix F**) provides a landfill closure, environmental management and monitoring framework that would be implemented both during and post landfill closure. The LCMP outlines the key landfill closure activities and documents the proposed final landform, capping system, leachate and gas management approach and monitoring protocols to be adopted for the landfill closure process.

The LCMP has been developed in accordance with the requirements of the POEO Act and in consultation with the NSW EPA and the Site Auditor accredited under the CLM Act. Construction and operation of the project would be carried out in accordance with the LCMP once finalised.

The key components of the landfill closure works would include:

- Final landfill cap
- Landfill gas management
- Leachate management
- Groundwater cut-off wall (discussed in **Chapter 19 Groundwater**)
- Landfill monitoring and management requirements.

Landfill cap design

The purpose of the landfill cap is to form a barrier between contaminated material (landfill wastes) and the ground surface in order to limit the potential migration of contaminants. In particular, the landfill cap would:

- Restrict surface water infiltration which would reduce the ability of the landfill to generate leachate
- Reduce the release of landfill gases to the atmosphere; and would also mitigate the release of landfill gases into the atmosphere
- Provide a physical barrier between the landfill waste and potential future site users.

The landfill cap design in the LCMP was developed following discussions with NSW EPA and in consideration of the following guidance documents:

- *Draft Environmental Guidelines Solid Waste Landfills. Second Edition* (EPA, 2015)
- POEO Act 1997. No 156, Section 76. Post-closure requirements for waste facilities or other licensed premises
- *Victoria Closed Landfill Guidelines* (EPA, 2012)
- Existing Environment Protection Licences (EPLs) and trade waste agreement:
  - EPL 4627: Waste disposal by application to land. The licence allows for acceptance of: general solid waste (non-putrescible) (application to land); waste tyres (application to land); asbestos waste (application to land); and any waste below the licensing thresholds in Schedule 1 of the POEO Act
  - EPL 12594: Recovery of general waste and waste storage (other types of waste)
  - Sydney Water (Trade Waste Agreement No. 29304) for the discharge of treated leachate to a sewer discharge point in Albert Street. The existing trade waste agreement would be maintained, and maximum discharge limits may be altered in consultation with Sydney Water to levels appropriate to the amount of treated leachate requiring disposal.

The landfill capping system for the landfill is described in the LCMP (**Appendix F**) and would comprise the following major components:

- A re-vegetation layer with localised thickening to accommodate taller vegetation (if required)
- A subsoil drainage layer
- A low permeability material layer comprising compacted clay and, in some areas, a geosynthetic clay liner
- A compacted earth cover (seal bearing layer)
- A gas collection system located within the waste material substrate.

The capping system will vary across the landfill to suit topography. An indicative cross section of the layers within the capping system is provided in **Figure 17-6**.

The proposed final landform would include areas of batter, which would be cut into landfilled waste and capped. These areas require a modified capping layer, to suit the slope of the batter. The final landfill cap design would be determined during detailed design in line with NSW EPA and the NSW EPA accredited site auditor's requirements.

A construction quality assurance report would be submitted to the NSW EPA, containing the as-constructed final landfill cap details and addressing the construction quality assurance requirements specified in NSW EPA (2015). For further detail refer to the LCMP in **Appendix F**.

Landfill gas management

Landfill gas issues have previously been identified at the Alexandria Landfill as described in **Section 17.2.4.** The landfill gas management system to be introduced as part of the project would manage gas emissions and odours identified in the subsurface. The proposed landfill gas management system is described in the LCMP in **Appendix F** and would comprise:

- A subsurface gas drainage system comprising collection pipes and gas vents
- Vertical active gas extraction wells across the landfill, with flow lines and header lines feeding a gas flare
- A network of subsurface landfill gas monitoring wells to monitor the effectiveness of the mitigation systems.

Details of the landfill gases identified at the Alexandria Landfill are provided in the Technical working paper: Contamination (**Appendix O**) and LCMP (**Appendix F**).

Leachate management

Leachate is generated by the infiltration of water from rainfall and groundwater flow into landfill waste. The management of leachate would be required during the construction of the St Peters interchange to maintain:

- Leachate levels below the level licensed in the Environmental Protection Licences
- Groundwater levels below the finished road level and foundations
- Radial groundwater inflow into the landfill to prevent leachate from migrating from the site and contaminating surrounding groundwater.

In addition, the New M5 westbound ramps and portal, as well as the cut and cover road infrastructure would be below the natural groundwater level. Consequently, a groundwater management system would be installed. Continual leachate pumping and construction of a cut-off wall would maintain groundwater and leachate levels below the St Peters interchange infrastructure design levels.

The existing leachate treatment plant is being upgraded to treat a minimum of 100 kilolitres per day of raw leachate from the site as part of effluent improvement program (upgrades have commenced under existing consents). A new leachate treatment plant (included as part of this project) would replace the upgraded existing treatment plant (with an approximate maximum leachate treatment capacity of 200 kilolitres per day). The existing upgraded leachate treatment plant would continue to operate until the new leachate treatment plant is commissioned.

The key components of the leachate management system include:

- The existing leachate collection system would be upgraded and maintained in the short term
- A new leachate collection system would be provided to collect leachate under the capping layer
- Collected leachate would be pumped to a new leachate treatment plant through a rising main
- Treated leachate would be discharged into the local sewer system under a Sydney Water trade waste agreement
- Stormwater runoff would be collected through a pipe and pit stormwater system into the stormwater pump station, before being pumped to the surface through a rising main and conveyed to a water quality control basin. After treatment, stormwater would be discharged to Alexandra Canal.

Landfill monitoring and management requirements

Landfill monitoring and management requirements would be followed in accordance with the existing Environment Protection Licences and trade waste agreement requirements and is outlined in the LCMP (**Appendix F)**.

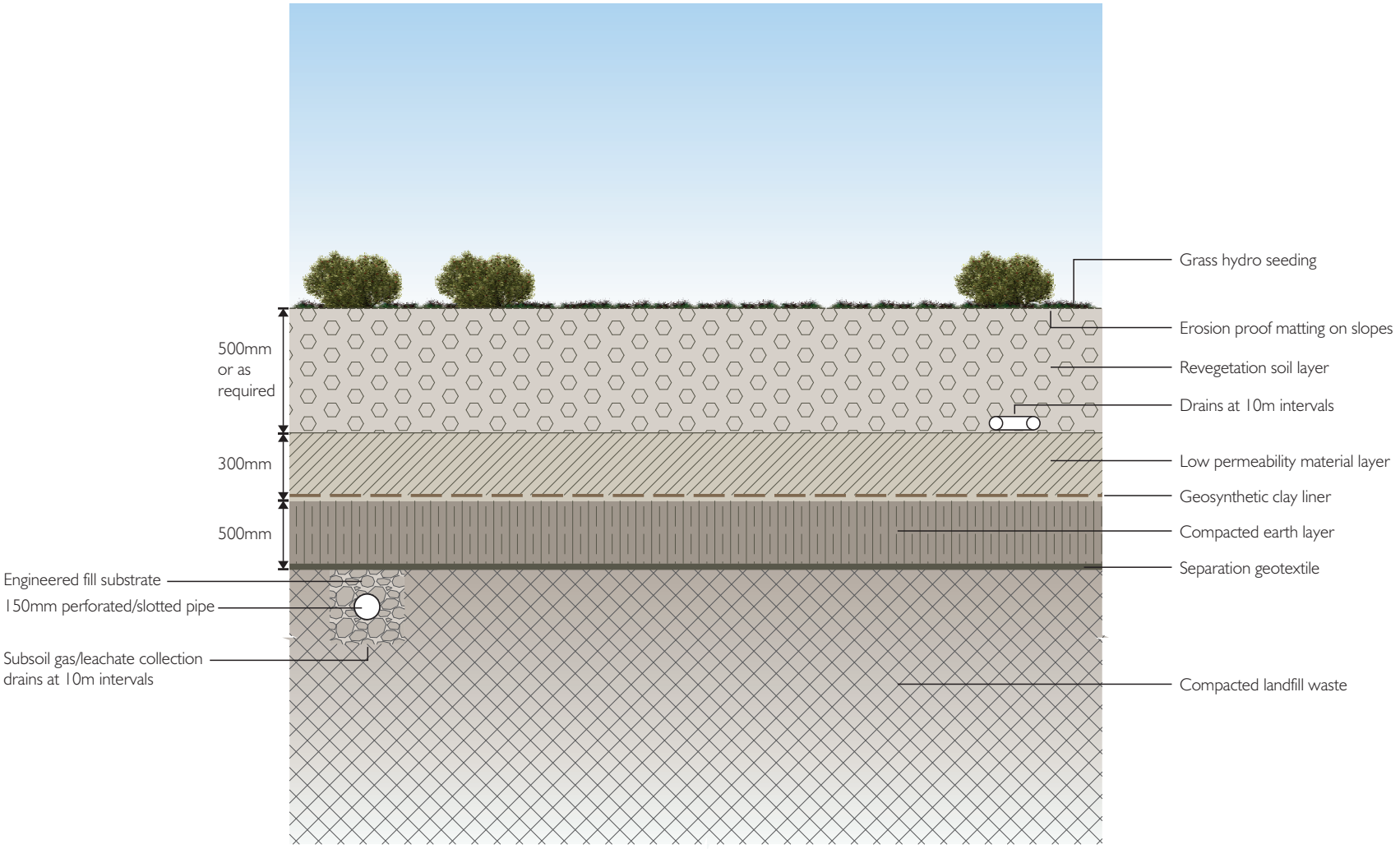


Figure 17-6 Components of capping layer

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17.4 Environmental management measures

Mitigation and management measures provided in **Table 17-7** would be implemented during construction and operation of the project to reduce or eliminate the risks posed by contamination. These measures are expected to make the land to be used as part of the project suitable for the proposed end use.

Potentially contaminated sites identified in **Section 17.2** would be subject to further investigation, remediation and / or management. Monitoring programs for the Alexandria Landfill and other sites identified through further investigations would confirm the effectiveness of the proposed mitigation and management measures.

Table 17-7 Environmental management measures - contamination

Impact	No.	Environmental management measure	Timing
Construction			
Landfill closure	CM01	The closure and ongoing management of the Alexandria Landfill would be undertaken in line with the LCMP (see **Section 17.3.4** and **Section 5.9.1**) and remedial action plan. This includes a landfill closure, environmental management and monitoring framework.	Pre-construction and construction
Landfill closure	CM02	A site specific management plan would be prepared for the Alexandria Landfill to manage the excavation of parts of the landfill during construction. The management plans, amongst other requirements would detail mitigation measures to: • Contain and treat landfill gas emissions from excavations • Treat offensive odours produced by leachate and landfill gas • Contain, extract and treat leachate within excavations • Protect workers and off-site receptors from exposure to potential biological, chemical and physical hazards encountered during the exhumation of landfill waste. • Manage asbestos contaminated wastes	Pre-construction
Disturbance and mobilisation of contaminated material	CM03	Potentially contaminated areas directly affected by the project would be investigated and managed in accordance with the requirements of guidance endorsed under section 105 of the CLM Act. This includes further investigations in areas of potential contamination identified in the construction footprint.	Pre-construction
General	CM04	An unexpected finds and hazardous materials procedure would be implemented to manage any potentially contaminated materials that may be encountered during site preparation and / or construction works.	Pre-construction

Impact	No.	Environmental management measure	Timing
General	CM05	Waste management plans, as part of the Construction Environmental Management Plan, would include procedures for handling and storing potentially contaminated spoil and undertaking waste assessment and classification for off-site disposal to appropriately licenced waste facilities. See **Chapter 24** (Resource use and waste minimisation) for more information.	Pre-construction
Asbestos	CM06	Site specific asbestos management plans would be developed where relevant. Refer to **Chapter 24** (Resource use and waste minimisation) for further information on asbestos management.	Pre-construction
Hazardous materials	CM07	A hazardous materials assessment would be carried out prior to and during the demolition of buildings. Demolition works would be undertaken in accordance with the relevant Australian Standards and relevant NSW WorkCover Codes of Practice, including the *Work Health and Safety Regulation 2011.*	Pre-construction, construction
Dangerous goods	CM08	A dangerous goods search of the WorkCover NSW records for licenced dangerous good would be undertaken prior to construction.	Pre-construction
Explosive ordnance	CM09	An explosive ordnance due diligence assessment would be completed at the identified former ammunition site (Project area 3), located between Flatrock Road, Bexley Road and Wolli Creek.	Pre-construction
General	CM10	In the event of encountering unexpected finds of contamination (i.e. the observation of offensive odours, soil discoloration, buried waste or potential asbestos containing materials) during construction, work in the area would cease until an appropriately qualified environmental consultant can advise on the need for further assessment, remediation or other action, as deemed appropriate. Further assessment and management of contamination, if required, would be undertaken in accordance with section 105 of the CLM Act.	Construction
Contamination	CM11	Appropriate mitigation measures to minimise sediment mobilisation as a result of construction activities at the location of the new stormwater infrastructure at Alexandra Canal would be detailed in the Construction Environmental Management Plan in accordance with the requirements of the Remediation Order in consultation with NSW EPA and Sydney Water.	Pre-construction and construction
Contamination	CM12	Appropriate mitigation measures including stockpiling and management of potentially contaminated material would be undertaken at construction compounds to prevent movement of material into receiving waters.	Construction

Impact	No.	Environmental management measure	Timing
General	CM13	Plant, equipment and supplies would be managed to prevent spills and leaks. See **Chapter 26** (Hazard and risk) for more information.	Construction
General	CM14	Tunnel washing water and waste would be appropriately contained, treated and disposed of. Refer to **Chapter 24** (Resource use and waste minimisation) for more information.	Construction
Contamination	CM15	Further *in situ* testing of soils in areas of known potential contamination to determine waste classification.	Construction
Operation			
General	OpCM1	The ongoing management of the Alexandria Landfill will be undertaken in line with the LCMP (see **Section 17.3.4** and **Section 5.9.1**)	Pre-construction, construction and post construction
Contamination	OpCM2	Procedures to address spills, leaks and tunnel washing would be developed and implemented during operation of the project	Operation
Scour protection	OpCM3	Measures to minimise sediment mobilisation during operation would be incorporated into the design of stormwater outlets at the location of the new stormwater infrastructure at Alexandra Canal. The design of the outlets, including discharge velocities and scour protection measures, would be confirmed during detailed design and supported by appropriate drainage modelling. The detailed design of the outlets would be provided to Sydney Water and NSW EPA for approval in accordance with the requirements of the Remediation Order.	Detailed design

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18 Flooding and drainage

This chapter assesses flooding and drainage impacts associated with the project. The assessment includes:

- The identification of existing flood behaviour and drainage infrastructure
- Assessment of the potential impacts of the project on flooding during construction and operation
- Identification of appropriate management and safeguard measures to minimise and manage flooding impacts.

This chapter has been informed by:

- Technical working paper: Surface water (**Appendix N**)
- Technical working paper: Flooding (**Appendix P**).

Table 18-1 sets out the Secretary's Environmental Assessment Requirements (SEARS) as they relate to flooding and drainage, and where in the environmental impact statement (EIS) these have been addressed.

Table 18-1 SEARS – flooding and drainage

SEARs	Where addressed
Identification of potential impacts of the proposal on existing flood regimes, consistent with the *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources, 2005), including impacts to existing receivers and infrastructure and the future flood mitigation options for and development potential of affected land, demonstrating consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the proposal. The assessment must demonstrate due consideration of flood risks during construction and in the proposal design.	An assessment of the potential impacts of the project on flooding is provided in **Section 18.3**. Consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the project is presented in **Chapter 25** (Climate change and risk adaptation).

18.1 Assessment methodology

18.1.1 Policy and planning setting

The assessment of potential flooding impacts of the project on existing flood regimes has been conducted in line with the requirements of the *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources, 2005), which incorporates the NSW Government's Flood Prone Land Policy. The key objectives of this policy are to identify potential hazards and risks, reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods. This policy also recognises the benefits of the use, occupation and development of flood prone land.

Other relevant government policies and guidelines were considered as part of the assessment of the project's potential flooding impacts. These are outlined in Technical working paper: Flooding (**Appendix P**).

In addition, the Local Environment Plans and Development Control Plans for the Local Government Areas of Canterbury, Hurstville, Rockdale, Marrickville, Sydney and Botany Bay were considered in terms of relevant floodplain planning provisions. The *Sydney Regional Environmental Plan No 33 – Cooks Cove* was also considered in relation to the potential flooding impacts in the area surrounding the Kogarah Golf Course in the suburb of Arncliffe (refer to Technical working paper: Flooding in **Appendix P** for further details).

18.1.2 Flooding impact assessments

Flooding impact assessments have been undertaken for localised and mainstream flooding for construction and operation of the project. Localised flooding occurs when components of the drainage system are undersized or blocked and cannot accommodate the incoming overland surface flows, resulting in the flooding of a localised area. Mainstream flooding refers to the flooding of land when water overflows the natural or artificial banks of a water body.

The flooding impact assessment included:

- Identification of the flooding assessment study area. The relevant study area for flooding impacts includes:
  - The upper Wolli Creek extent. This area is located within the Upper Wolli Creek Floodplain and between King Georges Road, Kingsgrove in the west, Illoura Park, Earlwood in the east, Poole Street, Kingsgrove in the north and the East Hills railway line, Beverly Hills to the south. This section of the study area, including its existing flooding behaviour, is shown on **Figure 18-1**
  - The lower Cooks River and Alexandra Canal extent. This area is located within the Lower Cooks River Floodplain and between Banksia in the south west and Wolli Creek to the north-west, and to just west of Sydney Airport in the east, for the Cooks River extent. For the Alexandra Canal extent, the study area includes the area from Mascot in the south to just north of Sydney Park Road, between St Peters and Alexandria from west to east. These sections of the study area, including existing flooding behaviour, is shown on **Figure 18-2** and **Figure 18-3** respectively
- A qualitative assessment of flooding during construction, using the existing flood behaviour and drainage infrastructure, for:
  - Localised flooding impacts relevant to the surface works, construction compounds and other structures such as noise barriers
  - Mainstream flooding impacts on the construction process and an assessment of the potential for construction activities to impact mainstream flooding behaviour and adversely affect inundation patterns for nearby properties
- A qualitative assessment of flooding during operation for localised flooding. The impacts of the project on localised flooding and drainage during operation of the project were made based on the connection of new and upgraded drainage systems to existing local drainage networks. Details of the existing networks were sought from the various authorities that own and maintain these networks, typically local councils and Sydney Water, and where available historical information about existing localised flooding issues were gathered
- A quantitative assessment of the potential mainstream flooding impacts during operation in upper Wolli Creek, lower Cooks River and Alexandra Canal.

The assessment methodology for the quantitative flooding assessment included:

- Development of a flood model and characterisation of the existing flood behaviour and drainage infrastructure within the flooding assessment study area. The frequency with which a flood event of a certain size occurs is generally described in terms of its average recurrence interval (ARI). For example, for a flood having a 20 year ARI, there would be floods of equal or greater magnitude once in 20 years on average. Flooding behaviour in the flooding assessment study area was defined for the 20 year ARI flood, 100 year ARI flood and probable maximum flood (PMF). The PMF is the largest flood that could conceivably occur at a particular location. The PMF is defined as the upper limiting value of floods that could reasonably be expected to occur. The 200 year ARI flood was also modelled and is contained in the Technical working paper: Flooding (**Appendix P**). The following flood models were used in the assessment:
  - RAFTS and DRAINS rainfall-runoff modelling software packages were used to generate design discharge hydrographs for input into the hydraulic models

  - TUFLOW two-dimensional (in plan) hydraulic modelling software was used to define flooding patterns in the study area. The structure of the upper Wolli Creek and lower Cooks River TUFLOW models was adjusted to incorporate details of the project
  - HEC-RAS hydraulic modelling software was used to define the upper envelope of flooding in the vicinity of Bexley Road in the upper Wolli Creek floodplain
- Assessment of the impacts that the operation of the project would have on flooding behaviour during the 20 year ARI flood, 100 year ARI flood and PMF. The future development potential of flood affected land outside the project corridor for residential (and by default commercial and industrial type development) and critical / vulnerable infrastructure was also considered
- Assessment of the impacts of flooding on the project during the 20 year ARI flood, 100 year ARI flood and PMF
- Assessment of the impacts a particle blockage (ie the accumulation of debris) of major hydraulic structures would have on flooding behaviour during operation of the project
- Assessment of the impact future climate change would have on flooding behaviour during operation of the project
- Identification of appropriate management and safeguard measures to minimise and manage flooding impacts.

The 20 year ARI flood and 100 year ARI flood were targeted in the flooding assessment because the:

- 20 year ARI flood provides a frequent flood event
- 20 year ARI flood is relevant to construction due to the duration and temporary nature of the construction works. The likelihood of a 100 year ARI event or a PMF occurring during the construction of the project is low
- 100 year ARI flood is considered the standard flooding planning level during operation. The *Floodplain Development Manual* requires land use planning to consider the 100 year ARI flood for residential development (and by default commercial and industrial type development).

Further details of the assessment of localised flooding impacts during construction and operation, and mainstream flooding impacts during construction are presented in the Technical working paper: Surface water (**Appendix N**). The assessment of mainstream flooding impacts during operation is presented in Technical working paper: Flooding (**Appendix P**).

18.2 Existing environment

A general description of the geomorphology and water quality of the existing catchment and watercourse environments is provided in **Chapter 16** (Soils and water quality). This section outlines:

- Existing drainage infrastructure and surface water management infrastructure of the flooding assessment study area
- The existing flood behaviour of the flooding assessment study area.

18.2.1 Existing drainage infrastructure

The components of the project would include western surface works, Bexley surface works, Arncliffe surface works and St Peters interchange and local road upgrade surface works areas. Within these areas surface water is currently conveyed as overland flow and is collected in established stormwater networks by a combination of stormwater infrastructure elements. These include lined and unlined drainage channels, kerb and gutter networks, and dish drains, all feeding into a well-developed subsurface pit and pipe network. Drainage infrastructure in the area is owned and operated by local councils and Sydney Water.

The existing systems were designed to accommodate the ten year ARI rainfall event, but more likely exceed capacity at around the five year ARI rainfall event. Local flooding usually occurs once the design capacity is exceeded in limited overland flow paths, and where limited downstream inlet capacity exists, resulting in rising water levels.

Table 18-2 summarises key aspects of the existing drainage systems of the sub-catchments relevant to the project.

Table 18-2 Existing drainage systems

Catchment	Project area	Existing drainage systems
Wolli Creek sub-catchment	Western surface works, Kingsgrove Road surface works and Bexley Road surface works	The upper Wolli Creek catchment is completely urbanised with a drainage system comprising of extensive pit and pipe networks. Runoff from the western surface works area and Bexley Road surface works area is conveyed as overland flow that currently flows into the M5 East Motorway drainage system. There is an open channel section of Wolli Creek between Kingsgrove Road and Bexley Road, as well as transverse drainage lines which convey runoff into Wolli Creek from areas north of the M5 East Motorway. The transverse drainage system was designed to convey flows up to the 100 year ARI flood magnitude. Several underpasses were also provided between King Georges Road, Bexley Road, and Kingsgrove Road provide additional capacity to convey flows greater than the 100 year ARI flood.
Cooks River catchment	Arncliffe surface works	The Cooks River catchment is highly urbanised, with extensive subsurface pit and pipe networks. The Arncliffe surface works would be located on the Kogarah Golf Course and would drain directly to the Cooks River.
Alexandra Canal sub-catchment	St Peters interchange and local roads upgrade	Alexandra Canal is a constructed canal, which flows into the Cooks River near the north-western corner of Sydney Airport. The canal is owned and operated by Sydney Water as are the major trunk drainage lines discharging into it. Numerous minor drains in the Alexandra Canal sub-catchment are managed by Sydney, Marrickville and Botany Bay Councils. Three channels discharge into Alexandra Canal: Munni Street Stormwater Channel, Sheas Creek Channel and the Botany Road to Doody Street Channel.

Catchment	Project area	Existing drainage systems
Eastern Channel sub-catchment	St Peters interchange and local roads upgrade	Stormwater runoff is presently generated by a significant catchment along Campbell Road, as far east as the Princess Highway and drains towards the intersection of Campbell Street / May Street / Bedwin Road / Unwins Bridge Road. An existing piped drainage system at the intersection directs runoff into a pipe, then a box culvert that crosses the adjacent railway line before connecting into the Eastern Channel. In larger storm events, stormwater ponds at the intersection before surcharging into an existing detention basin located at the western end of Camdenville Park. The existing basin cannot drain via gravity, and is dewatered by two pumps that direct stormwater into the above-mentioned box culvert. The intersection of Campbell Street / May Street / Bedwin Road / Unwins Bridge Road is frequently flooded as a result of both limited local inlet capacity in the piped drainage network, as well as limited hydraulic capacity in the downstream trunk drainage system.

18.2.2 Existing flood behaviour

Development within the study area is typically well established with a high proportion of residential and commercial land use. Land within the surface water study area is also predominantly of an urbanised nature with small pockets of open space, notably along some of the watercourses. Flood risk in the study area has increased since the onset of urbanisation, leading to catchments with a high percentage of impermeable land causing increased runoff during rainfall events. In addition, concrete drainage lines, relatively low levels of infiltration and reduced flood storage capacity within the catchments also results in a quick response to rainfall events. This is particularly significant in small, frequent storm events and results in high peak flows which can cause flooding in parts of the study area.

Localised flooding may occur within the area during high intensity rainfall events. It is anticipated that these localised flooding events would be of short duration and would have limited impacts to surrounding receptors and infrastructure. The potential for localised flooding is currently managed through the existing drainage and surface water management infrastructure as described above.

As presented in **Section 18.1**, the quantitative assessment focused on the Lower Cooks River floodplain and Upper Wolli Creek floodplain. The existing flood behaviour for these areas for the 20 and 100 year ARI flood is presented on **Figure 18-1** and **Figure 18-2** respectively, and discussed in the following sections.

A detailed assessment of the Eastern Channel was not undertaken as there would be no major structures constructed in its catchment. The mainline alignment tunnels have not been modelled as flooding impacts would not be expected as a result of subsurface works. The quantitative assessment is described in further detail below.

Upper Wolli Creek floodplain

Flooding patterns along Wolli Creek and within the flooding assessment study area were assessed for design floods of 20, 100 and 200 year ARI flood, as well as the PMF.

The areas around the western surface works that would be inundated as a result of a 20 year ARI flood are shown on **Figure 18-1** and include:

- The section of Wolli Creek running along the southern side of the M5 East Motorway, at Kirrang Street. Floodwater surging the channel at this location flows in an easterly direction, where it does not fully re-enter the channel system until it reaches the Kindilan Street underpass
- Residential property at 78 Tallawalla Street, on the southern side of the M5 East Motorway, between Kooemba Road and the Kindilan Street underpass. Property fencing would cause increased inundation, resulting in flows diverting into Tallawalla Street
- Commercial and industrial development located between Beverly Grove Park and Kingsgrove Road, which would be inundated as a result of floodwater surcharging from the southern arm of Wolli Creek. Inundation depths at several properties would exceed one metre.

The areas around the western surface works and Bexley Road surface works that would be inundated as a result of a 100 year ARI flood are shown on **Figure 18-1** and include:

- The northern side of the M5 East Motorway, within the Canterbury Golf Course, and from downstream of Beverly Grove Park to east of Arinya Street
- The southern side of the M5 East Motorway, within properties along the northern side of Tallawalla Street, between Kooemba Road and the Kindilan Street underpass
- Within the Kindilan Street underpass. Floodwater surcharging the main arm of Wolli Creek at Kingsgrove Road discharges in a northerly direction where it initially ponds beneath the M5 East Motorway underpass before discharging in an easterly direction along the northern side of the elevated M5 East Motorway
- The commercial and industrial development located between Beverly Grove Park and Kingsgrove Road, and extending along the northern side of Commercial Road, which would be inundated as a result of floodwater surcharging the from the southern arm of Wolli Creek. Inundation depths at several properties would exceed one metre.

The areas around the western surface works and Bexley Road surface works that would be inundated as a result of a PMF are:

- Areas along the northern side of the M5 East Motorway in the vicinity of Canterbury Golf Course, and to the east and west of Kingsgrove Road, which would experience major ponding of floodwaters during a PMF event
- Properties adjacent to the Wolli Creek canal between King Georges Road and Bexley Road, with major ponding extending along the southern side of the M5 East Motorway between Kooemba Road and Bexley Road.

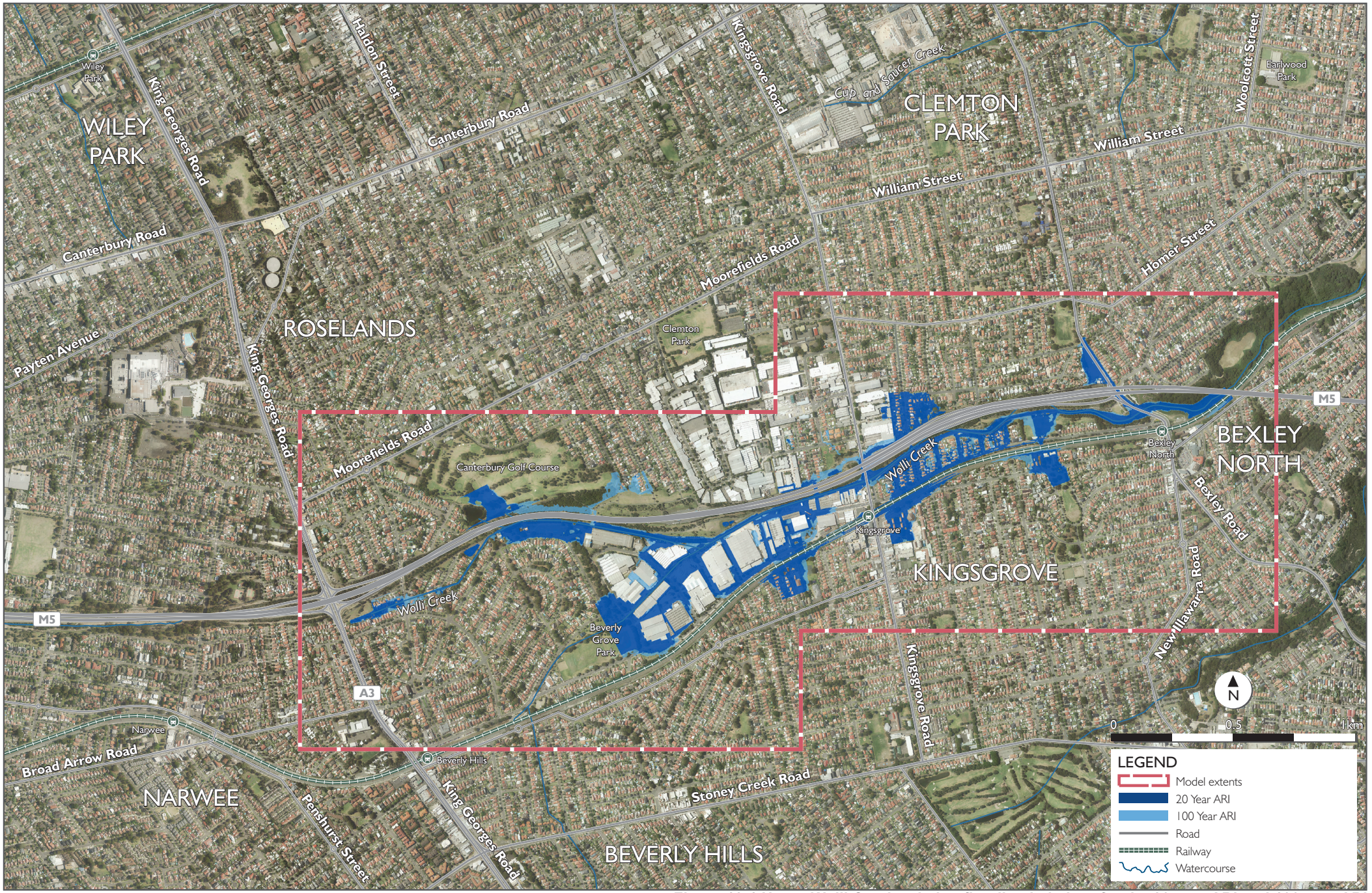


Figure 18-1 Upper Wolli Creek existing flooding behviour for the 20 year ARI and 100 year ARI

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Lower Cooks River floodplain

The present day flooding patterns along within the Lower Cooks River floodplain within the flooding assessment study area were assessed for design floods of 20, 100 and 200 year ARI, as well as the PMF.

The areas within the Lower Cooks River floodplain that would be inundated as a result of a 20 year ARI flood are shown in **Figure 18-2** and include:

- Cahill Park, on the eastern bank of the Cooks River, and adjacent properties
- Gough Whitlam Park and Mackey Park, to the north of the confluence between Wolli Creek and the Cooks River
- Kogarah Golf Course
- Barton Park South
- Lance Studdert Reserve
- Properties around Lynwen Crescent, Banksia, and northwards towards Spring Street, Banksia
- Properties along William Street, Rockdale.

During a 100 year ARI flood, the magnitude of flooding at the areas inundated during the 20 year ARI flood would increase, with additional flooding occurring in some adjacent areas. In the case of the PMF event, the Kogarah Golf Course would be inundated to depths exceeding two metres, with the peak flood level along its common boundary with Marsh Street reaching about 4.4 metres AHD.

Alexandra Canal flood extent

The present day flooding patterns along Alexandra Canal were assessed for design floods of 20, 100 and 200 year ARI flood, as well as the PMF.

The areas along Alexandra Canal that would be inundated as a result of a 20 year ARI flood are shown in **Figure 18-3** and include:

- Industrial areas south of Huntley Road, immediately upstream of where Sheas Creek becomes Alexandra Canal
- Industrial areas upstream of Campbell Road, St Peters
- Industrial areas along the western extent of Coward Street, and between Coward Street, Mascot and Alexandra Canal
- Downstream of the railway line, between Alexandra Canal and Swamp Road.

During the 100 year ARI flood, the main areas of additional flooding occur within Sydney Airport, and eastwards along Coward Street and Ricketty Street, Mascot. The PMF would cause flooding along the length of Alexandra Canal, extending beyond Kent Street, Mascot and up to the Princes Highway, St Peters. The PMF would also cause flooding within the Alexandria Landfill site.

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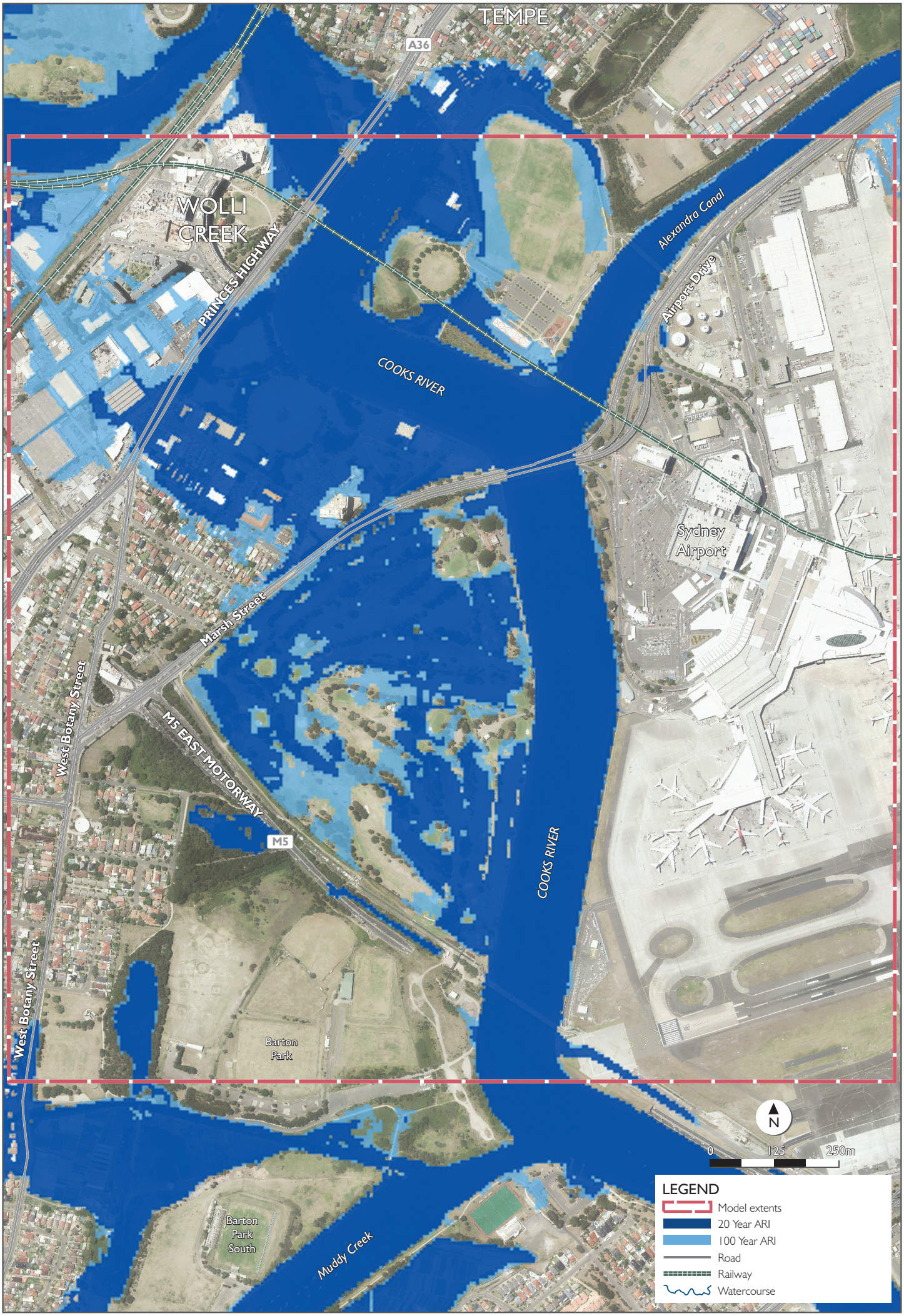


Figure 18-2 Lower Cooks River existing flooding behaviour for the 20 year ARI and 100 year ARI

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Figure 18-3 Alexandra Canal existing flooding behaviour for the 20 year ARI and 100 year ARI

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18.3 Assessment of potential impacts

Construction works and operational infrastructure have the potential to change flood behaviour and impact on the surrounding environment. In addition, flooding has the potential to impact on areas within and near construction sites and operational facilities (ie potential inundation of project sites).

An assessment of the flood risks to the project and the surrounding environment, along with development of appropriate mitigation measures, has been carried out in accordance with the Floodplain Development Manual (Department of Infrastructure, Planning and Natural Resources, 2005), the requirements of relevant environmental approvals and industry guidelines.

18.3.1 Construction

During construction, flooding and drainage impacts could result in localised and mainstream flooding. The potential impacts are considered further below.

Localised flooding

All construction works and facilities would have the potential to impact local overland flows and existing minor drainage paths through the disruption of existing flow mechanisms, both of constructed drainage systems or those of overland flow paths. Additionally, flooding during construction of the project could impact areas within and near construction sites (potential inundation of construction sites).

Existing drainage and surface water management infrastructure is identified in **Table 18-2**.

Potential localised flood-related impacts during the construction phase of the project include:

- Interruption of overland flow paths by installation of temporary construction ancillary facilities
- Blocking of drainage networks through increased sedimentation of surface water
- Damage to construction plant or machinery caused by inundation from flood waters
- Increased flooding of adjacent areas due to temporary loss of floodplain storage or conveyance of floodwaters
- Disruption to existing drainage lines during decommissioning, upgrade or replacement of drainage pits and pipes, resulting in localised flooding upstream
- An increase in runoff volumes, peak flows and/or time of concentration following rainfall events due to an increase in impermeable surfaces (ie construction compounds)
- Flow of water into the tunnel construction access points
- Localised areas of flooding and scour from the diversion of drainage lines
- The interruption or diversion of existing flood routes from the location of bunding or spoil within construction compound, resulting in a reduction of flood storage and an increased flood risk to adjacent areas
- Diversion of flow away from designed drainage structures and into new receiving areas, through the removal of existing pavement
- Increased flow rates and volumes in watercourses due to the discharge of treated water from the construction water treatment plants.

These potential impacts would be relatively minor and would be effectively managed through the implementation of mitigation and management measures, as detailed in **Section 18.4**. Further, the potential impacts would be considered during the detailed design phase to ensure that appropriate flood management and flood protection measures are included in the design of the project. For further information refer to Section 6.2.2 of the Technical working paper: Surface water (**Appendix N**).

Expected changes to flow rates and volumes would be managed through the control of discharge flow rates from the construction water treatment plants and standard construction management measures. Erosion and sediment controls would direct water away from the tunnel construction access points. Despite this, there remains a low potential for water to flow into the tunnel during high rainfall events.

During construction planning, an emergency response plan would be developed including the evacuation of the tunnel of construction personnel based on certain heavy rainfall events.

Mainstream flooding

The potential for mainstream flooding to affect the construction process has been assessed, as well as the potential for construction activities to impact flooding behaviour at any nearby properties.

Details of potential flooding impacts to construction compounds are provided in **Table 18-3**. Potential construction flooding impacts of a 20 year ARI flood have been assessed and are considered appropriate due to the duration of the construction works. The likelihood of a 100 year ARI flood or a PMF occurring during the construction of the project is low, and design of flood mitigation and management measures for these events during construction would not been reasonable.

Potential mainstream flooding impacts are generally minor in nature and readily mitigated by managing specific detailed design aspects of the construction compound and site planning to better suit identified flooding conditions and avoid the potential for off-site flooding impacts. Mitigation measures that would be employed are outlined in **Section 18.4**.

Potential flooding during tunnelling excavation

Tunnel boring and cut and cover excavation would occur through temporary shafts at a number of construction compounds and the tunnel portals. Ingress of floodwater into the shafts or portals would pose significant risk to personal safety to those working in the tunnel. Tunnelling excavation works would occur at the following compounds:

- Kingsgrove North construction compound (C1)
- Commercial Road construction compound (C3)
- Bexley Road North construction compound (C4)
- Bexley Road South construction compound (C5)
- Arncliffe construction compound (C7)
- Canal Road construction compound (C8).

Protection such as bunding would be provided to ensure floodwaters do not enter shafts or portals. A detailed risk assessment would be undertaken to inform the flood protection measures put in place, prior to construction. The flood immunity that would be adopted would take into consideration the duration of construction, magnitude of inflows, including local overland flows, and potential risks. The flood mitigation measures adopted to protect shafts and portals would be designed in a way that would not worsen flooding on adjacent property.

Flood management plans would be developed as part of the Construction Environmental Management Plan (CEMP) prior to construction to guide the design of compounds so as to minimise impacts of flooding.

Table 18-3 Potential construction flooding impacts

Project component	Existing flooding conditions	Potential impacts of activities for 20 year ARI event
Western surface works		
Kingsgrove North construction compound (C1)	The construction compound would be located outside of the 20 year ARI flood extent but partially within the 100 year ARI flood extent. The 100 year ARI flood extent would be predominantly confined to the construction compound car park and laydown area. The tunnel dive shaft would be located outside of the 20 year ARI flood, 100 year ARI flood and PMF extents.	None anticipated as the site would only be partially within the 100 year ARI flood extent.
Kingsgrove South construction compound (C2)	The construction compound would be located marginally within the 20 year and 100 year ARI flood extents along areas of the construction compound bordering Wolli Creek. Due to the local topography, the 20 and 100 year ARI flood extents within the compound boundaries are similar.	None anticipated as the 20 year ARI flood extent would not extend into the construction compound beyond inundating the fence/ boundary.
Commercial Road construction compound (C3)	The construction compound would be located completely within the 20 year ARI flood, 100 year ARI flood and PMF extent (including tunnel dive shaft).	All activities would be impacted by a 20 year ARI flood event. The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. Temporary compensatory drainage works would be implemented to minimise impacts adjacent to existing development as far as practicable.
Bexley Road surface works		
Bexley Road North construction compound (C4)	The construction compound would be located completely within the 20 year and 100 year ARI flood extents.	All activities would be impacted by a 20 year ARI flood event. The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. However these impacts are unlikely to impact existing development.

Project component	Existing flooding conditions	Potential impacts of activities for 20 year ARI event
Bexley Road South construction compound (C5)	The construction compound would be located partially within the 20 year and 100 year ARI flood extents. The boundaries of the 20 year and 100 year ARI flood extents are similar at this location. The compound (including tunnel dive shafts) would be located within the PMF flood extent.	The acoustic shed and flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. However these impacts are unlikely to impact existing development.
Bexley Road East construction compound (C6)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood.
Arncliffe surface works		
Arncliffe construction compound (C7)	The construction compound would be located predominantly within the 20 year and 100 year ARI flood extents.	The majority of activities would be impacted by flooding although the stockpile and acoustic shed are outside of 20 year ARI. Flood protection measures to protect against ingress of floodwaters into the compound would have the potential to impact flood conveyance and/or storage. Design of these measures will give consideration to minimising adverse flooding impacts adjacent to existing development north of Marsh Street as far as practicable.
St Peters interchange and local roads upgrade		
Canal Road construction compound (C8)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Campbell Road construction compound (C9)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Landfill Closure construction compound (C10)	The construction compound would be located completely outside of the PMF flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Burrows Road construction compound (C11)	The construction compound would be located completely outside of the 100 year ARI flood extent.	None anticipated due to its location outside of the 100 year ARI flood extent.
Alexandra Bridge construction compound (C12)	The construction compound would be located partially within the 20 year ARI flood extent and completely within the 100 year ARI flood extent.	Potential minor impacts to activities on the immediate banks of Canal. No measureable impact on flood storage or conveyance anticipated during a flood event.

Project component	Existing flooding conditions	Potential impacts of activities for 20 year ARI event
Gardeners Bridge construction compound (C13)	The construction compound would be only marginally affected by the 20 year ARI flood extent. It would be partially within 100 year ARI flood extent.	None anticipated as the site would be only marginally within the 20 year ARI and 100 year ARI flood extent.
Sydney Park construction compound (C14)	The construction compound would be located completely above the PMF flood extent.	None anticipated as the site would be outside of the PMF extent.

18.3.2 Operation

During operation, flooding and drainage impacts could include the following:

- Impacts from the operational water treatment plant
- Localised flooding
- Mainstream flooding.

The main objective for the drainage design of the project is to provide the required flood immunity for the project and to minimise changes to the existing flood behaviour of land around operational infrastructure.

Operational water treatment plant

As the project tunnels would be drained, there would be ongoing groundwater inflow into the tunnels (refer to **Chapter 19** Groundwater). This would require the ongoing capture, treatment and discharge of groundwater during the operation of the project. Other sources of wastewater within the project tunnels would include stormwater entering the tunnels via the portals, deluge water, washdown water and hydrant water. The discharge of treated water from the operational water treatment plant has the potential to increase flow rates and volumes in watercourses.

Details of the operational water treatment plant are provided in **Chapter 16** (Soils and water quality) and **Chapter 24** (Construction resource use and waste minimisation).

The tunnel drainage system would flow to one sump at the tunnel low point, with a capacity of around 412 cubic metres before being pumped to the operational water treatment plant. The capacity of the sump has been designed to include 50 cubic metres (50,000 litres) of 'spare' capacity to capture accidental operational hydrocarbon or other spillage within the tunnel (for example, in the case of an accident resulting in release of fuel from vehicles). Groundwater leakage from the tunnel walls and floors would also be transferred to the tunnel sump. After being pumped to the operational water treatment plant, the water would be treated and discharged to the Cooks River. The discharge flow rate would be controlled to manage changes to flow rates and volumes.

Localised flooding and proposed drainage infrastructure

Potential localised flood-related impacts during operation include:

- Blockage or temporary diversions of drainage infrastructure, which may result in localised flooding
- Altered catchments from new and widened roads
- New and altered drainage infrastructure, which may not have sufficient capacity to accommodate increased inflow rates.

Existing drainage and surface water management infrastructure as identified in **Table 18-2** would continue to manage surface drainage and potential flooding. Additional upgrades would be carried out where parts of the drainage infrastructure would be impacted by the project and/ or would require relocation.

The drainage structures incorporated into the project would include existing drainage infrastructure around the interchanges, tie-in and integration works, and operational ancillary facilities which would be augmented to meet additional capacity requirements associated with increased impervious areas. Appropriate protection would be provided downstream of relevant drainage infrastructure to prevent adverse impacts on bed and bank stability, and to protect the existing water quality of downstream watercourses. These drainage systems would be designed and implemented to minimise potential impacts on receiving watercourse.

Table 18-4 provides an overview of the proposed drainage systems as part of the project.

Table 18-4 Project drainage systems

Project area	Project component	Proposed drainage upgrades
Western surface works and Bexley Road surface works	Western portals, tolling infrastructure, Kingsgrove and Bexley Road motorway operations complexes (MOC1 and MOC2)	New and / or upgraded drainage infrastructure to be provided as part of the western surface works and Bexley Road surface works includes: • New operational drainage infrastructure connecting existing stormwater infrastructure to a concrete channel at Kirrang Street • A new basin to capture and treat runoff, including one within the western surface works area, one at the surface near the southern extension caverns and one near the corner of Burrows Road and Campbell Road • New and upgraded culverts, including: – A new box culvert to connect existing stormwater pipes to a concrete channel at Kirrang Street, Beverly Hills (near the western end of the western surface works areas) underneath the existing shared pedestrian and cycle path – Extension of the two existing culverts at Kooemba Road, Beverly Hills (near the western end of the western surface works areas), by around 30 metres to accommodate the widening of the motorway at this point.
Arncliffe surface works	Arncliffe motorway operations complex (MOC3)	New and / or upgraded drainage infrastructure as part of the Arncliffe surface works would be confirmed during detailed design. New pipe connections would be installed where the existing transverse drainage requires upgrade and/ or relocation. This would include new and upgraded trunk and transverse drainage infrastructure upgrades. A new basin would also be established to capture and treat runoff at the surface near the southern extension caverns. Pavement drainage would be designed for the 10 year ARI flood, with pits spaced to limit flow width to shoulders where provided or one metre into the adjoining traffic lane where no shoulder is provided. The project would discharge into the existing Wolli Creek concrete lined channel via transverse drainage upgrades.
St Peters interchange	St Peters and Bedwin motorway operation complexes (MOC4 and MOC5)	New and / or upgraded drainage infrastructure to be provided as part of the St Peters interchange works includes: • A new basin to capture and treat runoff near the corner of Burrows Road and Campbell Road • Two water quality basins within the St Peters interchange to capture, store and treat surface water runoff • Upgrades to the existing detention basin in Camdenville Park to ensure downstream peak flow rates are not increased for events up to and including 100 year ARI flood. The required increase

Project area	Project component	Proposed drainage upgrades
		in storage capacity would be confirmed during detailed design • Installation of new hydrodynamic oil and grit separators within the western surface works area, St Peters interchange and local road upgrade surface works area to capture and treat surface water runoff at locations where construction of a surface water basin is impractical and/ or due to site location constraints restricting the construction of a basin • Upgrades to the existing drainage infrastructure that serves local surface roads (within the St Peters interchange and local road upgrade surface works areas), including connection to the existing piped drainage network and/ or provision of a new drainage discharge point at Alexandra Canal.
Local roads upgrades	Local road upgrades affected by flooding	New pipe connections would be installed where the existing transverse drainage requires upgrade and / or relocation. The upgrades and replacements of drainage infrastructure would respond to altered and increased catchments attributed to newly paved areas. Due to the urbanised nature and relatively flat topography of the area, the majority of new pipes would connect into existing networks prior to discharging as surface water. The intersection of Campbell Road and Burrows Road has been identified as having the potential to flood relatively frequently. A culvert would be constructed under Burrows Road to the south of Campbell Road to convey flows to Alexandra Canal. This would be in addition to other smaller transverse drainage pipes. The Munni Street Stormwater Channel would be crossed by a widened bridge structure to allow for the widening of Euston Road. The detailed design of the bridge and roadworks would give consideration to minimising flooding impacts on adjacent property whilst achieving the geometric design requirements for the road. This would be informed by flood analysis with the benefit of detailed survey information relating to existing stormwater infrastructure, ground levels and existing development. The project would include two new discharge outlets into Alexandra Canal: • An open channel discharging immediately to the south-west of the new Campbell Road bridge • A piped discharge outlet immediately to the south-east of new Campbell Road bridge.

Mainstream flooding

Potential mainstream flood-related impacts during operation include:

- An increase in runoff volumes, peak flows and / or time of concentration following rainfall events due to an increase in impermeable surfaces (ie operational infrastructure)
- An increased flood risk in adjacent areas due to the location of operational infrastructure, which has the potential to interrupt or divert existing flood routes and also reduce flood storage.

Mainstream flooding during operation was assessed by modelling the impacts of operational infrastructure and future climate change on flood behaviour. Model scenarios included:

- The 20 year ARI flood, 100 year ARI flood and PMF events
- The impact of a 10 per cent increase in rainfall intensity during a 100 year ARI flood
- The impact of a 0.4 metre rise in sea levels by 2015 on a 100 year ARI flood and PMF.

Potential mainstream flooding impacts are generally minor in nature and readily mitigated by managing specific detailed design aspects and site planning to suit identified flooding conditions and avoid the potential for off-site flooding impacts. A summary of the key flood assessment findings for each project area is provided below and mitigation measures that would be employed are outlined in **Section 18.4**.

Technical working paper: Flooding (**Appendix P**) provides additional details of flood modelling and includes figures showing the predicted impact for each of the modelling scenarios.

Impact of the project on flood behaviour

The impact of the project on existing flooding behaviour on the upper Wolli Creek floodplain for design floods of 20, 100 and 200 year ARI flood, as well as the PMF were modelled (refer to **Figure 18-4**). The key findings of this assessment are as follows:

- The widening of the M5 East Motorway would result in an increase in peak flood levels along the northern side of the M5 East Motorway for floods up to a 100 year ARI. However, the resulting impacts would be confined to the M5 East Motorway corridor and the Canterbury Golf Course
- The project would not increase peak flood levels in existing residential development areas for all floods up to the 100 year ARI flood
- The constriction imposed on flow by widening the M5 East Motorway would lead to an increase in peak PMF levels from around 0.45 metres to about 0.95 metres in the vicinity of the Canterbury Golf Course. The effects of the road widening on peak PMF levels would extend into seven residential properties that are located to the west of the Canterbury Golf Course in Elouera Street and Kirrang Street, Beverly Hills. Flooding in the seven properties would generally be of a ponding nature, with flow velocities shown to be less than about 0.1 metres per second during a PMF event. Inundation of previously flood free land would generally be confined to the landscaped portion of five of the seven properties.

  However, floodwater would inundate land bordering the dwellings in Nos. 50 and 52 Elouera Street, Beverley Hills. While floor level survey would be required to determine whether the project would result in the above-floor inundation of these two dwellings, inspection of the LiDAR survey data shows that ground levels in the majority of No. 50 and in the south-west corner of No. 52 Elouera Street lie above the PMF level, indicating that evacuation would still be possible from the two properties by foot during an event of this magnitude. No measures are proposed to mitigate the impact of the project on these properties, as all properties would continue to lie above the residential flood planning level which in the Canterbury LGA is equal to the 100 year ARI event flood plus an allowance of 0.5 metres for freeboard
- The constriction imposed by the widening of the M5 East Motorway would lead to a reduction in peak PMF flood levels on the northern side of the M5 East Motorway in the vicinity of Beverly Grove Park and on the southern side of the M5 East Motorway in the vicinity of Tallawalla Street

  The minor change in the distribution of flow in the drainage system would result in a minor increase in peak 100 year ARI flood levels in two industrial / commercial properties located on the

southern side of the M5 East Motorway opposite the outlet of two transverse drainage structures. The maximum increase in peak 100 year ARI flood levels for both properties would be about 20 millimetres

- The realignment of a transverse drainage structure along the M5 East Motorway between Wolli Creek and Garema Circuit would not result in a redistribution of flow in the drainage system for all floods up to the PMF
- The project would not result in more frequent inundations of property or the local road network over the full range of flood events
- The project would not increase the duration of flooding for all events up to the PMF
- The project would not impact existing evacuation routes.

Based on the above findings, the project would not impact the development potential of existing properties for residential, commercial and industrial purposes. However the modelled increase in peak PMF levels along the northern side of the M5 East Motorway, in the vicinity of Canterbury Golf Course, would constrain development in at least one residential property located at Elouera Street, Beverly Hills. The development would be constrained if, for example, the owner wished to augment the existing dwelling to incorporate a more sensitive land use such as child or aged-care facility (note that the existing land zoning is R3 medium density residential under the Canterbury LEP 2012 which permits child care centres and respite day care centres with development consent).

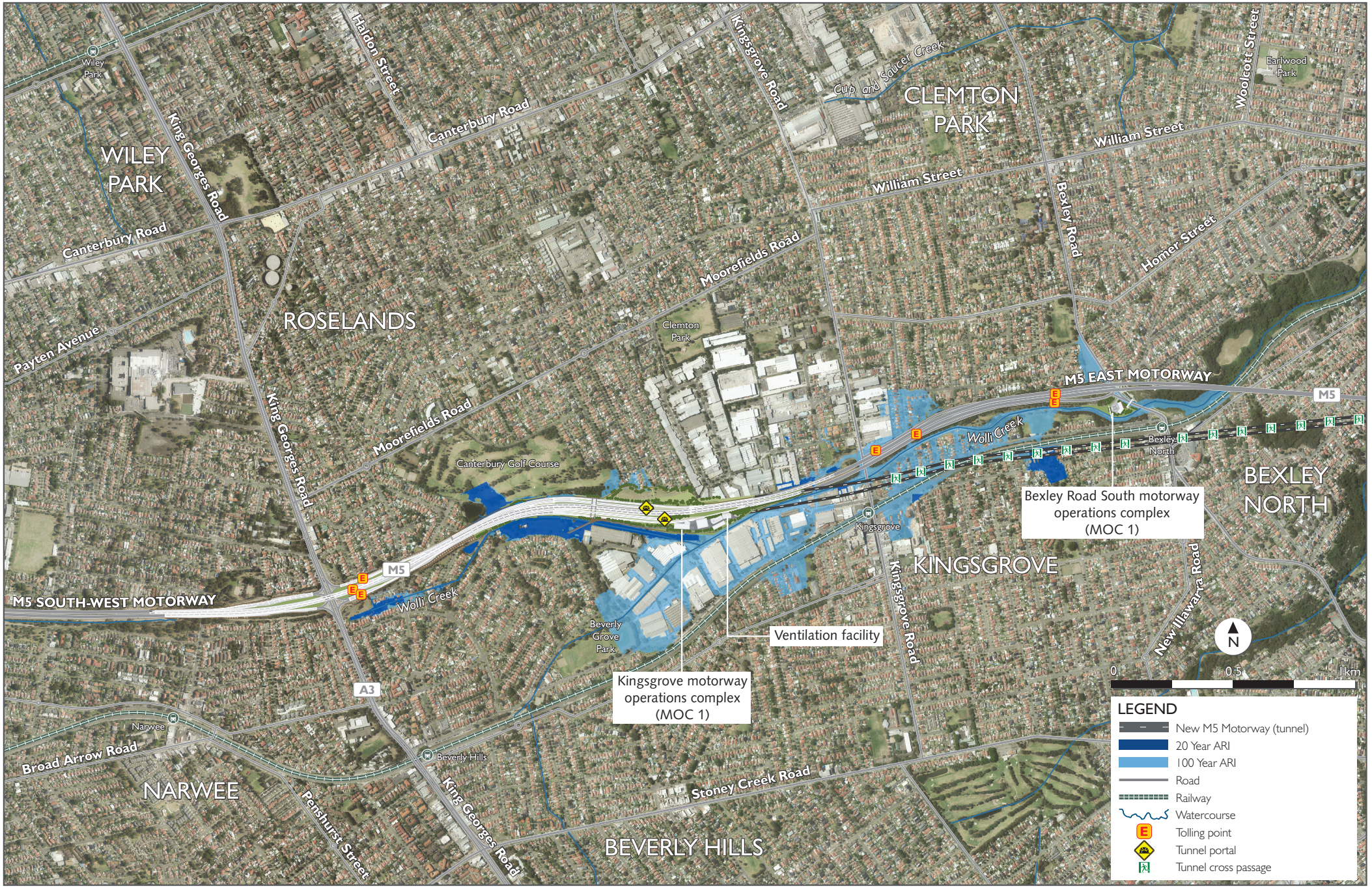


Figure 18-4 Impact of the project on flooding behaviour in the Upper Wolli Creek for the 20 year ARI and 100 year ARI

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The impacts of the project on existing flooding behaviour were modelled for the lower Cooks River floodplain and along Alexandra Canal for design floods of 20, 100 and 200 year ARI floods, as well as the PMF (refer to **Figure 18-5** and **Figure 18-6**). The key findings of this assessment are as follows:

The loss of about 12,000 cubic metres of floodplain storage associated with the construction of the Arncliffe motorway operations complex (MOC3) (based on a worst case disturbance footprint) would result in an increase in peak 100 year ARI flood levels in seven residential properties located on the northern (upstream) side of Marsh Street. The maximum increase in peak flood levels at these properties would be about 10 millimetres. A floor level survey would be required at the abovementioned properties to determine whether the project would result in the above-floor inundation of these properties due to flood levels. The potential impacts would be confirmed based on the detailed design of the Arncliffe motorway operations complex (MOC3).

- The construction of the two new road bridges across Alexandra Canal would generally not impact peak flood levels for events up to a 100 year ARI flood. However, the raising of the Campbell Road / Burrows Road intersection would impact local flooding patterns, leading to an increase in peak 100 year ARI flood levels by about 30 millimetres at two commercial / industrial properties, as well as in a recently upgraded section of TransGrid's Beaconsfield West Substation
- The loss of floodplain storage resulting from the construction of both the Arncliffe motorway operations complex (MOC3), the St Peters interchange and local road upgrades in combination with the constrictive effects imposed by the two new road bridges across Alexandra Canal would result in an increase in peak PMF flood levels across a large portion of the lower Cooks River floodplain. While increases in peak PMF levels would generally be in the range 10 to 50 millimetres, increases of greater than 100 millimetres would occur in an existing commercial / industrial development located on the western overbank of the Alexandra Canal immediately upstream of the Campbell Road bridge
- The resulting increase in peak PMF flood levels would not translate into a significant increase in the extent of flood prone land
- The flood risk at Sydney Airport would not be increased given the minor impact the project would have on flooding behaviour
- The project would not alter the distribution of flows on the lower Cooks River floodplain
- Peak flood levels would generally be increased in the range of 10 to 50 millimetres on the lower Cooks River floodplain, with greater increases to occur immediately upstream of the new Campbell Road bridge (generally in the range of 20 to 200 millimetres) and on the northern side of Marsh Street opposite the Arncliffe motorway operations control centre (MOC3)
- Additional pavement areas from the widening of Campbell Street and adjoining streets would cause a large increase in runoff within the catchment draining to Camdenville Park. The project would include improvements to the hydraulic standard of the drainage system servicing the roads that would be upgraded. This increase in runoff would be offset through provision of additional detention storage within and adjacent to Camdenville Park. This would limit increases in peak flow rates discharged to the downstream trunk drainage system. However the proposed drainage strategy would be determined during detailed design and would be based on not increasing flows into the Eastern Channel for all events up to and including the 100 year ARI flood. An option to achieve this would include the following key elements:
  - Enlargement of the existing detention basin through excavation to lower existing ground levels and the use of retaining walls adjacent to the upgraded sections of Bedwin Road and May Street. As this is a contaminated site, excavation would be planned accordingly. Based on preliminary analysis, the existing storage volume of around 6000 cubic metres would need to be increased to around 17,000 cubic metres to limit peak flow rates downstream of the basin to no greater than occurs under present day conditions for events up to and including the 100 year ARI flood. This required increase in capacity would be confirmed during detailed design
  - Upgrade of the existing discharge system and associated infrastructure including rising mains to suit the enlarged basin, to renew those assets while maintaining the existing pumping capacity

  - Construction of supplementary underground detention storage along the south-western side of Bedwin Road, within the space created by realignment of this road. This would be hydraulically connected to the upgraded basin, with discharge via an outlet control structure to the existing box culvert beneath the rail line. The need for this supplementary storage would be confirmed during detailed design.

- The project would not result in more frequent inundation of property or the local road network over the full range of flood events
- The project would not increase the duration of flooding for all events up to the PMF
- The project would not impact existing evacuation routes.

Based on the above findings, the project could potentially increase the frequency and depth of above-floor inundation in a number of residential properties that are located along the northern (upstream) side of Marsh Street opposite the Arncliffe motorway operations complex.

Consultation with TransGrid in relation to the Beaconsfield West Substation has confirmed that a conservative design approach was adopted in the recent upgrade of the substation. This included positioning critical infrastructure above about six metres AHD, and setting all transformer switch bays and reactive plant at ground level (about two metres AHD). Further design development would be undertaken during detailed design in order to mitigate the impact of the project on flooding conditions in the TransGrid site. This would include further refinement of design of the relief drain, as well as the western approach to the new Campbell Street bridge.



Figure 18-5 Impact of the project on flooding behaviour in the Lower Cooks River floodplain for the 20 year ARI and 100 year ARI

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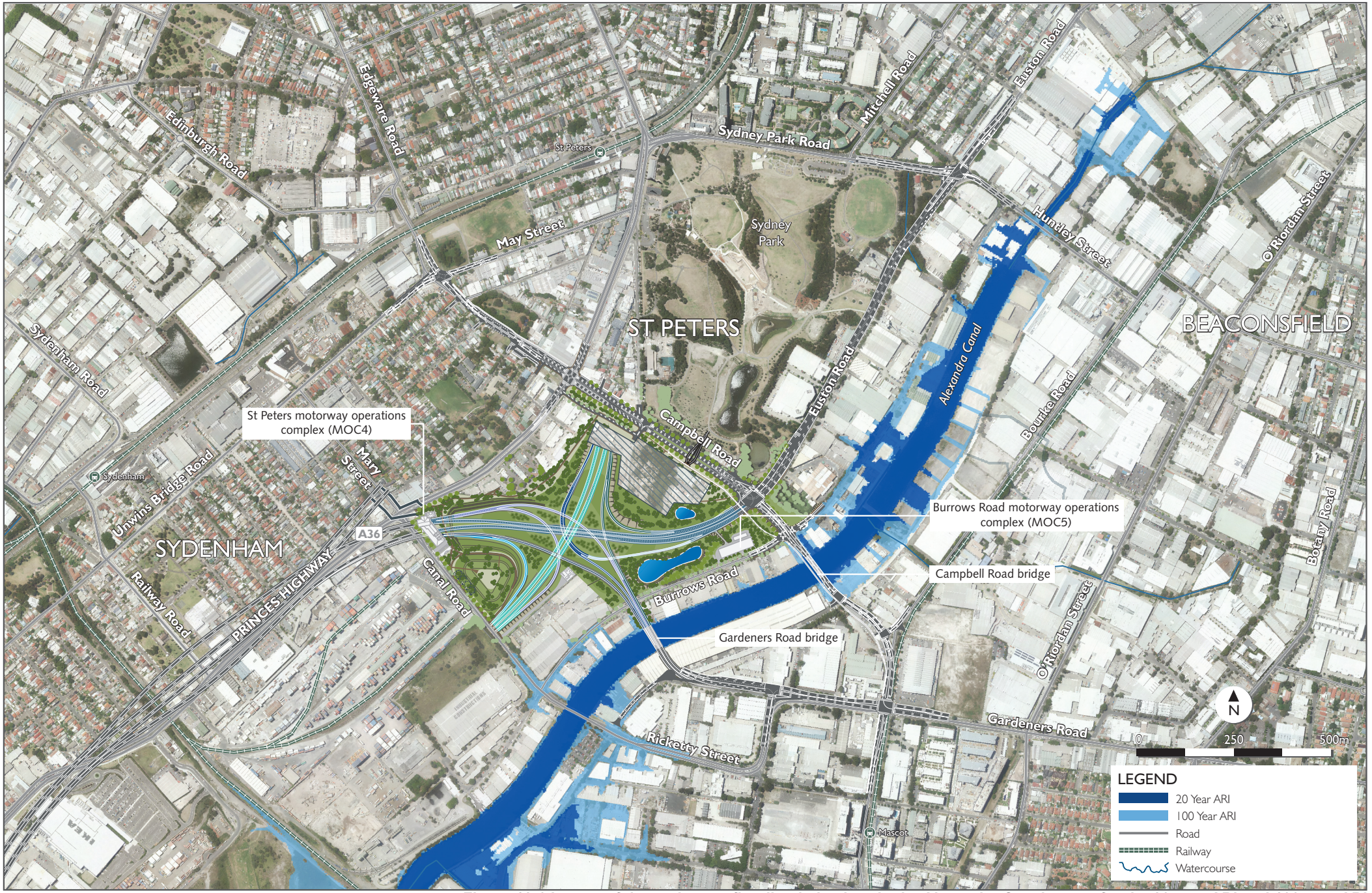


Figure 18-6 Impact of the project on flooding behaviour in the Alexandra Canal extent for the 20 year ARI and 100 year ARI

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Impact of flooding on the project

The Kingsgrove motorway operations complex (MOC1) would be located on land which lies above the extent of a PMF event, and would not be inundated during this event. The Burrows Road motorway operations complex (MOC5), which contains the Motorway Control Centre, would be located on land located above the 100 year ARI flood. However, it would be impacted during the PMF event.

Other motorway operation complexes would be located on land affected by a PMF flood event. Measures would be incorporated in the design of the Bexley Road South, Arncliffe and St Peters motorway operations complexes (MOC2, MOC3 and MOC4) to prevent the ingress of floodwater during a PMF event. For example, components critical to tunnel operations would be located on the first floor of the centre, which would lie above the peak PMF level. These measures would be further developed during the detailed design of the project.

The ventilation facilities at the Arncliffe and St Peters motorway operations complexes would also be designed to be above the PMF event.

Impact of a partial blockage of major hydraulic structures on flood behaviour

A partial blockage of major hydraulic structures located on the upper Wolli Creek floodplain would only have a minor impact on peak flood levels.

A partial blockage of the Southern Western Suburbs Outfall Sewer where it crosses the Cooks River would increase peak 100 year ARI flood levels adjacent to the Arncliffe motorway operations complex (MOC3). A partial blockage of major hydraulic structures located downstream of the Campbell Road bridge would also increase peak PMF levels adjacent to the St Peters interchange.

Impact of future climate change on flood behaviour

While climate change induced sea level rise would not impact the St Peters interchange for events up to the 100 year ARI flood, it would result in the more frequent inundation of Kogarah Golf Course in the vicinity of the Arncliffe motorway operations complex (MOC3). 100 year ARI flood levels would also be increased in the vicinity of the Arncliffe motorway operations complex MOC3 by about 0.49 metres and 0.84 metres in the case of a 0.4 metre and 0.9 metre rise in sea level, respectively.

A rise in sea level of 0.4 metres would result in an increase in peak PMF levels of about 0.13 metres in the vicinity of the St Peters interchange (including the Burrows Road and St Peters motorway operations complexes (MOC4 and MOC5) and about 0.14 metres in the vicinity of the Arncliffe motorway operations complex (MOC3). A sea level rise of 0.9 metres would result in an increase in peak PMF levels of about 0.29 metres in the vicinity of the Burrows Road and St Peters motorway operations complexes (MOC4 and MOC5), as well as the St Peters interchange and about 0.32 metres in the vicinity of the Arncliffe motorway operations complex (MOC3).

18.4 Environmental management measures

Environmental management measures relating to flooding for the construction and operation of the project are provided in **Table 18-5**.

The application of standard mitigation measures and refinements during detailed design are expected to be sufficient to mitigate potential mainstream flooding impacts during construction. Potential impacts on drainage and flooding during operation of the project are expected to be manageable through design of the project.

Table 18-5 Environmental management measures – flooding and drainage

Impact	No.	Environmental management measure	Timing
Construction			
Flood Management Strategy	FD01	A Flood Management Strategy would be prepared by a suitable qualified and experienced person in consultation with directly affected landowners, DPI-Water, OEH and the relevant local councils. It would include but not be limited to: • Identification of flood risks to the project and adjoining areas, including consideration of local drainage catchment assessments and climate change implications on rainfall, drainage and tidal characteristics • Design and mitigation measures to protect proposed operations and not worsen existing flooding characteristics during construction and operation, including soil erosion and scouring • Drainage system upgrades • Preparation of a flood / emergency management plan.	Pre-construction
Flood Management Strategy	FD02	The Flood Management Strategy would be peer reviewed and confirmed as meeting the requirements of this management measure by a suitably qualified and experienced independent hydrological engineer. It would be submitted to the Secretary of DP&E and the relevant local councils prior to construction works commencing in the vicinity of flood prone land and overland flow paths for the waterways and catchments in the vicinity of the project area, or as otherwise agreed by the Secretary of DP&E.	Pre-construction
Flooding design	FD03	The 100 year ARI flood level is to be adopted in the assessment of measures which are required to mitigate any adverse impacts attributable to the project. Changes in flood behaviour under PMF conditions would also be assessed in order to identify impacts on critical infrastructure and significant changes in flood hazards as a result of the project.	Detailed design
Hydraulic assessment	FD04	A detailed hydraulic assessment into the impacts the project would have on flooding behaviour and relevant mitigation measures would be undertaken.	Detailed design
Flooding design	FD05	Works within the floodplain would be designed to minimise adverse impacts on surrounding developments for flooding up to the 100 year ARI flood. Assessment would also be undertaken of the impacts during flooding in excess of the 100 year ARI flood up to the PMF in the context of impacts to critical infrastructure and flood hazards.	Detailed design
Survey	FD06	A floor level survey would be undertaken in affected areas to determine whether the project would increase floor damages in adjacent developments (ie in properties where there is a potential for increases in peak flood levels for events up to the 100 year ARI flood).	Detailed design

Impact	No.	Environmental management measure	Timing
Flood management	FD07	Flood management plans would be developed as part of the CEMP prior to construction to guide the detailed design of temporary ancillary facilities, including construction compounds, to minimise the potential impacts of flooding on the project.	Pre-construction
Flooding in existing residential development	FD08	Around 8,000 cubic metres of the projected 12,000 cubic metres of lost floodplain storage due to the operation of the Arncliffe motorway operations complex (MOC3) would be required to be recaptured. Floor level surveys would be undertaken to determine whether the project would result in the above-floor inundation of the following potentially affected properties. Further design development would be undertaken during detailed design to confirm the extent of works required to mitigate the impact of the project on flooding conditions at these existing residential developments.	Detailed design / construction
Flooding in existing commercial / industrial development	FD09	Detailed design would aim to reduce the impact of the project on flooding conditions for the following two potentially affected properties. This would include consideration of whether the project would result in above-floor inundation of these properties.	Detailed design / construction
Flooding in existing commercial / industrial development	FD10	The potential to reduce impacts of the project on flooding for the properties located on the western overbank of the Alexandra Canal would be considered during detailed design. This would also include consideration of whether the project would result in above-floor inundation of these properties.	Detailed design / construction
Flooding in TransGrid's Beaconsfield West substation	FD11	Further design development would be undertaken to mitigate the impact of the project on flooding conditions in the TransGrid site. This would include further refinement of design of the relief drain, as well as the western approach to the Campbell Road bridge.	Detailed design / construction
Hydrology and flooding	FD12	Existing transverse drainage structures would be left in place during construction where transverse drainage structures are to be upgraded or replaced. If this is not feasible, temporary drainage would be adopted.	Detailed design / pre-construction
Hydrology and flooding	FD13	Detailed flood modelling to understand the effects of likely rainfall events would be undertaken. Construction layouts would be finalised accordingly.	Pre-construction

Impact	No.	Environmental management measure	Timing
Hydrology and flooding	FD14	Tunnel dive shafts would be protected against flooding either through locating openings outside of flood prone areas or constructing temporary bunding and / or appropriate temporary drainage. Stockpiles would be located outside the 20 year ARI flood extent where possible. Where construction compounds are located in the 20 year ARI flood extent, a contingency plan to manage flooding would be prepared and implemented.	Detailed design / pre-construction
Hydrology and flooding	FD15	Further detailed assessment of flooding impacts for proposed construction compounds and relevant management measures would be undertaken during detailed design. Contingency plans to manage flooding would be prepared and implemented for high risk temporary facilities proposed including fuel storages, water treatment plants and substations, as well as for the following construction compounds (located either wholly or partially within the 20 year ARI flood extent): • Kingsgrove South construction compound (C2) • Commercial Road construction compound (C3) • Bexley Road North construction compound (C4) • Bexley Road South construction compound (C5) • Arncliffe construction compound (C7) • Alexandra Canal bridge construction compound (C12) • Gardeners Road bridge construction compound (C13). For these sites, suitable procedures for flood warning, emergency management, site evacuation and planning would be developed.	Detailed design / pre-construction
Hydrology and flooding	FD16	The following measures would be implemented to manage flooding risks on construction sites: • Temporary bunding around parts of the site that would be adversely affected by floodwaters • Temporary drains / detention areas within the site • Use of carparks to provide detention • Elevation of site buildings where necessary to get floor levels above expected flood levels • Use of erosion and sediment fences around noise barriers to provide bunding to some parts of the sites while directing overland flows through less sensitive parts of sites, particularly at Kingsgrove and Arncliffe.	Detailed design / pre-construction
Hydrology and flooding	FD17	A drainage strategy would be determined during detailed design to manage the increased runoff within the catchment draining into Camdenville Park. This drainage strategy would be based on not increasing flows into the Eastern Channel for all events up to and including the 100 year ARI flood.	Detailed design / construction

Impact	No.	Environmental management measure	Timing
Potential impacts of future climate change on flooding	FD18	A more detailed assessment would be undertaken during detailed design to determine the climate change related flood risks to the project and to scope requirements for any management measures. The assessment would be undertaken in accordance with the *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC, 2007)	Detailed design
Operation			
Bridges	OpFD01	Bridge crossings over the Alexandra canal would incorporate a suitable freeboard between the underside of the bridge structure and the peak 100 year ARI flood level.	Detailed design / operation
Flooding design	OPFD02	The project and associated arrangements would be designed to limit increases in peak discharges into the downstream drainage systems in accordance with local council requirements.	Detailed design
Drainage and localised flooding	OpFD03	The control and mitigation of potential localised flooding and drainage impacts during operation would include: • Drainage systems that are of insufficient capacity would be modified or upgraded to cater for increased flows • Where new drains connect with existing drainage networks a survey and condition assessment would be undertaken to inform detailed design • The efficiency of transverse drainage upgrades would be taken into account during detailed design • The effects a partial blockage of major hydraulic structures on flooding behaviour would be considered when determining finished road level and flood wall heights.	Detailed design / operation
Tunnel portals and ancillary facilities	OpFD04	Tunnel entries and associated flood protection barriers would be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater). The same hydrological standard would be applied to tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwaters would also have the potential to flood the tunnels.	Detailed design / operations
Tunnel design	OpFD05	A suitable freeboard would be incorporated into the design of openings into the new road tunnels (eg at the location of the tunnel portals and ventilation shafts). These designs would take into account the impacts of a partial blockage of major hydraulic structures as well as climate change induced sea level rise on PMF event levels.	Detailed design / operation

Impact	No.	Environmental management measure	Timing
Emergency response facilities	OpFD06	Emergency response facilities, including the motorway control centre, tunnel fire water tank and pump buildings and associated electrical substations would be locate above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).	Detailed design / operations

19 Groundwater

This chapter outlines the potential groundwater impacts associated with the New M5 Project (the project). A detailed groundwater assessment has been undertaken for the project and is included in **Appendix Q**.

Table 19-1 refers to the Secretary's Environmental Assessment Requirements (SEARs) as they relate to groundwater, and where in the environmental impact statement (EIS) these have been addressed.

Table 19-1 SEARs – groundwater

SEAR	Where addressed
An assessment of groundwater impacts (including ancillary facilities such as the tunnel control centre and any deluge systems), considering local impacts along the length of the tunnels and impacts on local and regional hydrology including consideration of any Water Sharing Plan and impacts on groundwater flow. The assessment must consider:	**Chapter 19** (Groundwater)
• extent of drawdown;	**Section 19.3.2**
• impacts to groundwater quality;	**Section 19.3.6** **Section 19.4.2**
• volume of groundwater that will be taken (including inflows);	**Section 19.3.1**
• discharge requirements;	**Appendix N:** Technical Working Paper: Surface Water
• location and details of groundwater management and implications for groundwater dependent surface flows, groundwater-dependent ecosystems and groundwater users.	**Section 19.3** **Section 19.4** **Section 19.5**
The assessment must include details of proposed surface and groundwater monitoring and be prepared having consideration to the requirements of the NSW Aquifer Interference Policy;	**Section 19.5** **Chapter 16** (Soil and water)
An assessment of the potential intersection of contaminated bed sediments in the Alexandra Canal and interception of contaminated water from the Botany Sand Beds aquifer	**Chapter 18** (Contamination)

19.1 Assessment methodology

A groundwater assessment has been undertaken in relation to the existing environment to determine the potential impacts of the construction and operation of the project. A summary of the groundwater assessment is provided in this chapter. The full technical working paper is included in **Appendix Q**.

The assessment includes:

- Consideration of the existing environment that the project would interact with, including the hydrogeological conditions and environmental values of the surrounding environment
- An impact assessment, which characterises the impacts of the tunnel on groundwater dependent systems and surrounding environment using numerical modelling techniques
- Groundwater management and monitoring measures required to mitigate impacts and manage tunnel inflows.

The assessment has been undertaken with consideration of relevant legislation, policies, guidelines and water sharing plans as listed in **Table 19-2**.

Table 19-2 Relevant groundwater assessment guidelines

Policy/guidance	Relevance to project
Water Management Act 2000 (NSW)	The project would take groundwater as a consequence of the interception of the Hawkesbury Sandstone aquifer. Section 91F of the Act requires an aquifer interference approval when carrying out an aquifer interference activity. However, section 91F of the Act does not currently apply. As the project is classified as State Significant Infrastructure, Section 115ZG, Clause 1(g) states that authorisations under water use approval, water management approval or an activity approval (other than an aquifer interference approval) are not required.
NSW Aquifer Interference Policy (DPI, 2012)	The impact limits in terms of drawdown magnitudes and offset distances outlined in the NSW Aquifer Interference Policy have been considered in this assessment and inform the overall structure of the assessment.
Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011	The Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources covers 13 groundwater sources. The project lies within the Sydney Basin Central groundwater source area, which is a porous rock aquifer. Interference and extraction of groundwater typically requires a water access licence. While the project does not require an authorisation (as discussed above), an equivalent level of assessment has been carried out.
NSW State Groundwater Quantity Management Policy (NSW Office of Water, n.d.)	The requirements of this policy are met by the general assessment requirements in the Aquifer Interference Policy and Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources.
NSW Groundwater Quality Protection Policy (DLWC, 1998)	The requirements of this policy are considered through the identification of baseline conditions for the study area and assessment of potential changes to groundwater quality as a result of the project.
NSW State Groundwater Dependent Ecosystems Policy (DLWC, 2002)	This policy requires the assessment of changes in water levels and flows near identified groundwater dependent ecosystems (GDEs).
Risk assessment guidelines for groundwater dependent ecosystems (NSW Office of Water, 2012b)	Volume 1 of the guidelines provides general guiding material, while Volumes 2 through 4 relate specifically to coastal aquifers.
NSW Water Extraction Monitoring Policy (Department of Water and Energy, 2007)	Under this policy, all groundwater extraction during construction and operation of the project would need to be monitored. Typically this would involve metering of all flows in and out of the tunnel and using the difference to identify the groundwater inflow contribution.
Australian Drinking Water Guidelines (National Health and Medical Research Council, 2013)	Existing and potential groundwater quality has been compared against the guidelines to identify the highest and best use of the groundwater and to assess the risk to the public from incidental exposure to untreated groundwater intercepted by the tunnel.
Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)	The national guidelines provide default trigger values of various analytes that can be compared with sampled values from the project. From the assessment of these trigger values, site specific values have been provided for the project.
National Environment Protection (Assessment of Site Contamination) Measure 1999	This measure has been reviewed and considered as appropriate for this assessment.

Policy/guidance	Relevance to project
Health screening levels for petroleum hydrocarbons in soil and groundwater (Friebel, E. and Nadebaum, P, 2011)	This technical report provides the relevant health screening levels for the assessment of petroleum hydrocarbon contamination that could occur as a result of the construction and operation of the project.
Regional Screening Levels – Tapwater (United States Environmental Protection Agency, 2013)	This guideline has been reviewed and used for the assessment of drinking water.

19.1.1 Study area

For the purposes of the groundwater impact assessment, the study area was defined by the alignment of the project with a buffer of one kilometre.

19.1.2 Desktop review

Searches were conducted across a range of databases between April 2015 and June 2015 to assist in developing an understanding of the existing environment. The purpose of the searches was to review existing hydrogeological data including geology, groundwater levels, groundwater quality, groundwater users, GDEs, acid sulphate soils and climate. The data collation included extraction from the following databases:

- Bureau of Meteorology 2015 Australian Groundwater Explorer (formerly NSW Office of Water groundwater database) and Pinneena Groundwater Database, version 10.1, dated October 2014
- Regional geology along the project corridor, as described in the Geological Survey of NSW 1:100,000 scale Sydney Map Sheet (sheet 9130, 1983)
- Australian Soils Resource Information System
- Appendix 4 of the *Greater Metropolitan Regional Groundwater Sources Water Sharing Plan 2011*
- Bureau of Meteorology 2015 On-line climate data.

Groundwater data have also been drawn from other groundwater investigations of major developments in the area including the M5 East development (1998-2001), the New Southern Railway project (1995-2000) and the Alexandria Landfill monitoring program (1997 – ongoing). The Alexandria Landfill is described in **Section 19.2.1**. Details of data sources are provided in the technical working paper: Groundwater (**Appendix Q**).

Groundwater investigations, including drilling boreholes, packer tests, groundwater gauging, ground water sampling and hydrogeochemical analysis were conducted across the study area between September 2014 and March 2015. Selected boreholes were chosen from the investigations in order to collect baseline data for the groundwater assessment. The locations of the boreholes within the groundwater monitoring network are shown in **Figure 19-1**.

Groundwater data collected included:

- Hydraulic conductivity (the rate at which groundwater naturally moves through the rock or sediments) determined through packer tests. Packer tests (in-situ water pressure tests) are conducted during the drilling program by injecting water under various pressures into the local geology. The measured amount of water is proportional to the hydraulic conductivity of the geological sequence that was injected.
- Groundwater levels (including fluctuations), determined through groundwater gauging and data loggers
- Groundwater quality, determined through hydrogeochemical sampling and analysis.

19.1.3 Hydraulic conductivity

Hydraulic conductivity is a fundamental aquifer property that assists in understanding the tunnel water inflows or the local drawdown that may be imposed on the local hydrogeological regime. Hydraulic conductivity is measured in metres per day and is a calculation of how easily groundwater flows through a porous medium (soil matrix or rock mass) under natural conditions. The higher the value of hydraulic conductivity, the greater the movement of groundwater expected (including into unsealed underground structures such as road tunnels).

During the drilling program packer tests were conducted to measure the hydraulic conductivity of selected rock mass intervals. Packer tests (or water pressure tests) involve injecting water under pressure into an isolated rock mass interval and measuring the water ingress over a given time period. The amount of water injected is proportional to the hydraulic conductivity.

The packer test results provide a bulk hydraulic conductivity for the intervals measured including horizontal and vertical features and the rock matrix.

Packer testing was undertaken along the project alignment by conducting 158 packer tests in 35 boreholes to assess the bulk hydraulic conductivity range within the Hawkesbury Sandstone and Ashfield Shale as shown in **Figure 19-2**. Up to seven tests were performed in each borehole. The packer tests provided an indication of the ability of the local geology to allow groundwater movement and informed the hydrogeological model prepared for the study area. Further detail on Packer testing is provided in **Appendix Q**.

19.1.4 Groundwater levels

A groundwater monitoring network was established as part of the WestConnex hydrogeological investigations (AECOM, 2015j). A total of 28 monitoring wells were constructed at selected locations along the project alignment between October 2014 and March 2015. The monitoring well locations were chosen to provide a representative spread along the proposed tunnel alignment in representative lithologies (refer to **Figure 19-1**).

The majority of monitoring wells targeted the Hawkesbury Sandstone (21 of the 28 wells) since most of the project tunnels would be constructed within the competent sandstone unit. Five wells targeted the Ashfield Shale, one targeted alluvial and estuarine sediments, and one targeted a Basalt dyke.

Groundwater levels were measured periodically with an electronic dip meter and automatically on a two hour interval with data loggers. The outcomes of the groundwater level monitoring program are outlined in **Appendix Q**.

19.1.5 Groundwater quality

Groundwater was sampled and analysed to characterise the local groundwater quality of each of the main hydrogeological units; specifically to identify any spatial variability, and to identify potential groundwater contamination. Fourteen monitoring wells were selected from the groundwater monitoring network between October 2014 and March 2015 to obtain representative groundwater samples along the alignment within the Hawkesbury Sandstone and Ashfield Shale.

The key groundwater quality guideline adopted for the establishment of groundwater criteria is the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000). Given the degraded nature of the receiving waters in Alexandra Canal and Cooks River, the 90 per cent level of protection has been adopted.

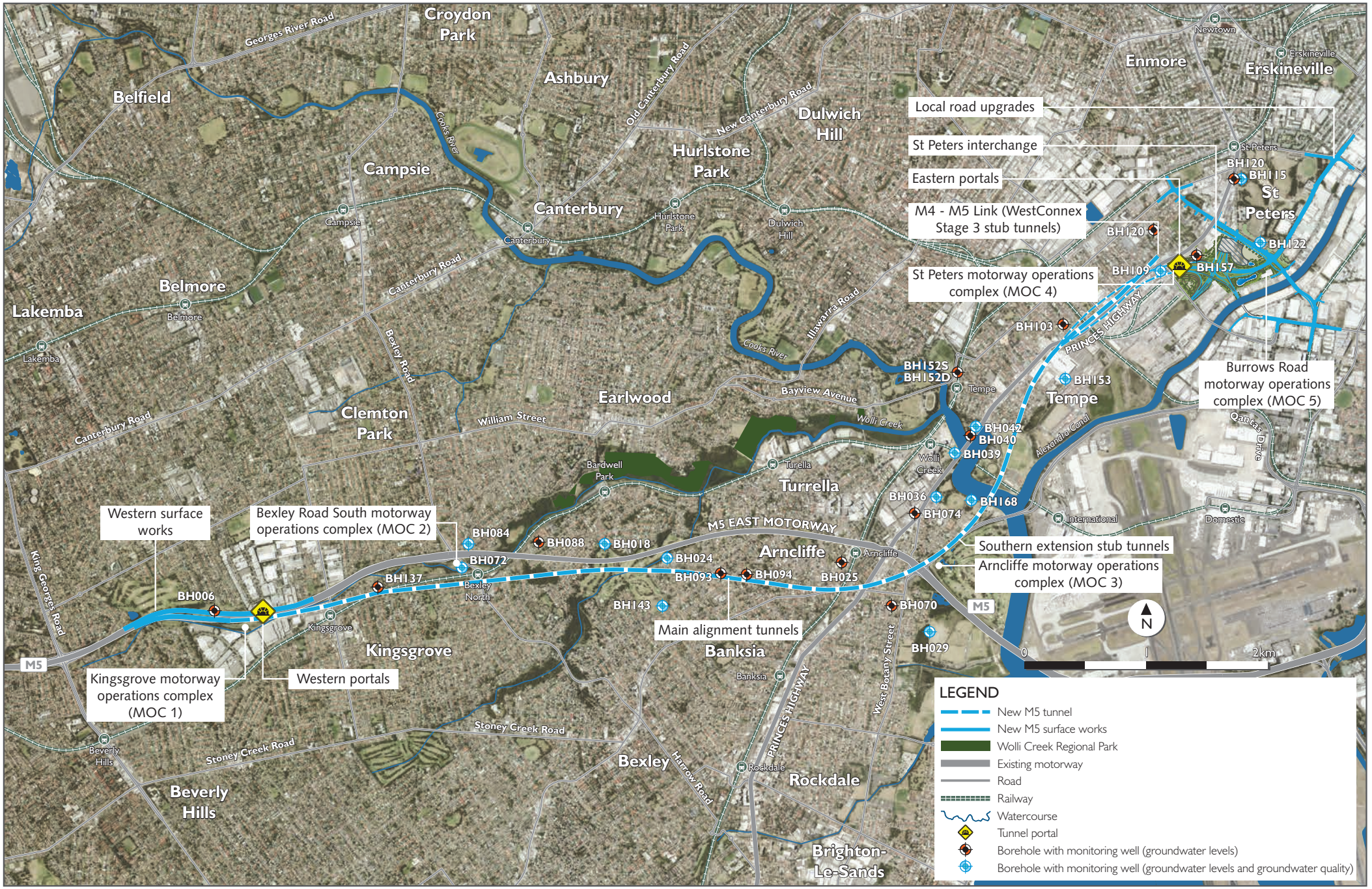


Figure 19-1 Groundwater monitoring network

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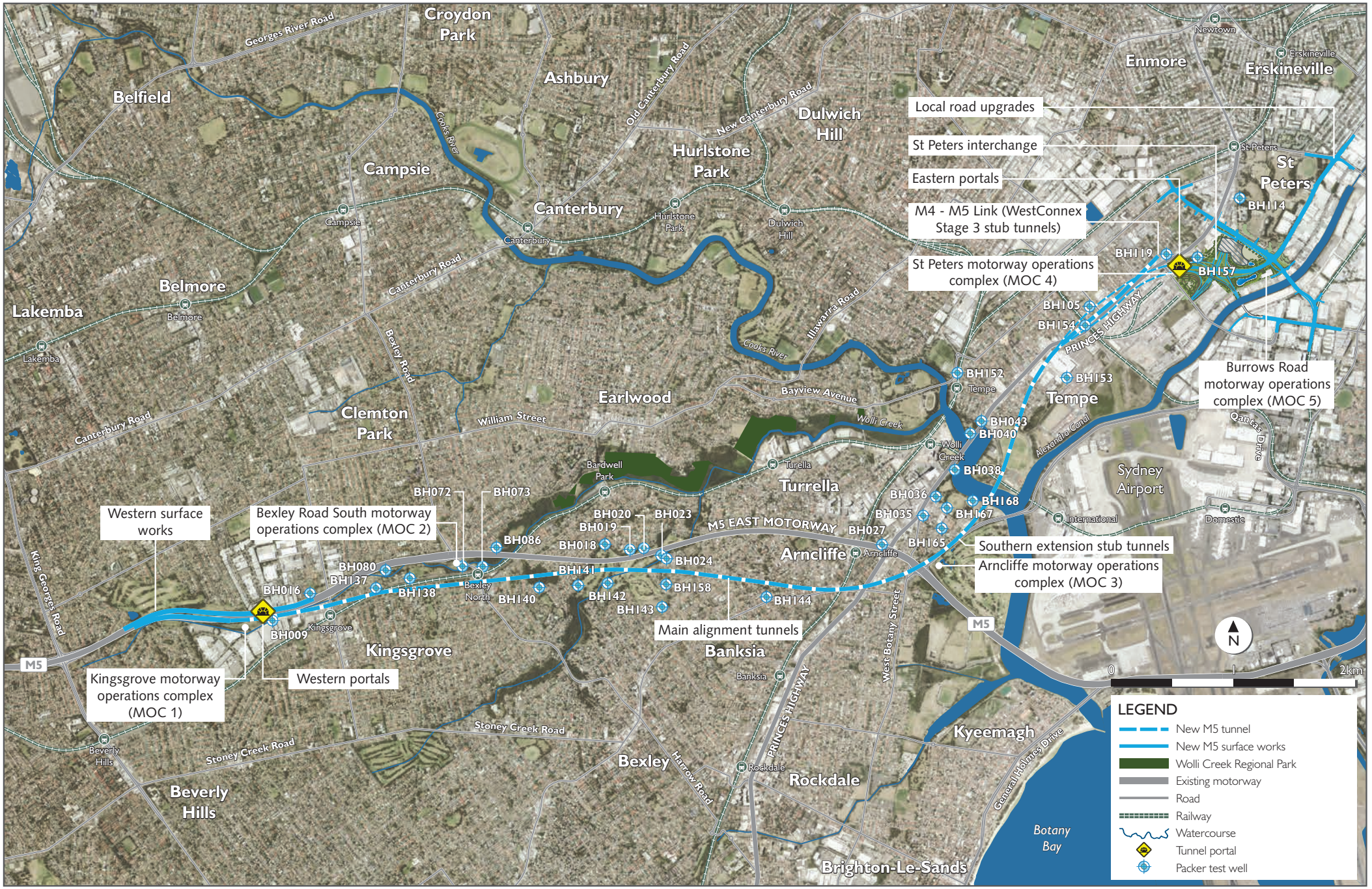


Figure 19-2 Packer test borehole locations

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Collected groundwater samples were transported to an external National Association of Testing Authorities (NATA) accredited laboratory for testing and analysis. Groundwater quality samples were tested for:

- Heavy metals and metalloids (including arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel and zinc)
- Benzene, toluene, ethylbenzene, xylene and naphthalene (BTEXN)
- Total recoverable hydrocarbons (TRH)
- Polycyclic aromatic hydrocarbons (PAHs)
- Inorganics (including major anions and cations, alkalinity, ammonia, electrical conductivity, ionic balance, total dissolved solids, pH and hardness)
- Organochlorine pesticides (OCPs)
- Organophosphate pesticides (OPPs)
- Semi volatile organic hydrocarbons (SVOCs)
- Volatile organic compounds (VOCs).

Field parameters tested were:

- Dissolved oxygen
- Electrical conductivity
- pH
- Temperature
- Redox conditions.

19.1.6 Groundwater Dependent Ecosystems

Groundwater dependent ecosystems (GDEs) are communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater, such as wetlands and vegetation on coastal sand dunes.

Sources reviewed to understand potential GDEs potentially impacted by the project include:

- *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* (NOW, 2011)
- Bureau of Meteorology Atlas of Groundwater Dependent Ecosystems (BOM)
- Threatened species database (OEH).

19.1.7 Ground settlement

Two types of ground settlement have been considered:

- Settlement due to volume loss during tunnel excavation
- Settlement due to groundwater drawdown and subsequent ground settlement.

A well-established empirical method (Burland et al, 1977, Boscardin and Cording, 1989) was used to predict ground movement due to ground volume loss during excavation.

The estimated volume loss during excavation is dependent on the type of material being excavated as well as the excavation method. Parameters are selected to estimate the magnitude of the settlement as well as the shape and extent of the settlement trough. Initial values were chosen based on past experience and back-analysed parameters from previous projects.

The results obtained from the initial empirical analysis were validated against those obtained from numerical models carried out at typical sections. The initial empirical parameters were refined such that the results of each method were comparable and the final parameters adopted for the remainder of the tunnel alignment.

The parameters adopted for the project tunnels are provided in **Table 19-3**:

Table 19-3 Ground loss settlement parameters

Excavation type	Volume loss	Trough width parameter (k)
Driven tunnel in sandstone	0.3%	0.5
Driven tunnel in shale	0.3%	0.5
Soft ground support	0.5%	0.5
Southern Connector cavern	0.45%	0.45
St Peters Interchange cavern	0.65%	0.55
President Avenue ramps cavern	0.45%	0.45

An assessment of potential damage to nearby buildings and utilities was carried out by identifying critical zones based on the types of structures within the study area as well as the maximum predicted settlement.

Within the critical zones, those buildings representative of others in the area, or buildings that appeared prone to ground settlement, were selected for detailed analysis. Similarly, a representative sample of utilities and other infrastructure crossing the project tunnel alignments was also selected for detailed assessment including:

- General routes with a high concentration of services, usually following major roads
- Specific services such as electricity cables, sewers, water pipelines and gas mains where these are not located in the general routes above
- Railway lines, concrete drainage channels and the M5 East Motorway.

In the detailed assessment, the total combined horizontal and vertical ground movement as well as angular distortion within the structure were determined. The acceptance criteria for each type of structure are outlined in **Table 19-4**.

Table 19-4 Acceptance criteria by structure type

Type of structure	Maximum total settlement (millimetres)	Angular distortion (Maximum slope)
Low rise and non-sensitive buildings	< 30	< 1:350
High rise, sensitive or heritage buildings	< 20	< 1:500
Roads	< 40	< 1:250
Utilities	< 40	< 1:250
Railways	< 20	< 1:1000
Tunnels	< 20	< 1:1000

In the case of buildings, the strain calculated within the building was also used to allocate a damage category. The criteria used in allocating each damage category are outlined in **Table 19-5**.

Damage categories of ‘negligible’ to ‘slight’ are considered acceptable as they represent potential aesthetic damage only. The ‘moderate’ to ‘very severe’ categories are related to serviceability and stability damage and are therefore not acceptable.

The assumptions included in the settlement assessment include:

- Use of the empirical method developed by John Burland et al 1997 and Boscardin and Cording, 1989
- Case studies of tunnel settlement from previous tunnel projects in Sydney NSW.

Table 19-5 Damage category strain limits

Damage category [1]	Description [1]	Tensile strain limits (%) [2]
Negligible (damage unlikely but possible)	Hairline cracks	0 to 0.05
Very Slight	Fine cracks that are easily treated during normal decoration. Damage generally restricted to internal wall finishes. Cracks may be visible on external brickwork or masonry.	0.05 to 0.075
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.	0.075 to 0.15
Moderate	The cracks require some opening up and can be patched by a mason. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and window sticking. Service pipes may fracture. Weather-tightness often impaired.	0.15 to 0.30
Severe to Very 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.	> 0.30

1. Burland J B, Broms B B and de Mello V F B (1977).

2. Boscardin M D and Cording J (1989).

19.1.8 Groundwater modelling

A three dimensional numerical groundwater model has been developed to simulate existing groundwater conditions (CDM Smith, 2015). By simulating the project tunnel alignments the groundwater model has also been used to predict future groundwater conditions and potential project impacts.

The model has been developed in accordance with the Australian Groundwater Modelling Guidelines (Barnett et al, 2012). The model development broadly followed the methodology outlined below:

- Review of appropriate modelling platforms to best suit the required predictive modelling along a linear feature
- Desktop review of relevant geological and hydrogeological reports within the Sydney Basin
- Desktop review of recent tunnelling projects within the Sydney region
- Collation of data and analysis of aquifer parameters
- Development of a modelling plan
- Development of a hydrogeological conceptual model
- Model development including setting model boundaries, model layers, model discretisation and modules to simulate surface water bodies and the interaction with groundwater
- Model calibration
- Sensitivity analysis
- Model predictions.

The numerical groundwater model was developed using MODFLOW-USG (2012). This version of MODFLOW was selected as it allows local grid refinement and is suited to simulating linear features (such as road tunnels).

The model was developed in steady state conditions rather than transient analysis. As a result the predictions of inflows and drawdowns are those that will apply in the long term, after equilibrium has been established. It is not known how long it will take for steady state conditions to be established.

The steady state inflows are likely to be lower than inflows during construction and the early years of operation. Conversely, the steady state predicted drawdowns are likely to be greater than those that occur during construction and the early years of operation. Predicted drawdown impacts are therefore likely to be "worst-case" impacts, but predicted inflows are likely to be "best case". As a consequence, predicted impacts on ecosystems and existing users are worst case long term impacts, and are likely to be greater than those that apply in the short term.

Further details on the method used for the groundwater modelling is provided in the Technical working paper: Groundwater (**Appendix Q**).

19.2 Existing environment

The existing environment has been characterised based on existing information and investigation data collected for the project, including:

- Topography and drainage
- Geological setting
- Hydrogeological setting, including groundwater levels and hydraulic conductivity
- Groundwater quality
- Groundwater users
- GDEs.

19.2.1 Topography and drainage

The project corridor extends from Beverly Hills, east beneath Arncliffe to St Peters. The western portion of the project corridor is relatively flat, low lying, with gentle undulating hills ranging between 30 metres Australian height datum (AHD) and 40 metres AHD, characteristic of Ashfield Shale type terrain. The topographically highest section of the project corridor is through the Bexley North and Bardwell Park areas at elevations of between 40 metres AHD to 50 metres AHD.

Wolli Creek and its southern tributary, Bardwell Creek have incised gullies through a subterranean (under the surface) sandstone and shale plateau. This plateau is higher in elevation by approximately 20 to 30 metres than other parts of the Sydney basin. Wolli Creek flows east to join the Cooks River. The Wolli Creek and Cooks River valleys widen as they approach Botany Bay and the incised valley floors have been filled with alluvial sediment to create relatively flat alluvial plains. The Wolli Creek and Cooks River channels have been modified over much of their length to improve drainage and control flooding.

The topography of the project corridor near the confluence of Wolli Creek and the Cooks River is relatively flat and low-lying (around five metres AHD to 10 metres AHD), and gradually declining towards Botany Bay. Land within and adjoining the central and north-eastern areas of the project corridor have been substantially modified over time due to land reclamation and industrial activities. The Botany Sands are present in the vicinity of Alexandra Canal.

The Alexandria Landfill is at the eastern extent of the project corridor and has been infilled by waste as part of historic landfill operations. Former brick pits beneath nearby Sydney Park in St Peters have also been infilled and re-contoured forming an irregular, man-made landform varying in elevation from 5 metres AHD to 25 metres AHD.

19.2.2 Alexandria Landfill

The Alexandria Landfill is a former quarry where weathered shale and clay was excavated for brickmaking. The landfill located at 10-16 Albert Road, St Peters extends over 15.7 hectares and is excavated to a maximum base level of around minus 31 metres AHD. The former quarry has operated as a landfill since 1988 and ceased receiving waste in late 2014. Leachate is generated on site and is collected and treated through an existing onsite leachate management system prior to off-site discharge to sewer (in accordance with the requirements outlined in the existing trade waste agreement, including testing for compliance with the environment protection licence). Leachate is generated primarily from surface water infiltration and groundwater inflow.

Surface water accumulating within the operational areas in the eastern portion of Alexandria Landfill drains to stormwater drains (with sediment control). Surface water that accumulates within the active filling area of the Alexandria Landfill collects in the leachate pond which is transferred to the leachate treatment system and is subsequently discharged to the trade waste system (sewer). Between 100,000 litres to 180,000 litres of leachate are pumped daily from the internal leachate collection system prior to environment protection licence compliance testing and disposal to sewer. Areas of the Alexandria Landfill that have been capped discharge to the stormwater system to nearby Alexandra Canal.

Groundwater flows from the Botany Sands and Ashfield Shale into the former landfill. The leachate pumping system artificially lowers the groundwater levels within the fill and Ashfield Shale and causes radial drainage centred on the leachate pump. The radial flow ensures leachate does not migrate off-site.

19.2.3 Geological setting

Regionally, the study area is located within the Permo-Triassic Sydney Basin that is characterised by sub-horizontal lying sediments of mainly sandstone and shale. To the east, the unconsolidated Quaternary aged Botany Sands overlap the basin and unconformably overlie the bedrock.

The main stratigraphic units that are expected to be encountered would comprise of the following from youngest to oldest (i.e. ground surface and down):

- Anthropogenic fill
- Quaternary Alluvium (recent beneath rivers, palaeochannels and Botany Sands)
- Jurassic Intrusions (volcanic)
- Triassic Ashfield Shale (Wianamatta Group)
- Triassic Mittagong Formation
- Triassic Hawkesbury Sandstone Formation.

Further detail on the stratigraphic units including weathering profiles and implications for hydraulic conductivity is provided in **Appendix Q**.

19.2.4 Hydrogeological setting

Across the study area the groundwater is typically a subdued reflection of the topography, with the groundwater level being deeper beneath hills and shallowest beneath creeks and gullies. Groundwater along the project alignment is recharged by rainfall runoff and infiltration.

Groundwater is present within the following hydrogeological units:

- Quaternary Alluvium
- Botany Sands Aquifer
- Palaeochannels
- Ashfield Shale
- Hawkesbury Sandstone.

Quaternary Alluvium

Quaternary alluvium (consisting of sand, silt, clay, gravels and some peat with a basal clay) underlies and flanks the Cooks River and its tributaries forming an aquifer. The depth is variable ranging from a thin surficial veneer up to 50 metres depth within the palaeochannels.

Groundwater is also present within localised alluvium in some gullies. Groundwater quality within the alluvium is variable ranging from low salinity in the upper reaches and becoming more saline and brackish in the lower reaches due to tidal influences and mixing.

The alluvium is generally of high hydraulic conductivity and the groundwater within the alluvium provides recharge to the underlying shale and sandstone via leakage. In the eastern part of the alignment the Quaternary alluvium flanks the Botany Sands. These two hydrogeological units are hydraulically connected.

The palaeochannels that occur beneath some of the major creeks or valleys extend to depths of up to 50 metres and are saturated. These palaeochannels are infilled with up to 50 metres of saturated sediments comprised of alluvium, estuarine and marine deposits.

Groundwater quality within the palaeochannels is typically saline due to recharge from the Ashfield Shale and leakage from tidally flushed rivers and tributaries. The alluvium infilling the palaeochannels is highly transmissive due to the coarse clean sands and gravels present (Parsons Brinckerhoff, 2010).

Fill is common along the project alignment ranging from shallow fill associated with landscaping to more extensive fill imported for the construction of buildings. More substantial filling has occurred along low lying areas such as reclamation works associated with the Cooks River and Alexandra Canal, Tempe Recreational Reserve, Kogarah Golf Course and Sydney Airport.

Perched groundwater is present within the fill at various locations along the alignment. The most substantial fill deposits are at the Alexandria Landfill have been infilled with uncontrolled fill to depths of 35 metres to 40 metres.

Botany Sands aquifer

The Botany Sands aquifer is a shallow, unconfined aquifer with a high hydraulic conductivity consisting of clay, silt and medium grained sand. The thickness of the unit is variable but is approximately ten metres thick at Alexandra Landfill and up to 15 metres thick at Kogarah Golf Course.

Groundwater levels are variable but under natural conditions are typically within five metres of the ground surface. Rainfall, tidal fluctuations and seasonal variations can result in temporal changes in the groundwater levels. Regionally groundwater flow is eastward discharging into Botany Bay and Alexandra Canal. The groundwater level can be influenced by other local factors such as distance from recharge and discharge areas, local development and dewatering.

The Botany Sands aquifer naturally contains low salinity groundwater which is moderately acidic. However, in many areas it has been contaminated by industrial activities, most notably in the southern portion of the aquifer near the Botany Industrial Park where groundwater use has been embargoed due to contamination. .

Variations in the groundwater quality in the Botany Sands aquifer can be attributed to a number of factors including:

- Proximity to recharge
- Presence of ponds and other wetlands (either enhanced recharge or enhanced evaporation loss)
- Localised recharge by infiltration of rainfall
- Presence of peaty sediments (elevated sulphide concentrations)
- Local seawater intrusion
- Industrial development (variety of chemical compounds)

- Application of fertilisers
- Leakage from sewage systems or petrol stations.

At the southern perimeter of the Alexandria Landfill, groundwater within the Botany Sands would have naturally flowed to the south discharging into Alexandra Canal.

Development of the quarry and later the landfill has created a sump locally reversing groundwater flow conditions within the Botany Sands. Groundwater levels within the Botany Sands between the landfill and Alexandra Canal range from minus two metres AHD to one metre AHD and are influenced locally by two groundwater extraction schemes, the landfill's leachate pumping system and discharge to the landfill and Alexandra Canal.

A groundwater divide has been inferred within the Botany Sands between the landfill and Alexandra Canal (Woodward Clyde, 1998). Groundwater to the north of the divide flows towards the landfill and groundwater to the south of the divide flows towards the canal. The presence of a groundwater divide indicates there is no groundwater flow between the landfill and Alexandra Canal. The findings of the groundwater investigations conducted as part of this groundwater impact assessment are consistent with the conclusions of Woodward Clyde. The local hydrogeological regime at Alexandria Landfill is discussed further in **Appendix Q**.

At Alexandria Landfill, groundwater flow from the Botany Sands into the landfill increases leachate generation. As part of the closure and ongoing management of the Alexandria Landfill site, it is proposed to engineer a solution by the construction of a cut-off wall to significantly reduce groundwater inflow and hence leachate generation. The cut-off wall has been designed to be around 1000 metres in length, with a thickness of 0.8 metres and hydraulic conductivity of 10^{-8} metres per second.

The Botany Sands aquifer is used beneficially for a number of purposes including irrigation, watering market gardens and domestic use. Groundwater is typically extracted from shallow spear points via vacuum extraction systems at groundwater yields typically up to two litres per second.

The NSW DPI Water advises that the whole Botany Sands hydrogeological unit is over allocated and to extract groundwater a water allocation must be bought on the open market.

Kogarah Golf Course is also underlain by the Botany Sands where ventilation shafts and tunnel ramps are to be constructed as part of the project.

Palaeochannels

Palaeochannels are ancient rivers that have subsequently become infilled with sediments. Deep incised palaeochannels have been carved into the sandstone and shale bedrock that underlie the study area and form deep drainage systems. In many cases they underlie the existing river systems such as Cooks River and Wolli Creek but also underlie Botany Sands and are independent of the current surface drainage systems such as the Arncliffe Station Palaeochannel.

The palaeochannels are of Pleistocene age and are older than the overlying Botany Sands. These palaeochannels are infilled with up to 50 metres of saturated heterogeneous sediments comprising alluvium, estuarine and marine deposits. The palaeochannels typically underlie alluvium associated with modern rivers or gullies and drain to the east towards Botany Bay. The sediments have a high hydraulic conductivity and water quality is variable but is typically saline.

Ashfield Shale

The Ashfield Shale caps ridgelines over the majority of the alignment outcropping west and north of Sydney Airport with the shale extending to a depth of up to 50 metres. The shale is a marine deposited sequence consisting of fine grained particles including clay, silt and sand that has undergone minor deformation and has developed into a laminated shale. The thickness of the shale is not well understood due to limited drilling data intersecting the shale. In general the shale can vary from a few metres thick to in excess of 50 metres.

Groundwater flow within the Ashfield Shale is poor due to the limited pore space (low porosity) and poor connectivity of the bedding planes. The majority of groundwater flow is via saturated fractures and joints with limited flow being via the rock matrix. The bulk hydraulic conductivity is typically low due to the poor connectivity of joints, fractures and bedding planes.

Regionally, the Ashfield Shale forms an aquitard reducing groundwater infiltration to the underlying Mittagong and Hawkesbury Sandstone Formations. Groundwater quality within the shale is highly variable but is typically brackish or saline, due to the marine salts contained within the shale.

The shale aquifer is characterised by low yields, limited storage and poor groundwater quality. Salinities typically range from 5,000 mg/L to 12,000 mg/L total dissolved solids (TDS) but may be up to 40,000 mg/L causing the groundwater to be corrosive to building materials.

Hawkesbury Sandstone

The Hawkesbury Sandstone is the dominant lithology across the project area and the majority of the project tunnels would be constructed through this competent sandstone. Lithologically the Hawkesbury Sandstone is described as a medium to coarse grained quartzose sandstone. The formation extends across the whole Sydney Basin and is up to 290 metres thick. The deepest boreholes drilled as part of this investigation into the Hawkesbury Sandstone was 110 metres and the base of the unit was not reached.

The Hawkesbury Sandstone is characterised as a dual porosity aquifer, possessing low intrinsic hydraulic conductivity. That is, groundwater is transmitted both within the interconnected void spaces between grains of the rock matrix (primary porosity) and also within structural features such as joints, fractures, faults, shear zones and bedding planes (secondary porosity).

The Hawkesbury Sandstone is not one aquifer but several 'stacked aquifers' due to the heterogeneous and layered nature of the unit. Hydraulic connectivity between the 'stacked layers' is variable, but it is common to have different hydraulic heads at various depths indicating poor connectivity. Interbedded shale lenses can provide local or extensive confining layers creating separate aquifers with different hydraulic properties including hydraulic heads.

The hydraulic conductivity of the Hawkesbury Sandstone is low (in the order of 10^{-3} to 10^{-1} metres per day) and fracture related storage is less than two per cent although unconfined matrix storage can be higher.

The groundwater quality within the Hawkesbury Sandstone is generally acidic and the salinity is variable but typically lower than the groundwater within the Ashfield Shale. Where the Ashfield Shale overlies the Hawkesbury Sandstone the salinity of the Hawkesbury Sandstone is typically elevated due to leakage of saline groundwater from the overlying Ashfield Shale. Groundwater within the Hawkesbury Sandstone tends to have naturally elevated iron and manganese concentrations. These elevated concentrations of dissolved iron and manganese naturally occur within the Hawkesbury Sandstone which can cause staining when discharged and oxidised.

Regionally, groundwater in the Hawkesbury Sandstone flows eastward discharging into the Tasman Sea. Recharge is via rainfall infiltration on fractured outcrop and through the soil profile. Discharge is via seepage to cliffs and creeks and evapotranspiration.

Groundwater levels

Groundwater levels are influenced by topography, creeks, rainfall, recharge and manmade structures. Natural groundwater levels are expected to generally reflect a subdued shape of the topography; the groundwater being deeper beneath hills and shallowest beneath creeks or gullies.

Measured groundwater levels within the Hawkesbury Sandstone along the alignment were lowest at Earlwood (WCXBH084 -4.93 metres AHD) and highest in Bardwell Park (WCXBH093, 24.2 metres AHD).

Monitoring has confirmed the groundwater table is impacted by infrastructure such as pumping or along the alignment of the M5 East Motorway tunnel which is a drained tunnel (allowing low levels of groundwater infiltration into the tunnel).

Conversely in some areas the local groundwater table may be elevated above natural conditions due to irrigation such as at the Kogarah Golf Course or subsurface structures such as infrastructure or building foundations that inhibit groundwater flow causing localised groundwater mounding.

Most of the project groundwater monitoring wells intersect the Hawkesbury Sandstone. All monitoring wells have been constructed with a three metre screen interval which varies in depth between 19 metres and 85 metres below ground level.

The groundwater elevation recorded at these monitoring sites is highly variable and dependent upon the topographical expression. Groundwater levels within the Hawkesbury Sandstone vary from 1.5 metres to 35 metres below ground level and from -1 to 24.2 metres AHD. Large vertical gradients are apparent in topographically high areas around Bardwell Park and Kingsgrove.

Groundwater level monitoring within the Ashfield Shale has been conducted to the east of the project alignment where the shale outcrops. Monitored groundwater levels in and around Alexandria Landfill in Ashfield Shale are influenced by the leachate pumping system that causes groundwater to flow towards the centre of the landfill. This radial flow pattern prevents contamination from the landfill dispersing into the Ashfield Shale and Botany Sands. Groundwater elevations within the Ashfield Shale vary from three to 15.5 metres below ground level or from minus 1.5 metres AHD to five metres AHD.

Limited groundwater level monitoring has been conducted within the alluvium and Basalt dykes. Groundwater levels have been measured in the Botany Sands, south of the Alexandria landfill and range from one metre below ground level to 10 metres below ground level (equivalent to minus 1.5 metres AHD to one metre AHD). Groundwater levels are influenced by groundwater abstraction and discharge to the landfill and Alexandra Canal. Groundwater levels beneath Kogarah Golf Course have not been measured but are expected to be shallow (in the order of two to three metres below ground level).

Groundwater levels within the basalt have been monitored in one monitoring well located at Tempe at 4.2 metres below ground level or minus 0.2 metres AHD.

Groundwater level fluctuations as monitored by the data loggers installed at project groundwater monitoring locations indicate that the fluctuations for most monitoring wells are less than one metre, suggesting that:

- The Hawkesbury Sandstone groundwater system is in equilibrium
- There are no external impacts on the hydrogeological regime
- Groundwater levels are not influenced by any external major feature.

In the context of tunnelling this means that hydrostatic pressures will not be significantly influenced by seasonal climatic variations, although drawdown into the tunnels is likely to be a larger influence.

Hydraulic conductivity

The packer test results are summarised in **Table 19-6**. Results of the packer tests are expressed as Lugeon units where one microlitre is equivalent to a hydraulic conductivity of $1x10^{-7}$ metres per second (8.8×10^{-3} metres per day).

The distribution of packer test results for all lithology's are presented in **Appendix Q**. **Table 19-6** shows that the majority of the rock mass results are classified as of low hydraulic conductivity suggesting that inflow rates would be low.

Table 19-6 Monitored hydraulic conductivity for each hydrogeological unit (metres per day)

Relative permeability	Basal	Ashfield Shale	Mittagong Formation	Hawkesbury Sandstone
Average	0.02	0.02	0.1	0.08
Minimum	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Maximum	0.04	0.07	0.9	4.3
Median	0.02	0.003	0.01	0.003
Number of samples	2	6	10	205

Due to the hydraulic conductivity in the Hawkesbury Sandstone and Ashfield Shale being mainly associated with secondary porosity (such as bedding planes, fractures and laminations), groundwater flow within the unit is primarily parallel to bedding.

Accordingly, the vertical hydraulic conductivity of the bedrock formations (vertical to bedding) is much lower than the horizontal hydraulic conductivity (parallel to bedding). This means that groundwater flow will tend to be dominated in a horizontal direction rather than vertically. The ratio of horizontal to vertical hydraulic conductivity can be around one and three orders of magnitude (ie 10 to 1,000 times).

Ashfield Shale generally has a lower overall hydraulic conductivity than Hawkesbury Sandstone, indicating groundwater flow through the shale is much slower than through the sandstone. The Ashfield Shale weathers to clay and silty clay resulting in a weathered soil profile with a reduced bulk hydraulic conductivity which can restrict recharge to the underlying shale and sandstone. Groundwater generally does not easily flow through Ashfield Shale in either a horizontal or vertical direction, particularly when compared with Hawkesbury Sandstone.

Falling head tests within the Botany Sands conducted as part of the Alexandria Landfill investigations (AECOM, 2015j) calculated a hydraulic conductivity range of 0.6 to 0.9 metres per day which was consistent with similar previous investigations,

Groundwater inflow in existing Sydney tunnels

The project tunnels would be constructed as drained tunnels, with ongoing groundwater inflow, capture and discharge. That is, the tunnel would be largely unlined allowing groundwater to seep into the tunnel from the competent Hawkesbury Sandstone and Ashfield Shale to be collected in drains within the tunnel and discharged.

The project would be constructed to limit groundwater inflow along the tunnel length to no greater than one litre per second across any given kilometre of tunnel. In areas of high local hydraulic conductivity, the natural rock mass permeability may have to be reduced by using shotcrete and grout. Groundwater inflow is to be collected in a drainage system, pumped to the surface for treatment and discharge. In contrast, undrained tunnels are lined to prevent water ingress into the tunnel, although in practice there is likely to be some minor seepage.

Limiting groundwater inflow into the tunnel to one litre per second per kilometre is a design requirement of the project. Rates of groundwater inflows from several unlined tunnels in the Sydney area with similar geology, hydrogeology and construction to the New M5 alignment have been identified in **Table 19-7**.

Inflow rates from other drained Sydney road tunnels vary from around 0.9 litres per second per kilometre inflow to less than three litres per second per kilometre.

Although these tunnels are drained, water proofing has been installed in high inflow zones to restrict groundwater inflow to the tunnels which is consistent with the proposed tunnel construction methodology for the project.

This inflow criterion refers primarily to the Hawkesbury Sandstone as the inflow from the Ashfield Shale will be significantly less due to the lower hydraulic conductivity and storativity of the shale. Any tunnel infrastructure that intersects the Botany Sands would require shoring and water proofing to stabilise the excavation and reduce the risk of groundwater inflow.

Historically in drained Sydney tunnels in the Hawkesbury Sandstone, a one litre per second per kilometre limit has developed as an average across the length of the tunnel. The criterion is not set as a regulatory requirement but has evolved as a realistic inflow rate.

In order to drive improved design outcomes, the project has applied this limit as an average measured across any kilometre of the tunnel (rather than the less stringent approach of applying it as an average along the entire tunnel). The total length of twin tunnels for the project is around nine kilometres. Therefore, the maximum discharge rate for each length of tunnel would be around nine litres per second (0.8 megalitres per day) or 18 litres per second (1.6 megalitres per day) for both tunnels.

Table 19-7 Measured inflow rates from other drained Sydney Tunnels

Tunnel	Type	Width (metres)	Length (kilometres)	Inflow (litres per second per kilometre)	Reference
Eastern Distributor Tunnel	Three lane road tunnel	12 (double deck)	1.7	1	Hewitt, 2005
Cross City Tunnel	Twin two lane road tunnels	8 (twin)	2.1	<3	Best and Parker, 2005
M5 East Motorway Tunnel	Twin two lane road tunnels	8 (twin)	3.8	0.9	Tammetta and Hewitt, 2004
Epping to Chatswood Rail Tunnel	Twin rail tunnels	7.2	13	0.9	Best and Parker, 2005
Lane Cove Tunnel	Twin three lane road tunnels	9 (twin)	3.6	0.6/1.7*	Coffey, 2012
Northside Storage Tunnel	Sewer storage tunnel	6	20	0.9	Coffey, 2012

*measured inflow in Lane Cove Tunnel varied from 1.7 litres per second per kilometre in 2001 to mid-2004 to 0.6 litres per second per kilometre in 2011.

19.2.5 Groundwater quality

The groundwater quality has been characterised prior to development to establish background conditions. This dataset will be used for comparison of post development groundwater quality monitoring. The natural groundwater quality is also required to meet discharge requirements and to inform the design of water treatment requirements. Groundwater can also be corrosive to building materials depending on hydrogeochemical factors including salinity, pH, sulfate and chloride concentrations. Understanding the corrosive nature of the natural groundwater intersected by the project assists in selecting building materials to minimise corrosive impacts to the project tunnels.

At Alexandria Landfill leachate is generated by the continual decomposition of waste within the landfill interacting with groundwater and rainfall infiltration. The leachate quality has been characterised through ongoing monitoring programs in accordance with the environment protection licence conditions. The leachate typically has elevated concentrations of ammonia and minor hydrocarbon contamination. Concentrations of total dissolved solids measured quarterly since 1996 range from 2,030 mg/ L to 6,450 mg/ L of total dissolved solids. The leachate is collected through a herringbone drainage network at the base of the landfill and pumped to an on-site treatment plant before discharge to sewer under a trade waste agreement. Leachate collection, treatment and discharge would continue after the construction of St Peters interchange through a new purpose built water treatment plant.

Background groundwater quality conditions for the various hydrogeological units are outlined in **Section 19.2.3**. A summary of the major hydrogeochemical parameters are outlined in **Table 19-8**.

Table 19-8 Summary of average major hydrogeochemical parameters

Parameter	Botany Sands	Ashfield Shale	Hawkesbury Sandstone
pH	6.2	6.2	6.25^
Salinity^^	8,983 milligrams per litre	6,537 milligrams per litre	4,560 milligrams per litre
Chloride (Cl)	2,405 milligrams per litre	1,314 milligrams per litre	777 milligrams per litre
Sulphate (SO4)	566 milligrams per litre	75 milligrams per litre	197 milligrams per litre
Total Iron (Fe)	62 milligrams per litre	10 milligrams per litre	5.1 milligrams per litre
Manganese	-	-	0.44 milligrams per litre
Number of samples	2	3	17

^Some field results not available ^^Salinity based on laboratory electrical conductivity

19.2.6 Groundwater receivers

Local groundwater use is generally low because the area has reticulated water supply provided by Sydney Water. Registered boreholes are constructed for many purposes including monitoring wells, groundwater extraction for domestic, irrigation, recreation purposes and exploration test bores.

A total of 61 registered boreholes were identified within the study area using the NSW Office of Water/ Bureau of Meteorology and Pinneena Groundwater Database (as shown in **Figure 19-3** to **Figure 19-6**). These boreholes have been grouped into five broad geographical areas. The geographical distribution of the boreholes falls within three general populations as follows.

- West of Arncliffe along existing M5 East Motorway (three boreholes) (**Figure 19-3** and **Figure 19-4**)
- At and near the Kogarah Golf Course at Arncliffe (15 boreholes) (**Figure 19-5**)
- At Tempe, St Peters and Alexandria (43 boreholes) (**Figure 19-6**)

A summary of the registered boreholes is provided in **Table 19-9**.

Table 19-9 Summary of registered bores within one kilometre of the project corridor

Purpose	Number of boreholes	Predominant lithology	Standing water level (metres)		Borehole depth (metres)	
			Minimum	Maximum	Minimum	Maximum
Water supply	31	Sand	0.3	8.22	3	108
Monitoring	21	Sand	0.16	37	2.8	162
Other	10	Sand	0.7	10.97	3.5	186

Review of the lithological data indicates the majority of boreholes are shallow (less than 10 metres) and extract groundwater from the sand. The raw bore records do not indicate the geological unit that the sand is associated with, however it is interpreted as either Botany sands or alluvium. Only 11 out of the 61 bores intersect the sandstone (eight) or shale (three). Drawdown within the alluvial boreholes is expected to be minimal as these hydrogeological systems are continually recharged.

19.2.7 Groundwater dependent ecosystems

GDEs are defined as ecosystems whose current species composition, structure and function are reliant on a supply of groundwater as opposed to surface water supplies from overland flow paths. The majority of ecosystems in Australia have little to no dependence on groundwater, although the full understanding of the role of groundwater in maintaining ecosystems is generally poor. The exception to this is wetland communities, for which it is thought that most have some level of dependence on groundwater resources. Shallow groundwater can support riparian vegetation either permanently or seasonally. Groundwater needs to be sufficiently shallow to support vegetation where root systems of vegetation communities are able to access groundwater.

A search of the GDE Atlas (Bureau of Meteorology) indicated that there are two GDEs within the study area. These include:

- Cooks River Castlereagh Ironbark Forest within Beverly Grove Park. There is about 1.8 hectares of this threatened ecological community, containing several native vegetation communities which are indicative of shallow groundwater tables and waterlogged soils. The GDE Atlas marks the Cooks River Castlereagh Ironbark Forest as being highly likely to have an inflow dependence on groundwater. The extent of this vegetation community is shown in **Chapter 21** (Biodiversity)
- The Cooks River is likely to be an inflow dependent GDE.

An additional three GDEs have been identified outside of the study area, but within the extent of land potentially impacted by groundwater drawdown:

- Seventeen hectares of Hinterland Sandstone Gully Forest with a moderate to high potential to be dependent on groundwater within Bardwell Valley Parkland and Broadford Street Reserve
- About 3.5 hectares of Coastal Sandstone Ridgetop Woodland within Stotts Reserve, Bexley North. This vegetation has a moderate to high potential to be dependent on groundwater
- About 3.4 hectares of Estuarine Fringe Forest between the southern bank of Wolli Creek and the rail line behind Wolli Creek Station, with a low to moderate potential to be dependent on groundwater

Outside the study area are the Towra Point Wetlands. These wetlands are a Ramsar listed (global environmental agreement) site and an estuarine complex comprising a mixture of spits, bars, mudflats, dunes and beaches located 6.8 kilometres south of the project corridor.

Chapter 21 (Biodiversity) further describes GDEs.

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Figure 19-3 Existing bores surrounding the project - Western surface works

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Figure 19-4 Existing bores surrounding the project - Bexley surface works

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Figure 19-5 Existing bores surrounding the project - Arncliffe surface works

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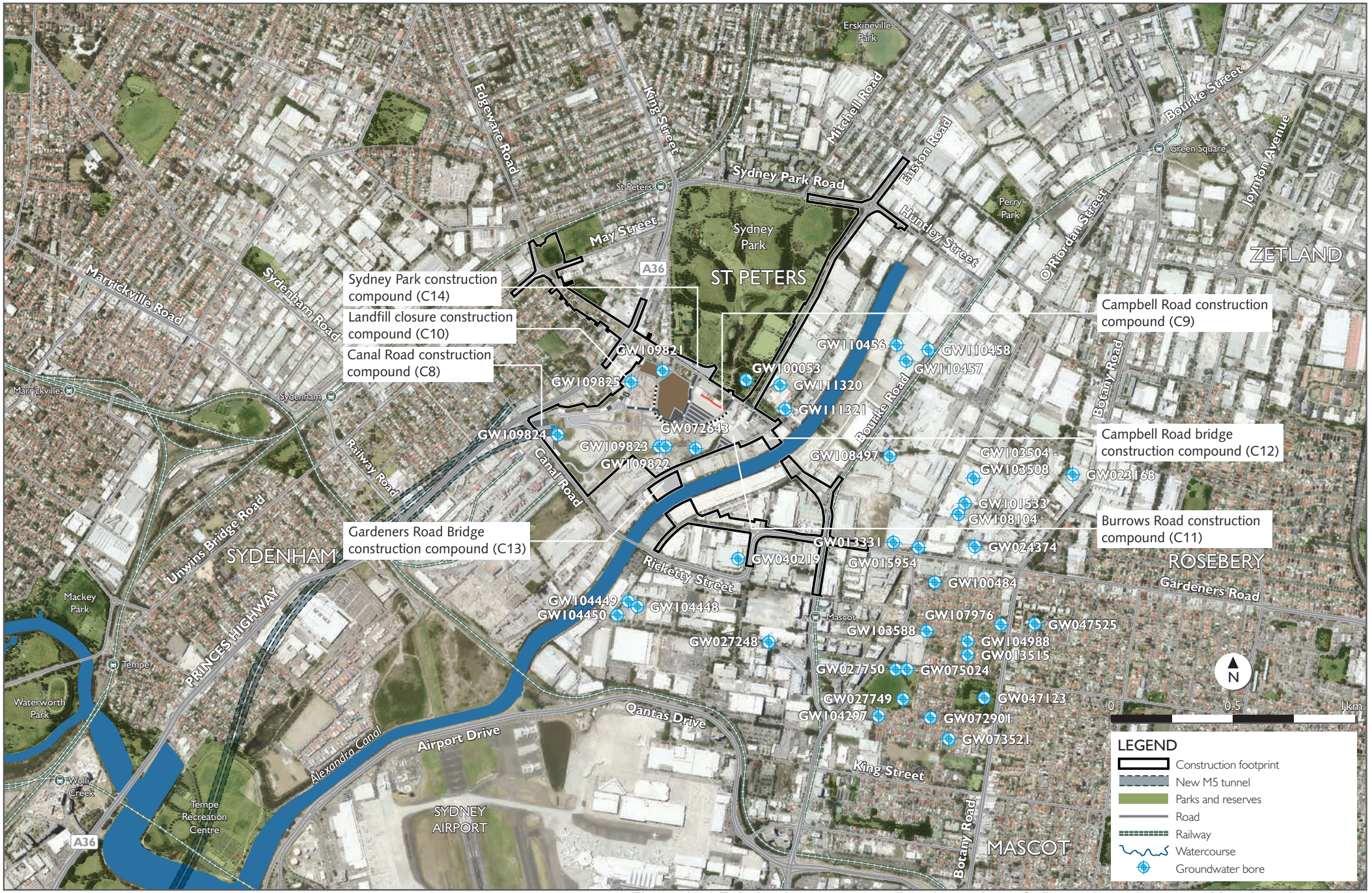


Figure 19-6 Existing bores surrounding the project - St Peters interchange and local road upgrades

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19.3 Assessment of potential impacts

Construction works and operational infrastructure have the potential to change groundwater behaviour and impact on the surrounding environment. An assessment of impacts has been carried out in accordance with the guidelines outlined in **Table 19-2**.

19.3.1 Construction

Groundwater along the project alignment has the potential to be impacted during the construction phase of the project. The potential impacts that have been identified are:

- Groundwater inflow
- Groundwater drawdown
- Reduced groundwater recharge
- Implications for existing groundwater users
- Changes in groundwater quality
- Impacts to the environment, including environmental receivers dependent on groundwater
- Disturbance of acid sulfate soils.

Each of these potential impacts is discussed below.

Groundwater inflow

Groundwater inflow is influenced by the geology and the geological structural features the tunnels intersect.

The tunnels are to be constructed predominately through the competent Hawkesbury Sandstone and to a lesser extent the Mittagong Formation and Ashfield Shale. The tunnel alignment is designed to not intersect the palaeochannels beneath Cooks River and Bardwell Valley by diving below these features. In the unlikely event that a palaeochannel is encountered, appropriate waterproofing would be installed by the construction contractor.

Groundwater inflow from the Hawkesbury Sandstone is expected to be low due to low bulk hydraulic conductivity values typically 0.008 metres per day. The Ashfield Shale overlying the Hawkesbury Sandstone typically has a lower hydraulic conductivity in the order of $1x10^{-3}$ to $1x10^{-2}$ metres per day (Hewitt, 2005) indicating groundwater inflow is expected to be lower.

Higher hydraulic conductivity values are expected along major structural features within the sandstone and shale such as joints, fractures and shear zones where higher inflows are expected. Higher inflows may also occur in dykes, Botany Sands, alluvium and palaeochannels.

Botany Sands

The majority of the project would be constructed below the Botany Sands where groundwater inflow should be limited. Beneath the Botany Sands there is a residual alluvial clay that separates the sands from the underlying bedrock and forms a hydraulic seal or aquitard. If there are locations where the clay has been eroded then there is potential for groundwater from the Botany Sands aquifer to enter the tunnel via fractured rock or downward leakage induced by drawdowns in the underlying Hawkesbury Sandstone. This downward leakage could potentially occur anywhere within the area of drawdown in the Hawkesbury Sandstone caused by tunnel drainage.

The project would have construction activity in sections of Botany Sands at Arncliffe and Alexandria Landfill. At Arncliffe, shafts to the motorway operations complex would be constructed using retaining walls to prevent groundwater inflow and stabilise the Botany Sands. Groundwater inflow from the Botany Sands is a major contributor to leachate generation at the Alexandria Landfill. Groundwater inflow at the site is currently managed by a pump and treat system, and discharged to sewer. A longer term solution for managing this inflow is discussed in Section 6.7 of the Technical working paper: Groundwater (**Appendix Q**).

Alluvium

As with the Botany Sands aquifer, alluvium associated with the Cooks River and its tributaries are saturated. Since the alluvium is hydraulically connected to the river, water can potentially flow from the alluvium via fractured sandstone or shale into the tunnel alignment.

Palaeochannels

Deep incised palaeochannels infilled with saturated sediments are present beneath the Cooks River and extend up to 50 metres below the ground surface. To reduce the risk of large groundwater inflows to the tunnel from the palaeochannels, it is proposed to construct the tunnels beneath these geological features.

Dykes

Dykes cross-cut the Hawkesbury Sandstone and Ashfield Shale and when competent or weathered to clay can form natural hydraulic barriers. Alternatively, the metamorphosed zone around the volcanic intrusion within the sandstone or shale can be fractured causing a conduit for preferred groundwater flow. Several dykes have been identified along the alignment.

Predicted groundwater inflows

Groundwater modelling predicted inflows of 1,115 cubic metres per day into the project tunnels. Over a modelled length of 20 kilometres an inflow rate of 0.63 litres per second along every kilometre of east bound (shallower) tunnel and 0.67 litres per second along every kilometre of the westbound (deeper) tunnel was predicted.

Groundwater modelling is based on well-established scientific principles, but predictions can be uncertain, because of the difficulty of inferring the properties of a large volume based on a relatively small number of measurements. In many respects, from a groundwater modelling point of view, an estimate of 0.6 litres per second along every kilometre is equivalent to an estimate of 1 litres per second along every kilometre. In this case, the fact that the model predicts a lower value for the proposed tunnels than for the existing tunnels means that geometry (depth of tunnels and hydrostratigraphy) and spatial variability in vertical and horizontal hydraulic conductivities combine to suggest smaller flows into the proposed tunnels.

The modelling has not predicted inflow rates during construction, but rather has predicted long term steady state inflows that would only apply once equilibrium has been reached. While it would in principle be possible to predict the evolution of leakage during construction, this is extremely difficult, mainly because the short term tunnel inflows are influenced by local fracturing and storage of water in nearby fracture networks (CDM Smith, 2015).

The predicted inflow rates are therefore long-term operational phase inflow rates. Initial inflows to tunnels during construction can be large, because of the large hydraulic gradients that develop near the walls, however these gradients dissipate in time as inflows approach a steady state. That is, during construction large inflows can be experienced for a short duration as the confined storage from water bearing fractures is released due to water expanding slightly as pressure drops. After the initial confined storage is released, inflow rates decline as storage is depleted and groundwater levels begin to decline. Eventually, steady state equilibrium is reached where rainfall recharge is balanced with groundwater inflow to the tunnels and the groundwater levels no longer decline due to tunnel inflows. The higher inflow rates during construction have been considered when assessing the construction impact assessment and mitigation and management measures.

It should also be stated that the model predicts average inflow rates. Higher rates are likely from zones of higher permeability, where saturated geological structural features are intersected. During construction these high inflow zones are to be grouted to reduce the inflow rate below one litre per second per kilometre.

During tunnelling, groundwater would be intersected and would be managed by either capturing the water that enters the tunnels and caverns and portals or restricting inflow by temporary dewatering or the installation of cut-off walls. During construction, long term water management solutions would also be constructed such as the installation of water proofing membranes. Groundwater inflows would be collected via the drainage system and pumped to the surface for treatment and discharge. Inflows into the tunnel during construction would be managed by contractors, and would have no immediate effect on the water table or GDEs.

It is recognised that high groundwater inflow during excavation is possible in faulted or fractured zones or other water bearing geological features such as beneath the Cooks River palaeochannels or beneath Wolli Creek. During construction, hydraulic gradients near the exterior surface of the tunnel are steep causing initial rates of inflow to be greater than at later stages.

To reduce groundwater inflows, pre-excavation pressure grouting would be undertaken to allow groundwater inflows to be more easily managed. This technique is undertaken by drilling a pattern of holes in advance of the excavation to conduct packer tests. Once the hydraulic conductivity is calculated grout is injected at a pre-determined pressure to reduce the bulk rock mass permeability. The implementation of this technique is dependent upon the local geology.

At the dive structures and shafts, groundwater flow within the fill, alluvium and weathered shale would be restricted by the construction of retaining walls such as secant pile, sheet pile walls or diaphragm walls founded in the Hawkesbury Sandstone.

The shafts constructed at the Bexley Road North and South construction compounds will intersect the Botany Sands and Hawkesbury Sandstone. Temporary shoring will be implemented during construction to stabilise the unconsolidated sands and reduce groundwater inflow. Temporary dewatering of the Botany Sands is likely to be required during construction which is typically undertaken by the installation of a series of spearpoints connected to a vacuum system. Water would be directed to the temporary construction water treatment plants prior to discharge into the stormwater system under license. Water treatment and discharge to stormwater will ensure minimal water quality impact on the local hydrology.

The shoring will be socketed into the underlying Hawkesbury Sandstone. Groundwater inflow from the Hawkesbury sandstone will be managed by the contractors in much the same way as during the road tunnelling methodology.

At Alexandria Landfill, water entering the former quarry is to be restricted by engineering solutions into the tunnel infrastructure design. Rainfall infiltration is to be restricted by capping the landfill and directing captured rainfall runoff off-site. Groundwater flow into the landfill from the Botany Sands is to be restricted by the construction of a cut-off wall around the southern perimeter of the landfill. This would locally reverse groundwater gradients away from the landfill and towards Alexandra Canal restoring pre-quarry hydrogeological conditions. The construction of the wall would reduce the pre-construction requirement of pumping groundwater from the Botany Sands to stormwater to reduce leachate generation.

Groundwater drawdown

Groundwater drawdown due to construction activities and temporary dewatering could impact the local groundwater table or surface water features where there is a hydraulic connection to groundwater. As the project tunnels would be drained structures, the tunnels could impact the natural groundwater system and potentially alter regional hydrogeological conditions.

During construction, the drawdown impacts due to tunnel construction would be minimal even though groundwater inflows are high due to high hydraulic gradients. That is, during tunnelling there is initially no drawdown at the water table, but eventually over time and certainly within tens of years, the effects of depressurisation at depth impact the water table causing a water table decline. This suggests that if water level elevations had been measured directly over the centreline of the M5 East tunnels, a transient decline would have been in observed in the past 15 years or so during which the water table would have started to fall and may ultimately have approached a steady state.

A steady state analysis predicts the equilibrium position of the water table, and the worst case scenario for the potential impact of tunnelling on the water table. The prediction remains uncertain, because of the relatively small number of measurements of water table elevation near the existing M5 East tunnels, especially directly along their centrelines.

The hydraulic conductivity of the Botany Sands is variable but previous investigations in the Botany Sands, such as at Alexandria Landfill, indicate that the hydraulic conductivity ranges from around 0.1 to five metres per day depending on the clay content. The volume of groundwater to be pumped during temporary dewatering is dependent on the hydraulic conductivity with the higher clay content reducing the volume of groundwater to be pumped. Dewatering is required to provide dry working conditions during construction.

Reduced groundwater recharge

The project is located in an urbanised part of Sydney where rainfall recharge is already reduced by hardstand areas and roofs directed to stormwater.

The majority of groundwater recharge occurs in parks, gardens, bushland and golf courses. Within the eastern portion of the project area, where the Botany Sands outcrop, groundwater recharge would be expected to be higher than areas underlain by sandstone and shale. This is due to the sands having a higher capacity to accept rainfall infiltration and the plumbing of some buildings directing stormwater to infiltration basins or trenches rather than stormwater.

The majority of the project is below ground surface and therefore is unlikely to directly impact groundwater recharge during construction. The potential impacts during the construction phase would be access roads, tracks and the isolation of areas for stockpiling of construction materials. This could potentially alter or reduce groundwater recharge. However, these impacts would be minor and temporary.

Alexandria Landfill would be capped to reduce recharge. Surface water run-off from the cap and road infrastructure would be directed off-site.

Impacts on existing users

A review of current groundwater use has been conducted to identify registered groundwater users within a one kilometre buffer of the project tunnel alignments. A three dimensional numerical groundwater model has been developed to assess the potential groundwater level drawdown at sensitive areas and where the impacts are expected to be in excess of two metres (in accordance with the Aquifer Interference Policy).

Existing users may be affected during construction through potential drawdown due to the extraction of groundwater during tunnelling. The drawdown is expected to be less in the construction phase than during the operational phase, since groundwater levels would continue to decline until steady state conditions are reached. Drawdown due to tunnel operation is discussed in **Section 19.4.2**.

There is potential for groundwater extracted from the alluvium to become more saline due to inducing saline water from tidal rivers towards groundwater bores. However, it is likely that alluvial groundwater hydraulically connected to the tidal rivers is already saline so the potential for further significant reductions in water quality is low.

Impacts to the environment

Drawdown beneath creeks and other surface water bodies could occur where they overlie the project. Losses to stream flows are dependent on the hydraulic connection between the stream channel and alluvium, and the underlying sandstone or shale. Long term predictions indicate that groundwater drawdown west of Arncliffe is expected to be less than other areas along the alignment. This is likely due to the drawdown caused by the existing drained M5 East Motorway tunnel.

The predicted extent of lateral drawdown would vary from approximately 500 metres in the western part of the project alignment to approximately one kilometre elsewhere. The lateral footprint of drawdown within the alluvium would be variable but less than the extent within the bedrock. Drawdown within the sandstone is unlikely to extend to the top of the project tunnels due to the interbedded sandstone and shale layers above the tunnels behaving as aquicludes restricting groundwater drawdown combined with rainfall recharge.

Shallow tunnels that dive beneath incised water courses or water bodies could be hydraulically connected with creek beds causing localised elevated inflows to tunnels and potential surface water losses. The alignment passes beneath several creeks. These creeks comprise of small ponds, mainly recharged by urban runoff in relatively small catchments. The tunnel cover varies between about 12 metres and 33 metres at the various watercourses and surface settlements due to groundwater drawdown are estimated at approximately 17 millimetres to 20 millimetres at these locations. Grouting or an impermeable membrane would be used where inflows are elevated beneath the watercourses to minimise these impacts.

Groundwater quality impacts

There is potential to contaminate groundwater from fuel and chemical spills, particularly if a leak or incident occurs over the Botany Sands or fractured sandstone. Spills as a result of incidents could occur during construction activities, refuelling operations or from storage areas. Stockpiling of construction materials may also introduce contaminants to the area.

Current and historical land-uses with the potential for contamination are located along the project alignment. The potential contamination risk to the project tunnels and caverns would be associated with the migration of contaminated groundwater plumes towards the tunnels. The majority of the tunnels would be constructed within the Hawkesbury Sandstone at depths greater than 20 metres at the western and eastern ends and up to 80 metres beneath Bardwell Park. Given these combined factors of the depth, location of the tunnels in relation to the contaminant source and low inflow rates, the risk of intercepting contaminated groundwater would be low.

Potential contaminated groundwater inflows could be derived from industrial sites that overlie the project tunnels at Alexandria, where the tunnels are relatively shallow but constructed within the Ashfield Shale. At 316 Princes Highway there is a former service station where underground fuel tanks remain which may potentially result in petroleum hydrocarbon impacts. Cut and cover ramp portals would be constructed near this site. However, the risk of significant interaction with contaminated groundwater in this area would be low because the ramps and project tunnels would constructed within the Ashfield Shale where the hydraulic conductivity and groundwater leakage would be low.

Leachate and elevated concentrations of ammonia are associated with the Alexandria Landfill. Geotechnical drilling to inform the design of the project did not identify localised faulting or fracturing which could provide leachate conduits.

Immediately south of the Alexandria Landfill, at the Canal Road site, lead contamination has been identified (AECOM, 2015d). The cut-off wall that would be constructed south of Alexandria Landfill (as part of the closure of the landfill) has been designed to reduce leachate generation by reducing groundwater inflow from the Botany Sands into the landfill. In addition, the lead impacted groundwater south of the landfill will continue to be directed to the landfill as a consequence of the cut-off wall where it will be extracted and treated prior to discharge to sewer.

Capping the landfill and construction of the cut-off wall is designed to reduce rainfall infiltration to the Botany Sands inside the cut-off wall. Therefore, groundwater recharge inside the cut-off wall would be reduced which would ultimately reduce the volume of leachate being generated.

Consequently the leachate generated post-construction is likely to contain a higher concentration of contaminants pre-construction that require treatment. Outside the cut-off wall, groundwater recharge is unlikely to be significantly impacted as this area will not be caped, although the paved area is likely to increase due to the construction of the road infrastructure.

Groundwater quality within the Botany Sands outside the wall is likely to be improved due to the groundwater contaminated with lead associated with the Canal Road site being captured by the cut-off wall.

The Botany Sands in the vicinity of the landfill is isolated from the remainder of the Botany Sands by the Alexandra Canal. No groundwater users have been identified within the narrow extent of sands that parallel the Alexandra Canal. Consequently construction activities are unlikely to impact any sensitive groundwater receivers.

In assessing groundwater drawdown impacts in and around the landfill the cut-off wall and landfill capping was included in the groundwater model. However these impacts were relatively minor to the local hydrogeological regime in comparison to impacts of continued leachate extraction on the depressurisation of the Ashfield Shale.

Captured groundwater and surface water as a result of tunnelling is likely to be contaminated with suspended solids and increased pH due to tunnel grouting activities. It is anticipated that about 65 per cent of water captured would be groundwater as a result of tunnelling activities with the remaining 35 per cent resulting from process water generated from construction activities. The assessment of the potential impacts from the quality of water discharged from the construction groundwater treatment plants is discussed in the Technical Working Paper: Surface Water (**Appendix N**).

Within the construction compounds there is potential to contaminate groundwater from fuel and chemical spills, including petrol, diesel, hydraulic fluids and lubricants stockpiled within the compound. Spills as a result of incidents can occur during construction activities, refuelling operations or from storage areas. Management and mitigation measures are outlined in **Section 19.4**.

Acid sulfate soils

Areas identified with suitable conditions for the presence of acid sulfate soils include alluvial deposits around creek lines such as Cooks River, Alexandra Canal, Wolli Creek and Muddy Creek. When exposed to air, either by excavation or dewatering, the iron sulfides (commonly pyrite) within acid sulfate soils can oxidise producing sulfuric acid.

The project tunnel alignments within most of the areas potentially containing acid sulfate soils is deep within the competent Hawkesbury Sandstone and beneath the alluvium. Therefore, in most areas the alluvial sediments are unlikely to be excavated and the potential for disturbance of acid sulfate soils is low.

Exceptions where acid sulfate soils may be intersected are near Alexandra Canal, at Alexandria Landfill and around the Arncliffe surface works. Near Alexandra Canal the project would be constructed at the ground surface with bridge crossings of the canal. Excavation of potential acid sulfate soils may occur during road construction works, the construction of bridge footings or dewatering.

Based on historical quarrying records at Alexandria Landfill, potential acid sulfate soils are most likely present in the southern and eastern areas of the site outside the areas that have been subject to quarrying. Acid sulfate soils could be excavated during earth moving works and/or acidic groundwater could be pumped during construction dewatering. Similarly potential acid sulfate soils may also be present beneath the Arncliffe surface works and could be excavated during the construction earthworks. Treatment of acid sulfate soils may be required as part of any re-contouring or excavation works within the Kogarah Golf Course site.

Groundwater aggressivity

Groundwater can be corrosive to building materials depending on a number of hydrogeochemical factors including salinity, pH, sulfate and chloride concentrations. Understanding the corrosive nature of the natural groundwater intersected by the project assists in selecting building materials to minimise corrosive impacts to the tunnel and its infrastructure.

Tunnel infrastructure including the construction of interchanges and installation of water proofing would be mostly located below the natural groundwater table and subjected to potential corrosion due to interaction with groundwater.

The presence of dissolved chloride and sulfate in groundwater is one of the main factors contributing to corrosion potential of concrete and steel. By application of the exposure classification in the Australian Standard AS2159-2009 for piling – design and installation, the water for all lithologies within the study area is mildly aggressive to concrete for average chloride and non-aggressive for average sulphate.

Along the project alignment, groundwater quality intersected by the project tunnels would be variable as different water bearing fractures are intersected.

Groundwater quality data indicates the groundwater with the highest aggressivity based on elevated electrical conductivity, sulfate and chloride concentrations would be in the eastern part of the project around the St Peters interchange where the Ashfield Shale outcrops. In addition, aggressive groundwater is also expected within the Hawkesbury Sandstone in the Tempe/ Arncliffe area near Cooks River. Piling standards also state that the exposure classification for piles intersecting domestic waste and industrial waste would be severe and very severe which is likely to impact the piles that would be constructed at the Alexandria Landfill site.

Corrosion and other associated impacts of high aggressivity on the tunnel infrastructure would be monitored during regular inspections outlined within the an Operational Environmental Management Plan (OEMP). Rectification of tunnel infrastructure during operations would be undertaken during regular maintenance operations as required.

The project tunnels have been designed to be drained and would require groundwater seepage, tunnel wash or deluge system water to be collected, treated and discharged. Water treatment would be required to reduce salinity and turbidity and adjust pH prior to discharge. Further information on surface water management including water treatment is provided in **Chapter 16** (Soil and water quality).

While it is acknowledged that the risk posed of the interaction with contaminated groundwater during construction within the Alexandria Landfill is low a contingency measure may include include a backup leachate treatment plant.

19.3.2 Operation

Groundwater along the project alignment has the potential to be impacted during the operational phase of the project. The potential impacts that have been identified are:

- Groundwater inflow
- Groundwater drawdown
- Changes in groundwater quality
- Impacts to the environment, including environmental receivers dependent on groundwater

Each of these potential impacts is discussed below.

Groundwater inflow

Long term groundwater inflows into the project tunnels would be influenced by the local geological and hydrogeological conditions, as outlined in the assessment of potential construction groundwater inflows.

Operational groundwater inflows are likely to be lower than the construction inflows. Based on groundwater inflows to other drained Sydney tunnels, the long term inflow is expected to be below one litre per second per kilometre.

Initial groundwater inflows into the project tunnels during construction are estimated to be between 7.6 and 18.6 litres per second (for the full tunnel lengths) depending on the actual hydraulic conductivity experienced. Inflow is likely to decrease with time as observed in other Sydney tunnels due to siltation, chemical induration and organic slimes that accumulate in intercepted geological defects, reducing the rock mass permeability. This is primarily due to the groundwater levels drawing down and inducing flow towards the tunnels from an increasingly broader region as the cone of depression expands over time. Inflows would also decline over time as groundwater pressures around the tunnel decline as the storages of higher inflow features drain.

The overall groundwater inflow is expected to achieve less than one litre per second per kilometre as high inflow zones are grouted during construction.

Groundwater inflow would be dependent on the final construction methodology and water proofing solutions as determined during detailed design. The predicted groundwater inflow rate (CDM Smith, 2015) along the 20 kilometres of project tunnels (including main alignment tunnels and ramps) is 0.63 litres per second along each kilometre of the eastbound (shallower) tunnel and ramps and 0.67 litres per second along each kilometre of the westbound (deeper) tunnel and ramps.

Groundwater drawdown

Previous tunnelling in the Hawkesbury Sandstone in the Sydney region has shown that groundwater inflow is typically highest during construction and then is reduced as the cone of drawdown expands and an equilibrium or steady state conditions are approached.

This equilibrium is achieved when the tunnel inflow is matched by rainfall recharge via infiltration. Groundwater drawdown within the palaeochannels and river alluvium would be minimal or not likely to occur as the hydraulic heads within saturated sediments are maintained by direct hydraulic continuity with surface water, supported by a slight reduction in river baseflow.

Immediately after tunnelling is completed, groundwater inflows would be at their highest but there would be no impact on the water table. With time, groundwater inflow to the tunnel would decrease while the water table would gradually decline until an equilibrium is reached.

Construction of the drained tunnels beneath the groundwater table may cause long term groundwater inflow, inducing groundwater drawdown along the tunnel alignments. There are two main mechanisms that influence groundwater drawdown, the actual water table drawdown and the hydraulic pressure drawdown.

The Hawkesbury Sandstone is also interbedded with shale lenses that locally act as aquicludes or aquitards restricting vertical groundwater movement. Shallow perched water over shale lenses (recharged by rainfall) also occurs, which potentially sustains surface ecosystems. To the west of the project alignment, the deeper groundwater table within the Hawkesbury Sandstone is already influenced by drawdown induced by the drained M5 East Motorway tunnels. Localised groundwater drawdown could also be expected around existing shafts and portals that extend below the groundwater table.

Long term dewatering caused by tunnel drainage could lower the groundwater table within the Hawkesbury Sandstone and reduce the amount of groundwater available for shallow rooted plants. The groundwater table underlying the majority of the project alignment is on average two metres below ground surface and the flora is unlikely to be completely dependent on groundwater. This would not change as the unsaturated zone is influenced by rain infiltration. The availability of water for plants in low lying areas is not expected to change due to the low permeability of the clayey soils, frequent rainfall events and higher recharge due to surface water concentration.

Residual soil profiles developed on the weathered sandstone and shale bedrock are typically relatively thin, stiff and of low compressibility. Therefore in most cases, the risks associated with water table drawdown and associated dewatering induced settlement is minor and less than the seasonal influences of shrink-swell movements in the residual clay soils. At Alexandria Landfill where the shale residual soil profile is of considerable thickness the impacts due to dewatering such as induced settlement have already occurred due to many years of artificial depressurisation caused by the leachate pumping system (AECOM, 2015k).

The predicted drawdown at the various watercourses above and around the project would vary depending on local geology, horizontal distance from the tunnel and depth to the tunnel. Typical drawdown within the alluvium has been estimated to be negligible as it is recharged by rainfall infiltration and would continue to discharge to surface water.

Long term dewatering could impact existing groundwater users registered with the NSW Office of Water. A review of the NSW Office of Water groundwater database indicates that of the registered bores within one kilometre of the project alignment approximately half are registered as being used for water supply or irrigation. The majority of these registered bores are shallow (no greater than 10 metres in depth) located within the Botany Sands, Wolli Creek and Cooks River alluvium. Groundwater drawdown at these locations due to drainage into the project tunnels is not expected due to the hydraulic connection of the alluvium with the surface water in Wolli Creek and Cooks River. A clay aquitard typically underlies the Botany Sands reducing hydraulic continuity between the alluvium and underlying sandstone.

Groundwater modelling has been used to predict potential impacts on natural systems and the groundwater table. Output from the groundwater model shows predicted groundwater table elevations after completion of the project (refer to **Figure 19-7**) and drawdown caused by the project (refer to **Figure 19-8**).

The groundwater elevations shown in **Figure 19-8** indicate an elongated cone of depression that is predicted to develop along the project tunnel alignments, especially to the west of Cooks River. The groundwater table is predicted to remain relatively high near Bardwell Creek which is attributed to the presence of deep alluvium along this drainage line.

Drawdown of the groundwater table is predicted to be less where the project tunnels pass beneath Cooks River and its connected alluvium, due to induced leakage from the river. Being connected to the ocean, the river can supply water to the tunnels below, without affecting water levels in the river. However, a gradient would develop from the river in both westerly and easterly directions. It has been previously observed that higher inflows to tunnels beneath palaeovalleys may be an effect of valley bulging, and enhanced hydraulic conductivities due to fracturing. The groundwater model suggests that higher inflows can also be explained by availability of water and rapid transfer of water to alluvium over underlying rock.

To the east of Cooks River, heading eastwards from the edge of the alluvium, the predicted drawdown would increase significantly. The sudden change in drawdown as the project alignment approaches St Peters would be due to the tunnels transitioning from sandstone into shale.

Drawdown does not extend far into the main Botany Sands aquifer, because this unit is able to transmit water (due to its higher hydraulic conductivity) with relatively flat hydraulic gradients. Groundwater modelling predicts the project would not have additional impacts in the area of the Alexandria Landfill.

Justification for a drained tunnel

The project is designed as a drained tunnel and would be constructed predominately through sandstone with sections of shale.

The option to construct drained tunnels rather than lined undrained tunnels can have a large impact on the project outcomes and economic feasibility. The decision is either driven by mitigation of potential impacts or from the outcomes of a whole of life cost assessment (i.e. capital cost versus operational cost).

A review of the ground conditions within the project corridor indicated that the hydrogeological conditions were similar to where other major Sydney drained tunnels have been successfully constructed. With the exception of Lane Cove Tunnel and the cross City Tunnel, groundwater inflows along the tunnel length have averaged below one litre per second per kilometre. Low inflow rates are maintained by grouting or otherwise sealing water bearing structural features that otherwise could provide large inflows to the tunnel.

Typically, drained tunnel sections that extend beneath creeks are grouted to reduce the risk of increased tunnel inflow. There are many other drained tunnels excavated in sandstone and shale throughout the Sydney Basin and very few undrained tunnels, in part due to the competent nature of the bedrock.

In general, DPI (Water) does not support an activity that causes perpetual inflow volumes, although in the case of constructing important major infrastructure exemptions can be granted. On-going tunnel inflows are estimated to be less than 18 litres per second (i.e. less than one litre per second per kilometre on average). To retain this volume of water within the natural groundwater system, by constructing an undrained tunnel would approximately double the project costs.

There are potential environmental, sustainability, social and safety impacts associated with excavating larger tunnels, to accommodate a liner which includes moving more spoil, and transporting and disposing of more materials for tunnels. In addition, these factors can contribute to a higher capital cost, but there would be an off-setting reduction in operating costs. On-going operating costs for a drained tunnel would include the collection, treatment and discharge of groundwater. In the absence of any indication for potential impacts associated with a loss of baseflow to creeks that may adversely affect sensitive GDEs; a reduction in groundwater levels in registered boreholes used for water supply; or damage to existing infrastructure due to the settlement of compressible soils, it was considered reasonable to specify a groundwater control (in the form of an inflow limit) instead of an undrained requirement.

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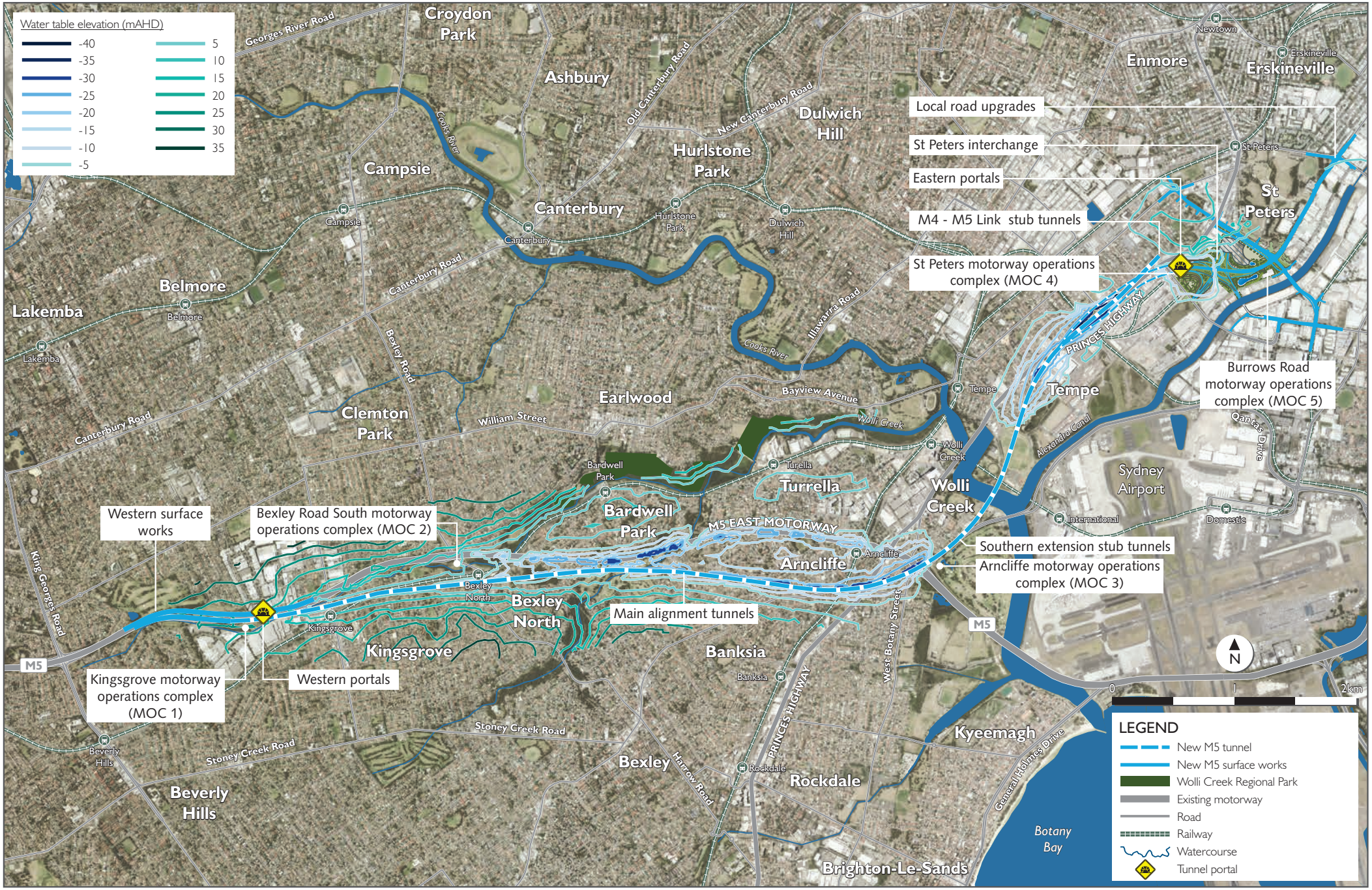


Figure 19-7 Predicted water table elevations after completion of the project

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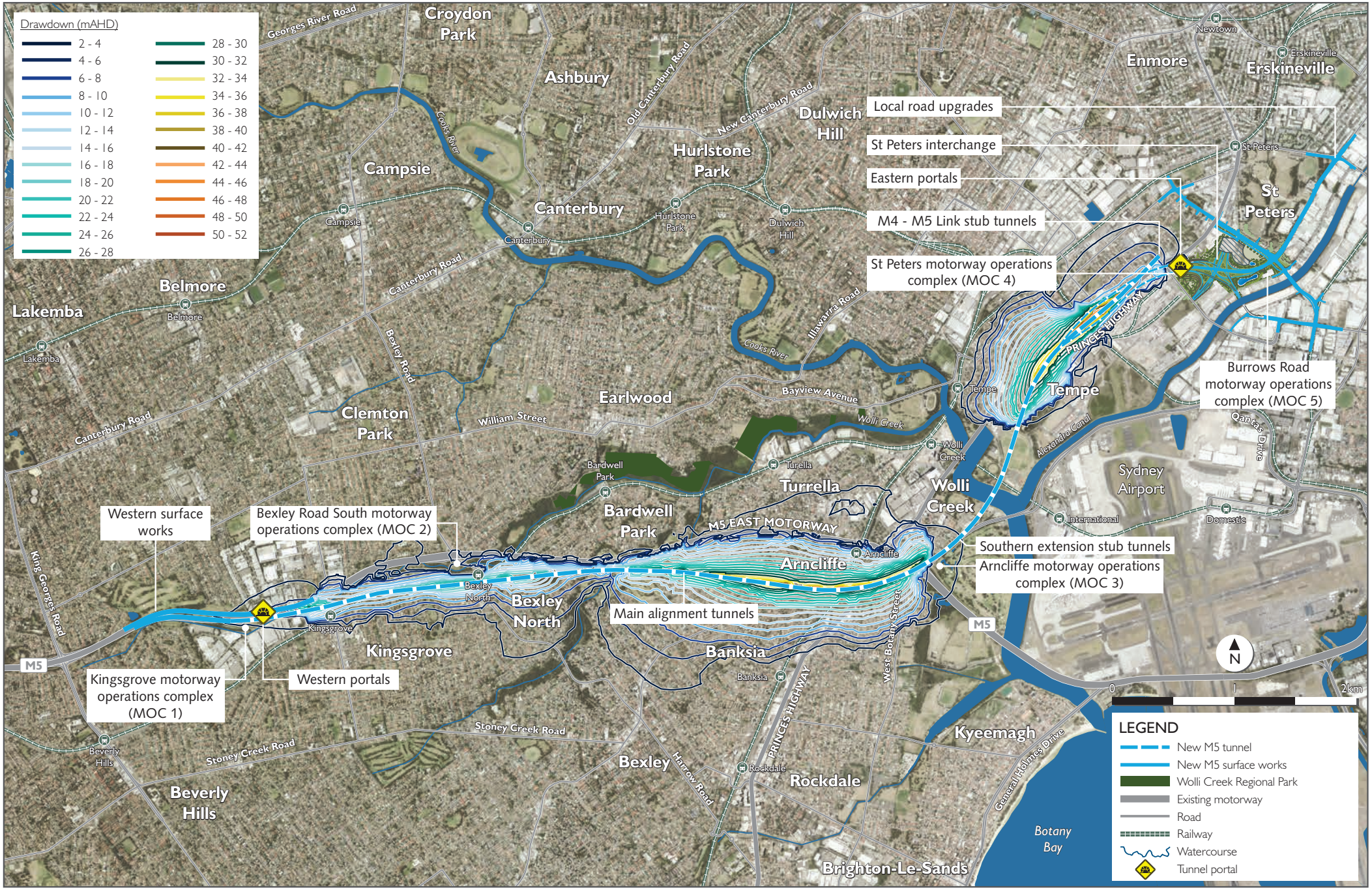


Figure 19-8 Predicted drawdown caused by the project

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Groundwater quality impacts

Road runoff can contain pollutants associated with vehicular movement and normal use due to leaks, spills and crashes. Expected contaminants from groundwater within the region indicate that contaminants would include iron, hydrocarbons (petrol, diesel, oil and grease), metals and suspended solids.

In the event of a hydrocarbon spill within the project tunnels, water and fuel would be pumped to the surface and stored in holding ponds for treatment prior to discharge. The drainage system has been designed to capture groundwater and surface water inflows to the tunnels separately via different drainage networks to streamline the treatment process. In addition, groundwater would be collected separately east and west of the sump.

The rationale is that groundwater from St Peters, Alexandria and Tempe is more likely to be contaminated than groundwater collected west of Arncliffe. Sources of potentially contaminated groundwater would be from former and current industrial areas of St Peters, Alexandria and Tempe. The risk is considered low due to the depth of the project tunnels, and where contaminated groundwater is identified, waterproofing would be applied to reduce inflows of contaminated groundwater. Calculated groundwater leakage into the project tunnels adjacent to Alexandria Landfill would consist of 86 per cent background water and 14 per cent leachate impacted groundwater.

While it is acknowledged that the risk posed by the interaction with contaminated groundwater during construction within the Alexandria Landfill is low, a backup leachate treatment plant may be provided as a contingency measure.

The water treatment plant is designed to treat water from a variety of sources including groundwater, stormwater that enters the portals and a series of smaller incidental flows including deluge for fire suppression, hydrants, fire system testing and liquid tanker spill. Predicted groundwater inflow to the tunnel is 0.65 litres per second over 20 kilometres or 13 litres per second. The water treatment plant is designed to treat a predicted maximum of 20 litres per second but could be expanded to treat 27 litres per second if required. Where there are high inflows of water such as from deluge or hydrants water would be pumped to a surface holding tank to increase water holding capacity if required,

The assessment concerning the treatment and discharge of treated groundwater can be found in the Technical Working Paper: Surface Water (**Appendix N**).

Induced drawdown caused by tunnel drainage may cause saline water to be drawn into the tunnels due to the connection with the Cooks River. The Cooks River is in hydraulic connection with alluvium and has the capacity to supply saline water to the alluvium, potentially degrading groundwater quality.

As the alluvium directly overlies the sandstone and may be in hydraulic connection there is potential for saline water to enter the sandstone. However, groundwater beneath the Cooks River is likely to already have elevated salinity and consequently the project is unlikely to further adversely impact groundwater quality beneath the river.

Impacts to existing users

The drawdown in registered bores has been predicted by the groundwater model. The modelling predicts that 11 bores would be drawn down in excess of two metres due to tunnel induced drainage. The modelled drawdown in the registered bores varies from 2.2 metres to 11.5 metres. Of these bores, only four are used for water supply – two or domestic purposes and two for industrial purposes. The remaining wells are classified as either monitoring wells, test bores or ‘other’.

Three of the water supply wells where the drawdown is predicted to be in excess of two metres are shallow bores intersecting sand where the water table is expected to be drawn down below the base of the bore. In these cases, it may be possible to extend the bores to intersect deeper groundwater. The fourth bore is constructed for industrial purposes within the Hawkesbury Sandstone to a depth of 186 metres. In this bore the groundwater table is at a depth of 93 metres and the drawdown is predicted to be 5.7 metres.

Impacts to the environment

Impacts to groundwater inflows to the Cooks River

The Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2015) identifies the Cooks River as being highly likely to have an inflow dependence on groundwater, meaning that the Cooks River estuary receives groundwater passively through its bed. Some of this groundwater may flow underneath the Kogarah Golf Course at Arncliffe, which could be intercepted during tunnelling. The volume and rate of groundwater flow into the Cooks River is unknown; however, the hydraulic connection to the Cooks River is likely to be limited by the concrete and brick lining along the banks.

Although the Cooks River is highly likely to receive groundwater, there are no known ecosystem components which would be significantly impacted by a reduction in groundwater as a result of groundwater interception from tunnelling.

Impacts to the Cooks River Castlereagh Ironbark Forest

Construction of the project is expected to require the clearance of 1.4 hectares of Cooks River Castlereagh Ironbark Forest, which contains several native vegetation communities which are indicative of shallow groundwater table and waterlogged soils. The GDE Atlas marks the Cooks River Castlereagh Ironbark Forest as being highly likely to have an inflow dependence on groundwater.

The residual Cooks River Castlereagh Ironbark Forest around the western surface works area may be affected by groundwater drawdown from tunnelling (refer to **Chapter 21** (Biodiversity)).

Impacts to GDEs from groundwater drawdown

The maximum amount of groundwater drawdown is expected to be about five to 10 metres. Drawdown would be the greatest directly above the main alignment tunnels, and would decrease towards the drawdown boundary. Five GDEs (including the Cooks River and the Cooks River Castlereagh Ironbark Forest) have the potential to be impacted as a result of groundwater drawdown. **Table 19-10** provides a summary of impacts to GDEs as a result of groundwater drawdown and further information, including details of the impact assessment methodology, can be found in **Chapter 21** (Biodiversity).

Table 19-10 Summary of impacts to GDEs from groundwater drawdown

GDE	Location	Summary of impact	Significance of impact
Cooks River Castlereagh Ironbark Forest	Western surface works within the construction footprint	Vegetation to be retained is likely to be highly groundwater dependent. Lowering of the water table at this location is likely to place this vegetation under stress.	Moderate
Cooks River	Adjacent to the Arncliffe (C7) construction compound	Drawdown may reduce the flow of water from aquifer to river. The current flow rate at this location is unknown, but is unlikely to be significant because large reaches of the bank and bed are lined with concrete or brick.	Low
Hinterland sandstone gully forest	Within Bardwell Valley Parkland and Bradford Street Reserve outside of the construction footprint but within the groundwater drawdown extent	Drawdown could lower groundwater to a point where it is below the roots of dependent trees. As this GDE is near the edge of the drawdown boundary, the impact is not expected to be significant	Low
Coastal sandstone ridgetop woodland	Within Stotts Reserve, Bexley North outside of the construction footprint but within the groundwater drawdown extent	Stotts Reserve is located directly above the main alignment tunnel. Drawdown could be up to 10 metres, and if trees are dependent on groundwater, a large part of the reserve could show signs of stress in prolonged dry periods.	Moderate

GDE	Location	Summary of impact	Significance of impact
Estuarine fringe forest	Between the southern bank of Wolli Creek and the rail line behind Wolli Creek Station, outside of the construction footprint but within the groundwater drawdown extent	This tract of vegetation is on the bank of Wolli Creek, near the edge of the drawdown boundary. It is unlikely that drawdown would have a significant impact.	Low

Impacts to wetlands from groundwater drawdown

Outside the study area is the Towra Point Wetlands. These wetlands are located 6.8 kilometres south of the study area, separated from the project by Botany Bay, and are a sufficient distance from the project to not be impacted by the drawdown around the tunnels. The Eve Street Marsh and Landing Lights wetlands are underlain by saturated alluvial sediments that flank Cooks River. The project tunnels would be located to the north of these wetlands within the Hawkesbury Sandstone. Any leakage from the alluvium into the sandstone and project tunnels would be replaced by surface water from Cooks River. In addition these wetlands are tidal and regularly flushed further suggesting the wetlands are unlikely to be impacted by the project.

Groundwater modelling has predicted that groundwater drawdown at Tempe Wetlands located close to Alexandra Canal would be negligible (CDM Smith, 2015). This is because the Cooks River and Alexandra Canal are tidal, with water levels controlled by the sea. Landing Lights Wetland, Eve Street Wetland and Marsh Street Wetland are located in alluvium, on the fringe of an area where there may be groundwater table decline when steady state has been reached. The presence of a low permeability organic layer beneath the alluvium would restrict groundwater leakage from the alluvium. In addition, groundwater drawdown at the wetlands may be less than predicted by the groundwater model as recharge over the alluvium is likely to be higher than the 40 millimetre per year set for the whole regional model. Furthermore, predicted drawdown may be less than calculated due to a phenomenon known as induced recharge. That is, as the groundwater table declines, the vegetation takes less water (evapotranspiration is reduced), such that the difference between (net recharge to the groundwater table) increases. Therefore, by this mechanism the predicted drawdown is less than actual.

Impacts to other vegetation from groundwater drawdown

There is potential for groundwater drawdown to impact trees near watercourses. The majority of the project alignment has a water table below about two metres depth and below the growth zone. Trees are not completely dependent on the water table, as trees survive in unsaturated soils and rocks. This would not change as the unsaturated zone is influenced by rain infiltration. In low lying areas the low permeability of the clayey soils in combination with frequent rainfall events and higher recharge due to surface water concentration is not expected to change availability of water for plants. The predicted drawdown at the various creeks varies depending on local geology, horizontal distance from the tunnel and depth to the tunnel.

Ground settlement

A list of reference buildings and assessment results for potential ground settlement impacts is provided in **Table 19-11**. These building locations have been identified along the project alignment in areas most likely to be affected by peak ground settlement effects based on tunnelling activities and local geology. **Table 19-12** provides a summary of maximum vertical settlement as calculated at key locations. **Figure 19-9** to **Figure 19-13** provide the predicted vertical settlement contours due to tunnel excavation along the project alignment.

Most of the buildings have a predicted settlement of less than 20 millimetres and have been assessed as having a building damage category of ‘negligible’. The exceptions are those buildings located nearest the tunnel portals and cavern locations. The Southern extension caverns and the M4-M5 Link caverns have a predicted settlement higher than 20 millimetres but are less than the limit of 30 millimetres for non-sensitive buildings. The St Peters interchange eastern portals predicted settlement exceeds the 30 millimetres for non-sensitive buildings.

Two buildings at Canal Road in St Peters have an assessed damage category of 'very slight'. These damage categories may result in cosmetic damage only. All investigated buildings have a maximum predicted slope less than 1:500.

Table 19-11 Select reference buildings and predicted settlement

Building reference	Address	Maximum settlement (mm)	Maximum slope (1:X)	Maximum tensile strain (%)	Damage category
B1	14-26 Commercial Road, Kingsgrove	12.1	1201	0.042	Negligible
B2	30 Commercial Road, Kingsgrove	13.1	1021	0.039	Negligible
B3	6 Shaw Street, Bexley North	9.5	3591	0.003	Negligible
B4	238 Slade Road, Bexley North	10.4	3760	0.004	Negligible
B5	197 Slade Road, Bexley North	10.3	3125	0.011	Negligible
B6	23-25 Forest Road, Arncliffe	6.5	10896	0.001	Negligible
B7	140 Princes Highway, Arncliffe	9.3	11381	0.001	Negligible
B8	132-138 Princes Highway, Arncliffe	9.2	9209	0.001	Negligible
B9	M5 East Motorway Control Centre	8.6	8893	0.004	Negligible
B10	32 Valda Avenue, Arncliffe	14.6	5720	0.002	Negligible
B11	24A Marsh Street, Arncliffe	24.0	2222	0.003	Negligible
B12	28 Marsh Street, Wolli Creek	22.0	2361	0.005	Negligible
B13	20 Levey Street, Wolli Creek (Mercure Sydney Airport)	10.0	4850	0.003	Negligible
B14	1 Levey Street, Wolli Creek	9.8	5869	0.002	Negligible
B15	728-750 Princes Highway, Tempe	8.8	6601	0.003	Negligible
B16	634-726 Princes Highway, Tempe	9.7	5636	0.006	Negligible
B17	545 Princes Highway, Tempe	24.5	2959	0.004	Negligible
B18	541-543 Princes Highway, Tempe	28.6	3699	0.006	Negligible
B19	9 Samuel Street, Tempe	25.8	2166	0.003	Negligible
B20	489 Princes Highway, Sydenham	9.1	10283	0.001	Negligible
B21	42 Reilly Lane, Sydenham	8.8	9583	0.001	Negligible
B22	459-461 Princes Highway, Sydenham	8.4	27218	0.001	Negligible

Building reference	Address	Maximum settlement (mm)	Maximum slope (1:X)	Maximum tensile strain (%)	Damage category
B23	574 Princes Highway, St Peters	7.7	5682	0.007	Negligible
B24	347 Princes Highway, St Peters	12.9	3035	0.003	Negligible
B25	380-396 Princes Highway, St Peters	8.7	3989	0.005	Negligible
B26	364-370 Princes Highway, St Peters	9.9	3548	0.028	Negligible
B27	321-323 Princes Highway, St Peters	10.0	10273	0.002	Negligible
B28	309 Princes Highway, St Peters	6.2	7660	0.011	Negligible
B29	295 Princes Highway, St Peters	7.4	6548	0.010	Negligible
B30	344 Princes Highway, St Peters	13.4	1725	0.007	Negligible
B31	340 Princes Highway, St Peters	19.3	1028	0.021	Negligible
B32	1-3 Canal Road, St Peters	16.9	649	0.065	Very slight
B33	6 Canal Road, St Peters	29.7	501	0.073	Very slight

Table 19-12 Maximum vertical settlement at key locations

Location	Maximum calculated surface settlement (mm)
Main alignment tunnels near the western surface works, Kingsgrove	25.5
Southern Connector Junction Caverns	24.3
St Peters Interchange Junction Caverns	28.5
St Peters interchange eastern portals	35.3

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Figure 19-9 Settlement contours - map 1

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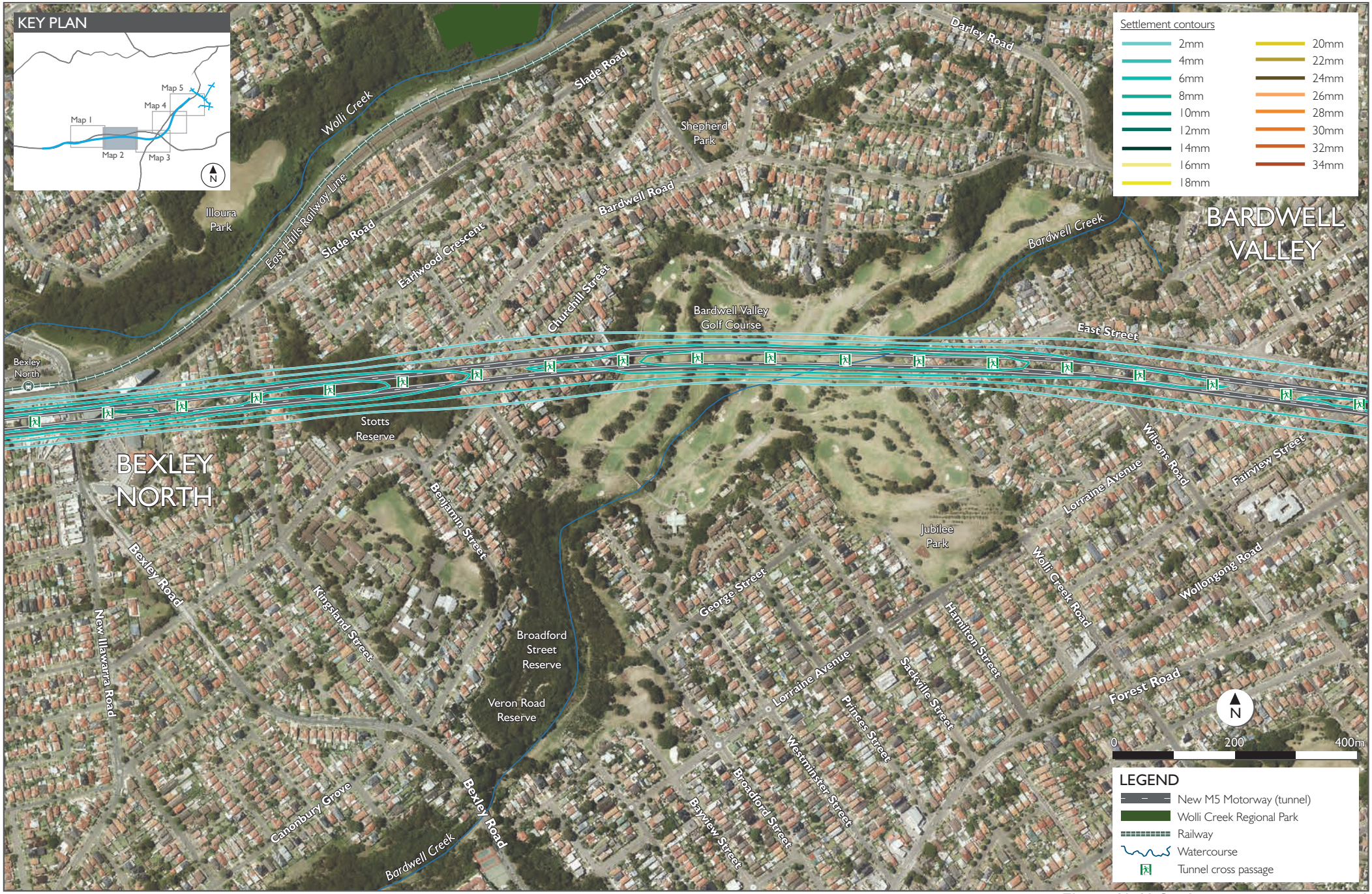


Figure 19-10 Settlement contours - map 2

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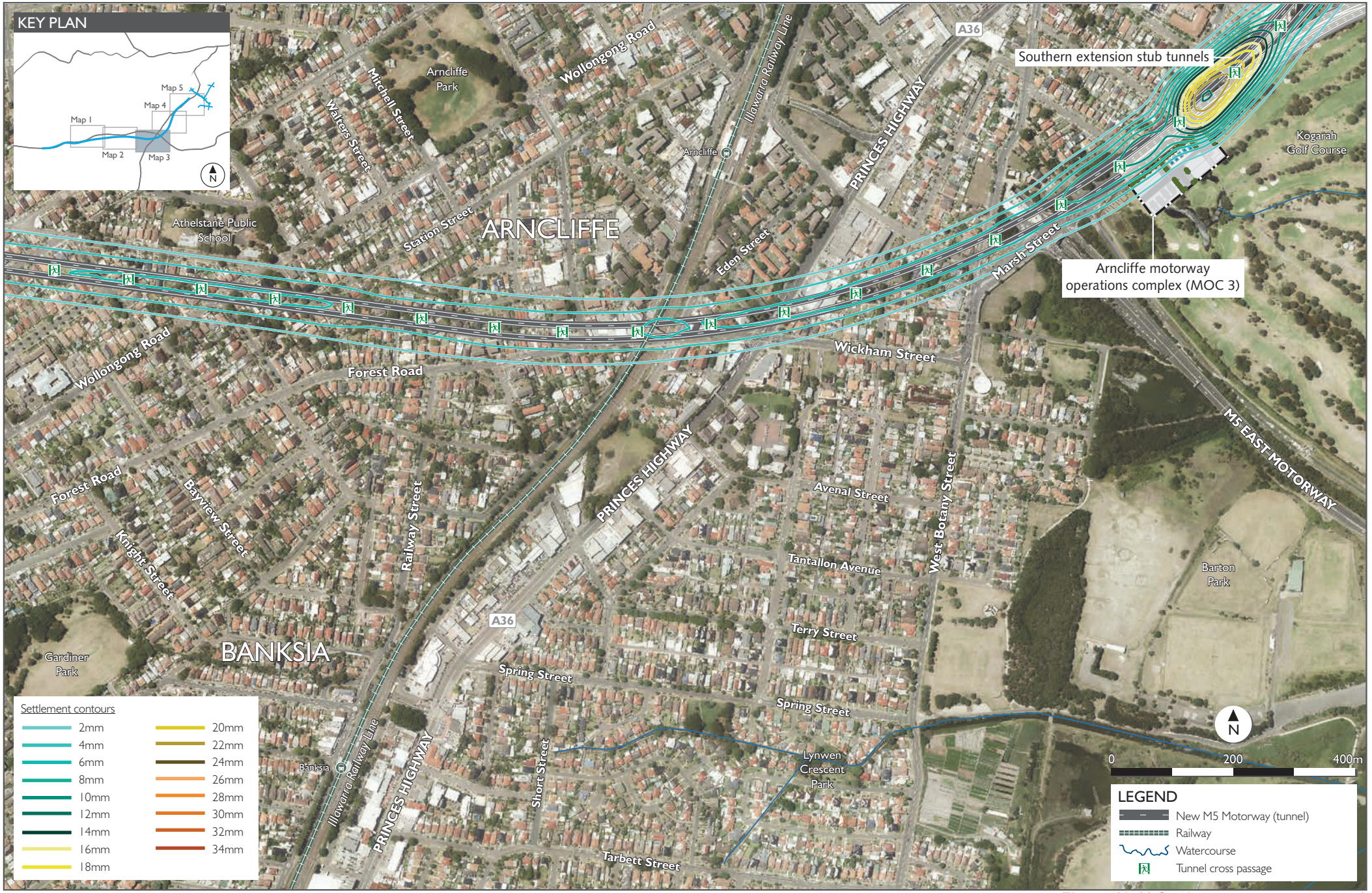


Figure 19-11 Settlement contours - map 3

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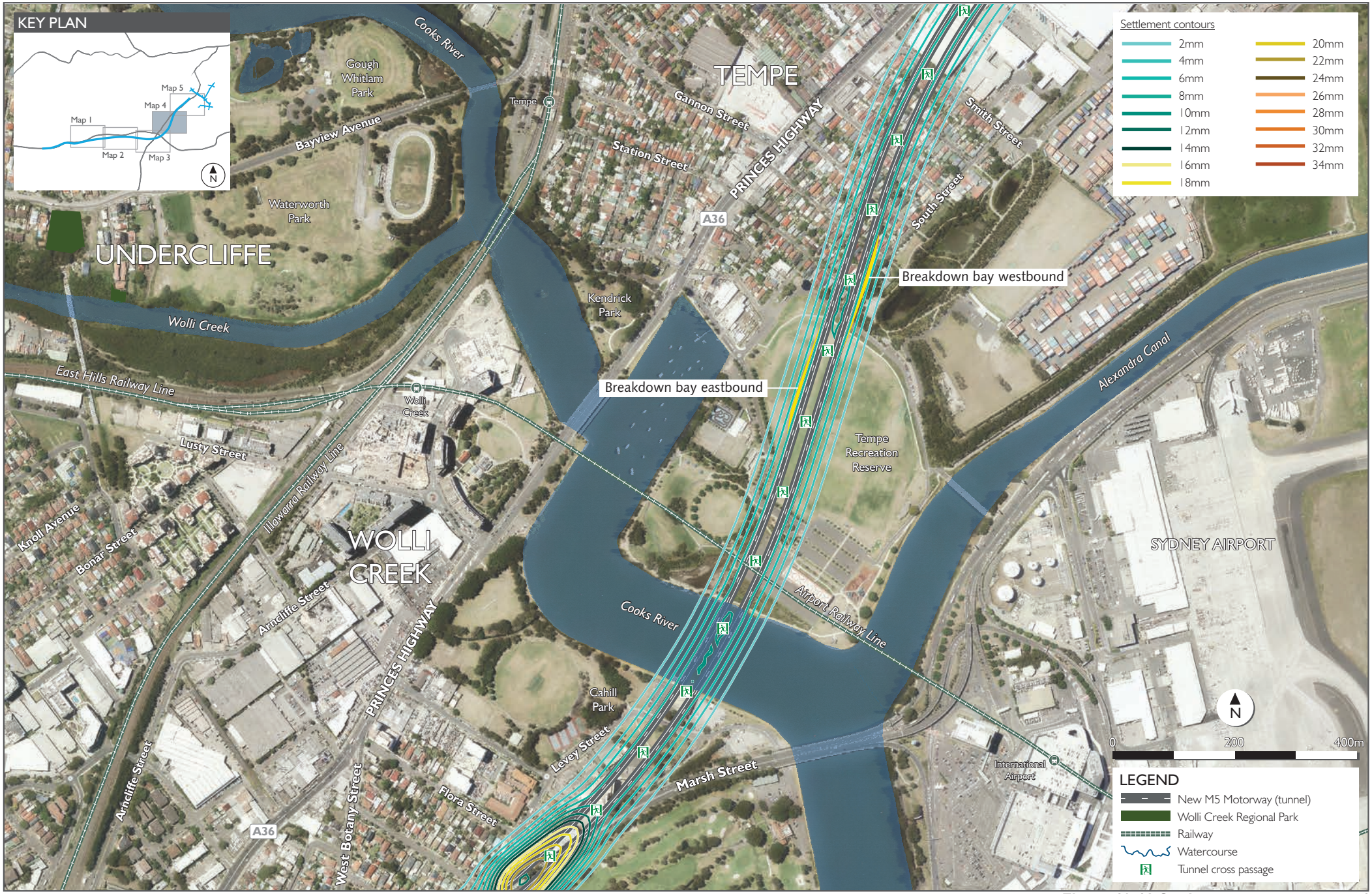


Figure 19-12 Settlement contours - map 4

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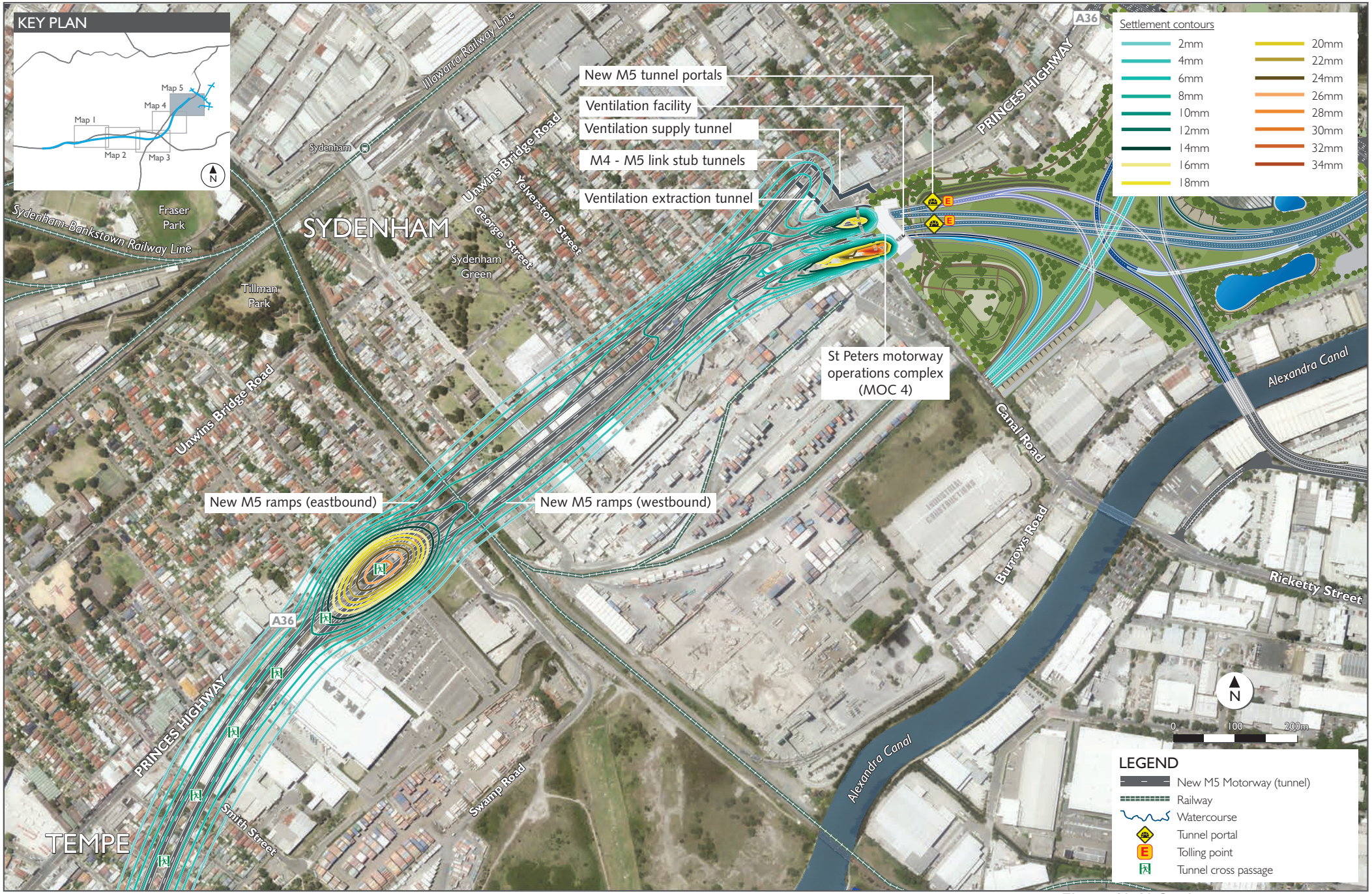


Figure 19-13 Settlement contours - map 5

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Potential settlement impacts on utilities have also been assessed. A summary of the utilities assessment is shown in **Table 19-13**

All of the assessed utilities have predicted settlement less than 40 millimetres and angular distortion predicted to be less than 1:250.

At Canal Road, St Peters the predicted settlement is 36.2 millimetres and the worst angular distortion is calculated as about 1:400. Potential settlement impacts in this location would be within acceptable limits, and represent the point of maximum predicted impact.

The predicted ground movement at rail lines and tunnels would also be less than the allowable limits adopted in this assessment.

Notwithstanding these results, and since the ground movement is approaching close to the vertical settlement and angular distortion limits for some roads, utilities and buildings, further detailed investigation would be carried out in these areas during the project's detailed design phase, and prior to construction. Where the risk of settlement induced damage is assessed to be high, additional ground support measures may be implemented to control ground movement and limit surface settlement.

Table 19-13 Utilities and predicted settlement

Category	Reference	Description/ location	Maximum settlement (mm)	Maximum slope (1:X)
Roads	U101	Kingsgrove Avenue, Kingsgrove	10.3	9992
	U102	Kingsgrove Road, Kingsgrove	8.0	2976
	U103	Bexley Road, Bexley North	9.8	3477
	U104	Princes Highway, Arncliffe	9.1	10129
	U105	West Botany Street, Arncliffe	8.8	9556
	U106	Marsh Street, Arncliffe	23.4	4609
	U107	Princes Highway, Tempe to St Peters	24.4	4701
	U108	Canal Road, St Peters	36.2	397
Utilities	U201	TransGrid transmission cable	6.0	14958
	U202	TransGrid transmission cable	10.9	5749
	U203	TransGrid transmission cable	35.5	411
	U204	Gas main	10.7	3559
	U205	Gas main	8.8	9311
	U206	Gas main	9.7	5502
	U207	Gas main	9.9	5172
	U208	Water main	9.9	7511
	U209	Sewer main	10.6	6462
	U212	Power line	8.7	8361
	U213	Power line	18.0	677
Other infrastructure	U301	M5 East Motorway, Kingsgrove	6.6	22301
	U302	M5 East Motorway tunnels, Bardwell Park	0.2	227145
	U303	M5 East Motorway tunnel portals westbound	9.3	6026
	U304	M5 East Motorway main tunnel portals westbound	9.8	5852
	U305	M5 East Motorway main tunnel portals eastbound	9.7	6045
	U306	M5 East Motorway ramp tunnel portals eastbound	8.9	6469
	U307	Passenger railway (Kingsgrove - Bexley North)	10.0	12494
	U308	Passenger railway (Arncliffe)	6.8	8643

Category	Reference	Description/ location	Maximum settlement (mm)	Maximum slope (1:X)
	U309	New Southern Railway (Tempe)	14.1	1466
	U310	Freight rail line, Sydenham	10.2	5544
	U311	Wolli Creek	24.0	528

Groundwater drawdown settlement

Settlement due to groundwater drawdown has been calculated based on geological interpretation of boreholes in the vicinity of the project tunnel. The drawdown at each borehole has been estimated and the resulting consolidation settlement calculated according to the depth of overlying soft ground and the degree of consolidation that may occur in that material.

Generally, in areas with the deepest sediment deposits, the drawdown settlement has been calculated to be 20 millimetres to 25 millimetres. This settlement is expected to decrease with distance from the project tunnels (due to smaller drawdown) and with shallower rock head level.

The assessment carried out does not take into account the degree of consolidation that may have already occurred due to previous projects. The impact of groundwater drawdown in the zone above the existing M5 East Motorway tunnels is expected to be reduced due to the drawdown that is anticipated to have already occurred in that area.

Combined settlement

For the Project, the maximum predicted settlement due to groundwater drawdown does not coincide with settlement due to ground loss.

The settlement caused by redistribution of stress around a tunnel usually occurs within a few days of the tunnel face advancing. The methodology for estimating such settlement is industry standard and is based upon an empirical methodology that dates back to the 1960s and which is extremely well documented. This methodology involves the estimation of a displacement field of horizontal and vertical movement. This is characterised by two parameters which are based both on previous history in very similar tunnels in Sydney and on the results of numerical modelling. The models prediction of the response of buildings and services to this type of settlement is also based on industry standard methodology, which is also extremely well documented. The response of the buildings are based on combining predictions of horizontal strain and bending strain imposed upon the buildings by the displacement field as calculated. In summary:

- Settlement caused directly by the tunnel excavation process occurs very quickly after the tunnel passes the point of concern
- There is a well-documented empirical and numerical methodology for predicting the displacements due to the tunnel excavation process
- There is a well-documented methodology for predicting the possibility of building damage caused by the above displacements
- The method states that building damage is caused by horizontal and bending movements imposed on the building by the above settlements.

In the case of settlement caused by groundwater drawdown, there are significant differences. Each of the calculation steps are subject to significant uncertainty. The predicted magnitude of the groundwater drawdown settlement can be quite high, but the settlement is usually spread over a wide area and is unlikely to cause significant horizontal strain or bending strain in buildings. The settlement that occurs due to groundwater drawdown generally occurs very slowly, possibly over years, and is often indistinguishable from settlement that is already occurring due to groundwater drawdown that might already be occurring and seasonal effects related to swell and shrinkage of the soil.

In summary:

- Settlement caused by groundwater drawdown can have a significant magnitude, yet not cause damage to buildings
- There is considerable uncertainty in the methodology and assumptions used in calculating this settlement.

For these reasons, it is considered that the two settlement predictions do not need to be combined. A prediction of five millimetres of groundwater drawdown settlement over the alignment is not significant and most groundwater drawdown settlement predictions involve zero horizontal strain and negligible bending due to the large area over which it occurs. It is likely that the ground already moves more than this in response to annual fluctuations of rainfall and evapotranspiration. However, a prediction of five millimetres is the industry standard threshold for tunnel excavation settlement, and numbers greater than this are associated with measurable and significant horizontal and bending strains on buildings and services.

Settlement near tunnel portals

Settlement associated with construction of the western tunnel portals and associated trough structure may arise from the drawdown of the groundwater table during construction. Predicted settlement associated with the trough structure at the western portals could be as high as 40 millimetres., However, it is expected that these calculated settlements would be an overestimate of settlement due to the conservative settlement model underestimating the level of pre-consolidation in the ground.

Settlement in the vicinity of the eastern portals would be limited due to the presence of shallow shale rock and the stiffness of the pile wall at the portals, adjacent to Canal Road. There may also be some minor settlement arising from the excavation of the driven tunnel with shallow rock cover under the road. Accordingly, the settlements arising from cut and cover construction are expected to be less than 25 millimetres.

Summary of impacts having regard to the Aquifer Interference Policy

The predicted groundwater impacts have been compared against the minimal impact criteria in the NSW Aquifer Interference Policy (NoW, 2012a).

The majority of the study area is considered to be within a ‘less productive groundwater source’ within fractured rock, based on the low number of registered bores in the area. The groundwater within the Botany Sands is considered to be in a ‘highly productive groundwater source’.

The minimal impact considerations for ‘less productive groundwater’ in a fractured rock aquifer are considered in **Table 19-14**. The minimal impact considerations for ‘highly productive groundwater’ in a coastal aquifer are presented in **Table 19-15**.

Table 19-14 Minimal Impact Considerations for a 'less productive fractured rock aquifer'

Minimal impact considerations	Response
Water Table – Level 1 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: High priority groundwater dependent ecosystem, or High priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a two metre decline cumulatively at any water supply work.	There are no high priority GDEs listed under Schedule 4 of the Greater Metropolitan Regional Groundwater Sources Water Sharing Plan that are within the Hawkesbury Sandstone or Ashfield Shale. No culturally significant sites have been identified in the Greater Metropolitan Regional Groundwater Water Sharing Plan. Groundwater modelling has indicated that there is one registered bore within a one kilometre radius of the project tunnels that intersects Hawkesbury Sandstone and the groundwater drawdown at this location is predicted to be in excess of two metres. In this case the bore is 186 metres deep and the predicted drawdown is 5.7 metres. This impact could potentially be addressed by lowering the pump in the borehole by five to 10 metres.
Water Table – Level 2 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: 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. If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.	
Water Pressure – Level 1 A cumulative pressure head decline of not more than a two metre decline, at any water supply work.	The groundwater modelling has included the cumulative impacts of the existing M5 East Motorway tunnels. Mitigation measures have been recommended for the one bore where it has been predicted that the drawdown exceeds a water level decline of more than two metres. This mitigation measure includes lowering the pump in the borehole by five to 10 metres.
Water Pressure – Level 2 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.	

Minimal impact considerations	Response
Water Quality – Level 1 Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity.	The beneficial use category of groundwater will not be changed beyond 40 metres of the tunnel. Level 2 does not apply as Level 1 criteria are not exceeded.
Water Quality – Level 2 If the Level 1 requirement 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.	

Table 19-15 Minimal impact considerations for a 'highly productive coastal aquifer'

Minimal impact considerations	**Response**
Water Table – Level 1 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: High priority groundwater dependent ecosystem, or High priority culturally significant site listed in the schedule of the relevant water sharing plan, or A maximum of a two metre decline cumulatively at any water supply work.	There are no high priority GDEs listed under Schedule 4 of the Greater Metropolitan Regional Groundwater Sources Water Sharing Plan. There are two wetlands near the project corridor at Tempe known as the Eve Street Wetland and Landing Lights Wetland. Groundwater modelling conducted as part of this investigation suggests that the groundwater table at these wetlands is unlikely to undergo a water level decline of more than two metres. No culturally significant sites have been identified in the Greater Metropolitan Regional Groundwater Water Sharing Plan

Minimal impact considerations	Response
Water Table – Level 2 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: 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. If more than a two metre decline cumulatively at any water supply work then make good provisions should apply.	Groundwater modelling has predicted that three water supply bores within a one kilometre radius of the project tunnels are likely to be drawn down by more than two metres. Mitigation measures for these impacts include drilling deeper bores at these locations, or if not possible providing connection to the reticulated water supply or providing monetary compensation.
Water Pressure – Level 1 A cumulative pressure head decline of not more than a two metre decline, at any water supply work.	The groundwater modelling has included the cumulative impacts of the existing M5 East Motorway tunnels. Mitigation measures have been provided for the three water supply bores where it has been predicted that the drawdown exceeds a water level decline of more than two metres. Mitigation measures for these impacts include drilling deeper bores at these locations, or if not possible providing connection to the reticulated water supply or providing monetary compensation.
Water Pressure – Level 2 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.	
Water Quality – Level 1 Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 metres from the activity	The beneficial use category of groundwater would not be changed beyond 40 metres of the project tunnels. Level 2 does not apply as Level 1 criteria are not exceeded.
Water Quality – Level 2 If the Level 1 requirement 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.	

19.4 Environmental management measures

Mitigation and management measures would be implemented during construction and operation of the project to reduce or eliminate the risks posed to the existing groundwater regime. These environmental mitigation measures, including management, engineering solutions and monitoring, are summarised in **Table 19-16**.

Table 19-16 Environmental mitigation and management measures – groundwater

Impact	No.	Environmental management measure	Timing
Construction			
Disturbance of acid sulfate soils during excavation	GW01	An Acid Sulfate Soil Management Plan (ASSMP) would be prepared including the measures and monitoring to be undertaken where potential acid sulfate soils are expected. The plan would outline the type of treatment required for acid sulfate soils, bunding and requirement for treatment ponds.	Pre-Construction
Intersection of saline soils and groundwater	GW02	A groundwater and soil salinity report would be prepared prior to the commencement of earthworks to assess the potential impacts to the local hydrogeological regime.	Pre-Construction
Failure of the leachate pumping system	GW03	Contingency measures to address leachate management at the Alexandria Landfill during construction and prior to the commissioning of the new leachate treatment plant would be explored during detailed design. Identified measures would be detailed in the Construction Environmental Management Plan and implemented during construction.	Construction
Migration of contaminated groundwater into the tunnels.	GW04	The tunnel construction program would be constructed in accordance with an overarching Construction Environmental Management Plan for the project which would include measures to manage contaminated groundwater issues. This may include removal of the source of the contamination by excavation and remediation of shallow impacted soils or engineering a solution to prevent the migration of contaminated groundwater into the tunnels.	Construction
Intersection of shallow perched groundwater within Alexandria Landfill or Botany Sands	GW05	Intersected shallow contaminated groundwater would be directed to the construction water treatment plant prior to discharge. Elsewhere, collection and treatment options would be considered and releases made under relevant discharge criteria.	Construction

Impact	No.	Environmental management measure	Timing
Intersection of shallow contaminated groundwater during construction activities at Arncliffe	GW06	The intersection of shallow groundwater at the Arncliffe construction compound (C7) would be managed under Construction Environmental Management Plan(s) for the project. In the event that contaminated groundwater is intersected the approach would be to either remove the source of the contamination by excavation and remediation of shallow impacted soils or engineering a solution to prevent the migration of contaminated groundwater into the project tunnels.	Construction
Unsustainable release of groundwater resources	GW07	Treated waste water would be stored and re-used for project purposes wherever possible. Groundwater reuse would be in accordance with the policies of sustainable water use of the NSW Office of Water, such as dust suppression and earthworks	Construction
Excessive inflows during construction that may exceed the design inflow criterion of 1L/sec/km	GW08	Where saturated faults and fractures are intersected additional rock support would be installed in order to ensure tunnel stability. Appropriate waterproofing measure to reduce the inflow to an acceptable quantity will be applied as required. Measures can range from a spray- on membrane to grouting or installation of a sheet membrane	Construction
Possible high groundwater inflows and sustained pressure heads (no drawdown) beneath the Cooks River and higher fracture permeabilities	GW09	Where higher than expected inflows are experienced as beneath the Cooks River and under other major surface water features, appropriate waterproofing measure to permanently reduce the inflow to an acceptable quantity will be applied as required. Measures can range from a spray-on membrane to grouting or installation of a sheet membrane depending on the inflow volume	Construction
Aggressive groundwater chemistry such as elevated sodium, chloride, ammonia, low pH conditions that are aggressive to concrete and steel.	GW10	Building materials that are resistant to aggressive groundwater conditions would be selected.	Detailed design

Impact	No.	Environmental management measure	Timing
Spills and incidents relating to fuels, oils, lubricants and refuelling.	GW11	The project works would be undertaken in accordance with a Construction Environmental Management Plan(s) for the project which would include the following management measures: • Stockpiles of fuels, hazardous liquids and chemicals would be stored in an impervious bunded area in accordance with Australian Standards and EPA guidelines • The storage of fuels and chemicals would be limited to locations more than 40 metres from any water course • Refuelling of vehicles and machinery would occur off-site where possible or in a designated re-fuelling area • Vehicles would be properly maintained to minimise the risk of fuel/oil leaks and routine inspections of construction equipment would be undertaken to identify any fuel/oil leaks • Emergency spill kits would be kept on-site and project personnel would be aware of the location of spill kits and trained in their use • Hazardous materials handling procedures would be documented and implemented • In the event of an incident resulting in impacts to human health or the environment, works would cease immediately and the EPA would be notified (if required) • Erosion and sediment control measures would be regularly inspected, and particularly following rainfall events. The controls would remain in place until construction works are completed and areas are stabilised	Construction
Groundwater inflow into tunnels exceeding project requirements	GW12	A tunnelling procedure that details a methodology to determine when and what type of waterproofing is required to be installed during construction would be implemented during construction. Pre-excavation pressure grouting may also be used in locations identified that could produce substantial inflows to reduce groundwater inflows to an acceptable level. Post grouting (ie grouting undertaken post excavation) may also be required to further reduce groundwater inflows. Post grouting would occur within one month post excavation.	Construction

Impact	No.	Environmental management measure	Timing
Construction of the tunnels could adversely impact surface and groundwater quality, resources and wetlands.	GW13	A groundwater monitoring program would be prepared and implemented to monitor groundwater impacts during construction. The program would be developed in consultation with the EPA, DPI (Fisheries), NSW DPI Water and relevant councils.	Construction
Cracking creek beds, localised elevated inflows to tunnels from fractured rock beneath the creeks and potential surface environmental consequences from the increased flows	GW14	Where the project alignment passes close to watercourses and inflows are elevated, appropriate waterproofing measures to permanently reduce the inflow to an acceptable quantity would be applied as required	Construction
Impact to existing registered bores.	GW15	In the event that the drawdown in a water supply bore or irrigation bore exceeds two metres (in accordance with the Aquifer Interference Policy) measures would be taken to 'make good' the impact by restoring the water supply to pre-development levels. The measures taken would be dependent upon the location of the impacted bore and would 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.	Construction Operation
Ground settlement	GW16	A Settlement Monitoring Plan would be prepared that would provide details on: • Location of monitoring points • Duration of monitoring • Data collection and review • Roles and responsibilities for review of data • Triggers and actions for corrective actions	Construction
	GW17	Building conditions surveys would be undertaken in the zone of influence of the tunnel settlement where the settlement is expected to have a potential impact. In the unlikely event that any damage occurs to a property, appropriate rectifications would be carried out.	Construction
	GW18	Services in locations where differential/ angular settlement is anticipated would be identified. A monitoring plan, triggers and actions would be agreed with the relevant utility owner prior to potential impacts occurring.	Construction

Impact	No.	Environmental management measure	Timing
	GW19	A monitoring program, undertaken as part of the Settlement Management Plan, would be carried out prior to excavation until all relevant settlement has stabilised. Monitoring would be for a period of not less than six months after settlement has stabilised.	Construction
Operation			
On-going groundwater extraction and treatment during operation	OpGW01	An OEMP would be prepared and implemented to outline management measures for groundwater inflows, treatment and discharge and protocols for spillages or incidents. Monitoring parameters may include groundwater levels, groundwater quality including field parameters, laboratory analytes and sample frequency.	Operation
Build-up of precipitated iron (slimes) and silt and sand due to slaking of the sandstone.	OpGW02	The drainage system would be regularly maintained in accordance with the Operational Environmental Management Plan.	Operation
Impact on surface and groundwater quality, resources and wetlands as a result of operation	OpGW03	A groundwater quality monitoring program would be prepared and implemented to monitor groundwater impacts during tunnel operations. The program would be developed in consultation with the EPA, DPI (Fisheries), NSW DPI Water and relevant councils.	Operation
Failure of the leachate pumping system	OpGW04	Contingency measures to address leachate management in the event of pump failure would be explored during detailed design and implemented in the Landfill Closure Plan.	Operation

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20 Non-Aboriginal heritage

A Technical working paper: Non-Aboriginal heritage (**Appendix R**) has been prepared to assess the potential impact of the project on non-Aboriginal heritage. This chapter provides a summary of the technical report.

Table 20-1 presents the Secretary's Environmental Assessment Requirements (SEARs) as they relate to non-Aboriginal heritage and where in the environmental impact statement (EIS) these have been addressed.

Table 20-1 SEARs – non-Aboriginal heritage

SEAR	Where addressed
Impacts to State and local non-Aboriginal heritage (including conservation areas, built heritage landscapes and archaeology) must be assessed. Where impacts to State or locally significant historic heritage are identified, the assessment must: • outline the proposed mitigation and management measures (including measures to avoid significant impacts and an evaluation of the effectiveness of the mitigation measures) generally consistent with the guidelines in the NSW Heritage Manual (Heritage Office and Department of Urban Affairs and Planning 1996), • be undertaken by a suitably qualified heritage consultant(s) with relevant heritage expertise (note: where archaeological excavations are proposed the relevant consultant must meet the NSW Heritage Council's Excavation Director criteria), • include a statement of heritage impact for all heritage items / conservation areas to be impacted (including significance assessment). This must include detailed mapping of all heritage items and how they are affected by the proposal, • include details of any proposed mitigation measures (architectural and landscape), • consider the impacts from vibration, demolition, archaeological disturbance, altered historical arrangements and access, increased traffic, landscape and vistas, and architectural noise treatment, and • develop an appropriate archaeological assessment methodology, including research design, in consultation with the Department and the Heritage Council of New South Wales, to guide physical archaeological test excavations and include the results of these excavations.	Impacts to non-Aboriginal heritage have been assessed in **Section 20.3** and in Sections 7.0 and 9.0 of **Appendix R**. Proposed mitigation and management measures are presented in **Section 20.4** and in Section 8.0 of **Appendix R**. The assessment has been undertaken by a qualified heritage consultant. Qualifications are presented in Section 1.6 of **Appendix R**. A statement of heritage impact is provided in Section 9.0 of **Appendix R** and summarised in **Section 20.3.1**. The potential impacts of the project have been considered in **Section 20.3**, including impacts that may arise as a result of vibration, demolition, archaeological disturbance, altered historical arrangements and access, increased traffic, access, increased traffic, landscape and vistas, as well as architectural noise treatment. Archaeological management measures are proposed for the Alexandra Canal, and palaeontological management measures are proposed for the St Peters Brickpit (refer **Table 20-7**). The methodology for the non-Aboriginal heritage assessment is presented in **Section 20.1**. Details of consultation are presented in **Section 20.1** and **Chapter 7** (Consultation). No further archaeological assessment was considered necessary (refer **Section 20.1**)

20.1 Assessment methodology

The methodology for the non-Aboriginal heritage assessment included:

- Identifying the study area relevant to non-Aboriginal heritage and the project
- A literature and database review, including a search of relevant heritage registers and schedules to identify properties within the non-Aboriginal heritage study area that may be impacted during construction and operation of the project
- A field survey of the identified properties within the study area
- An assessment of heritage significance for the non-Aboriginal heritage items that may be impacted by the project, including by locating / updating existing statements of heritage impact and preparing new statements of heritage impact where none previously existed
- Assessment of the likely level of impact during construction and operation on the identified properties and non-Aboriginal heritage items, including preparation of statements of heritage impact
- Identification of proposed mitigation and management measures, including measures to avoid significant impacts and an evaluation of the effectiveness of the mitigation measures.

The non-Aboriginal assessment was undertaken in line with following guidelines:

- The Burra Charter (the Australia ICOMOS charter for places of Cultural Significance) (ICOMOS (Australia), 2013)
- Assessing Heritage Significance (NSW Heritage Office, 2001)
- Assessing Significance for Historical Archaeological Sites and Relics (NSW Heritage Branch, 2009)
- *Heritage Curtilages* (NSW Heritage Office and NSW Department of Urban Affairs and Planning, 1996b)
- Levels of Heritage Significance (NSW Heritage Office, 2008).

Apart from the abovementioned guidelines, no further components of the *NSW Heritage Manual* were considered relevant in assessing the potential impacts of the project. Furthermore, as no impacts to the archaeological potential of heritage items would occur as part of the project, it was not considered necessary to prepare a specific archaeological assessment methodology, nor was it considered necessary to prepare for archaeological test excavations in consultation with the Heritage Council of NSW.

20.1.1 Study area

The study area for the non-Aboriginal heritage assessment is shown in **Figure 20-1**, which includes the sub-surface tunnel alignments and all surface works with a 50 metre buffer on both. The 50 metre buffer has been determined as adequate to assess the potential impacts of the project on heritage items.

20.1.2 Literature and database review

A review of archaeological and historical data relevant to the project has been completed, which included heritage registers, databases and schedules, local histories and archaeological reports. This literature and data review was used to identify known non-Aboriginal heritage sites located within the study area.

A search of the relevant heritage databases was conducted on 13 April 2015 and updated on 1 September 2015 to identify non-Aboriginal heritage items within the study area. The following heritage databases have been searched:

- Statutory databases:
  - World Heritage List (World Heritage Committee, UNESCO)
  - The Commonwealth Heritage List (Australian Heritage Council)
  - The National Heritage List (Australian Heritage Council)
  - The State Heritage Register (NSW Heritage Branch, OEH)
  - The State Heritage Inventory (NSW Heritage Branch, OEH)
  - Section 170 Heritage and Conservation Register compiled by Roads and Maritime
  - Section 170 Heritage and Conservation Register compiled by Sydney Trains
  - Section 170 Heritage and Conservation Register compiled by Transport for NSW
  - Section 170 Heritage and Conservation Register compiled by Sydney Water
  - Section 170 Heritage and Conservation Register compiled by Ausgrid
  - Schedule 5 of the Hurstville Local Environmental Plan 2012 (Hurstville LEP)
  - Schedule 5 of the Canterbury Local Environmental Plan 2012 (Canterbury LEP)
  - Schedule 5 of the Rockdale Local Environmental Plan 2011 (Rockdale LEP)
  - Schedule 5 of the Botany Bay Local Environmental Plan 2013 (Botany Bay LEP)
  - Schedule 5 of the Marrickville Local Environmental Plan 2011 (Marrickville LEP)
  - Schedule 5 of the Sydney Local Environmental Plan 2012 (Sydney LEP), including proposed industrial heritage listings currently under consideration for inclusion in Schedule 5 (City of Sydney, 2014).
- Non-statutory:
  - The Register of the National Estate (Australian Heritage Council)
  - The Register of the National Trust of Australia (NSW).

Other literature was also consulted for relevant information about the non-Aboriginal heritage of the study area, including:

- A review of historical materials, such as historical parish maps and plans, to determine the historical context of the study area and identify any potential for archaeological heritage items
- Archives from the:
  - National library of Australia
  - State Library of NSW
  - City of Sydney Archives
  - Land and Property Information's on-line Historical Land Records Viewer
  - Trove digitised newspaper collections
  - Relevant local libraries.

Non-Aboriginal heritage items and areas identified through searches of these databases and registers are summarised in **Table 20-4**, **Section 20.2.2**, and are shown in **Figure 20-1**.

20.1.3 Field survey

Known non-Aboriginal heritage items and areas identified as having the potential to be impacted (either directly or indirectly) by the project were subject to a targeted inspection to determine their current condition. Results from these inspections were used to inform an assessment of potential impacts on non-Aboriginal heritage values. This process comprised:

- Review of mapped non-Aboriginal heritage listings to identify those properties with the potential to be directly or indirectly impacted during construction or operation of the project
- Compilation of available information on potentially impacted non-Aboriginal heritage listings, including past inspection photographs, as a point of comparison
- Field inspections of the identified listings, which involved recording the current condition of each site. Each listed item was photographed and compared to past descriptions / photos. Interior features or the condition of the interior of each site, if relevant to the listing, were based on the details provided within the database
- Field investigation of other potential items of non-Aboriginal heritage additional to those recorded listing locations that may be impacted by the project
- Updates to existing background information with results of field inspections.

Field inspections were carried out from 20 to 23 April 2015 and included a pedestrian and vehicle survey from the public domain within the study area. Sites marked on parish plans or identified as part of the survey were inspected and:

- The structure and / or features identified at each site were recorded
- The structures / features were then assessed for historical significance
- Photographs were taken of the structures / features with details maintained in a photo log.

An additional day of survey was conducted on 21 May 2015 to inspect the interior of the Rudders Bond Store (53-57 Campbell Road, St Peters) and several heritage listed terraces in St Peters (15, 36, 40, 44, and 126 Campbell Street, St Peters).

20.1.4 Significance assessment

Assessments of significance were undertaken to determine why particular sites are important and to enable appropriate site management and curtilage to be determined (refer **Section 20.2.4**). A heritage item may be significant at a local level (ie to the people living in the vicinity of the item), at a State level (ie to all people living within NSW) or to the country as a whole (National / Commonwealth significance). The significance assessment criteria are provided in Section 3.3 of the Technical working paper: non-Aboriginal heritage (**Appendix R**).

Significance assessments were undertaken for all properties identified as listed non-Aboriginal heritage items located within the bounds of, or within 50 metres of, the project area. These listed heritage items were assessed for current condition and compared to photographs from past inspections (where available) and the descriptions contained in heritage listings. Statements of significance were sourced from the published listings for these properties.

20.1.5 Impact assessment

For the purpose of the non-Aboriginal heritage impact assessment, the potential areas of impact were divided into the following components:

- The western surface works and Kingsgrove Road surface works
- The main alignment tunnels
- The Bexley Road surface works
- The Arncliffe surface works
- The St Peters interchange and local road upgrades.

More detailed descriptions of activities proposed at each of the areas listed above are provided in **Chapter 5** (Project description) and **Chapter 6** (Construction work).

Impacts on non-Aboriginal heritage items have been categorised as follows:

- Direct – where the project would be located within the curtilage of the heritage item and / or involve the demolition or modification of the heritage item
- Potentially direct – where the project may impact on the heritage item subject to the condition of the item, more detailed investigation, construction methodologies and / or the implementation of mitigation and management measures. For example, where the project may impact on the item through construction vibration, settlement, or the application of acoustic treatment
- Indirect – where the project would change the visual context and surroundings of a heritage item.

Types of impacts that may result from the construction or operation of the project are identified and described in **Table 20-2**, and are outlined in more detail below.

Table 20-2 Types of impacts to non-Aboriginal heritage items

Impact	Description
Direct	
Demolition	Demolition of structures.
Modification	Modification to a heritage item to cater for the project.
Acquisition	Impacts resulting from the full or partial acquisition (and associated demolition) of properties that contain heritage items. An example of heritage impact arising from acquisition would be a change from original use.
Change in heritage conservation area values	Construction of a new element within a heritage conservation area.
Potentially direct	
Acoustic treatment	Properties, some of which may be listed heritage items, may qualify for at-property acoustic treatment. This may impact on the fabric or the significance of the heritage item.
Vibration, settlement and groundwater drawdown from tunnelling works	The area of potential impact for the main alignment tunnels, on ramp and off ramp tunnels includes a zone on the surface equal to a distance of 50 metres from the outer edge of the underground tunnels. The potential impacts on non-Aboriginal heritage items may be caused by: • Construction vibration from blasting works as the road headers pass underneath properties • The settlement of land if tunnelling activities are conducted underneath or close to heritage features • Impacts on tree roots, in the case of street trees, depending on the depth of the tunnelling activity.
Vibration from surface works	Depending on the setback of buildings from the construction footprint, there is the potential for vibration impacts associated with surface road works, building construction and / or the cut-and-cover sections of the main alignment tunnels, and on and off-ramps.
Dust	Construction activities may result in the generation of dust where construction works are at the surface or during the handling of spoil. Spoil handling would be in part undertaken inside acoustic sheds at compounds. Air quality impacts during construction would be managed by implementing standard and best practice mitigation measures. As such, this potential impact has not been considered further. For further information on dust management, see **Section 10.11.1** (Air Quality).

Impact	Description
Indirect	
Visual	There may be temporary and permanent visual impacts as result of the project. These may include: • Construction of new road infrastructure or ancillary facilities • Alterations to surface roads • New noise walls or modifications to existing noise walls, including changes to the height of noise walls • Removal of vegetation • Establishment and use of construction compounds. For more information see **Sections 14.3.1** and **14.3.2** (Visual impact and urban design).

The degree to which the impacts listed above would affect the heritage value or significance of identified non-Aboriginal heritage items would vary. In order to undertake a comparative assessment, a set of impact ratings were established and used to rank the degree of impact. These impact ratings are described in **Table 20-3** below.

Table 20-3 Non-Aboriginal heritage impact criteria

Impact assessment	Criteria
Negligible	• Impacts to the heritage item in question would be negligible and would not affect the overall heritage significance of the item.
Minor impact	• Minor impacts may occur to the listed item, typically with respect to its reported curtilage as opposed to the listed item itself • These impacts would be minimal and would not affect the overall heritage significance of the item • Impacts that can be mitigated through remediation and repairs.
Significant impact	• Impacts to the heritage item are unavoidable with the current project design • The heritage value of the item would be impacted.

20.2 Existing environment

20.2.1 Historical context

The literature and data review was used to inform a description of the historical context of the region from pre-European contact until the present day, as follows:

- Aboriginal history - the study area falls within the traditional country of the Darug people, who spoke the Darug (also spelt Dhaŕ-rook, Dharrook, Dhaŕook, Dharruk and Dharug) language. Individual bands of up to around 60 individuals occupied the Cumberland Plain (Attenbrow, 2010), with much larger groups of Aboriginal people, numbering in the hundreds, coming together for events such as corroborees, ritual combats and feasts
- Post-contact history - traditional hunting and camping grounds of the Darug-speaking peoples of the Sydney Region were rapidly claimed and settled by Europeans, and Aboriginal populations decimated by introduced diseases such as tuberculosis and small pox (Attenbrow, 2010). Further details regarding the Aboriginal history and heritage of the region can be found in **Section 23.2**, and Section 4.2 of the Technical working paper: Aboriginal heritage (**Appendix R**)
- European settlement:
  - The Cooks River and Wolli Creek area was one of the last areas close to Sydney to be settled by Europeans. From 1799, the land from what is today Tempe and St Peters to the modern suburb of Kingsgrove was settled as pasture and timbered lands (Wolli Creek Preservation Society, 2011). The area known today as Beverly Hills was settled in 1810. It contained dense forest, small market gardens, dairies, timber getters and charcoal burners (City of Canterbury Library, 2012). Arncliffe was settled in the 1830s and the land was used for farming, including the raising of pigs, poultry, cattle and horses (Rathborne, 1997)

- The first large estate in the area was owned by James Chandler who purchased Sylvester Farm in 1822, around 100 acres (about 40 hectares) to the west of Wolli Creek adjoining Kingsgrove which was added to with a further grant of 1,200 acres (about 485 hectares), covering what is today Bexley, Bexley North, Kogarah and part of Rockdale (Rathborne, 1980)
- The depression of the 1840s plunged many big estate owners into bankruptcy, resulting in subdivision of land along Wolli Creek for smaller farms and market gardens (Wolli Creek Preservation Society, 2011)

- Early 20th century:
  - Many older houses and mansions in the region were subdivided and replaced by working class housing and industries. Bexley remained an elite suburb, Arncliffe accommodated noxious industries such as tanneries, boiling down works and wool washing, and St Peters was famous for its brickworks (Thorp, 1994)
  - The opening of the East Hills railway line in 1931, as well as the break-up of former private lands. Greater access to cars as a means of transport encouraged significant increase in the region's suburbanisation. However, Bexley North, Kingsgrove and Kyeemagh remained sparsely settled until after World War II (Thorp, 1994).
- Post World War II:
  - Small farms, dairies and market gardens closed in the 1960s following pressures of increased urbanisation (Wolli Creek Preservation Society, 2011)
  - Incremental development of Sydney Airport took place over time with the addition of new passenger and military infrastructure. Following WWII, Cooks River was diverted to develop new runways. A third runway was opened in 1994, requiring the Commonwealth government to acquire properties in the area. In 2002 the airport was privatised (Sydney Airport Corporation Limited, 2009)
  - In 2001, the Roads and Traffic Authority (now Roads and Maritime) opened the M5 East Motorway to traffic (Roads and Maritime, 2015c).
- Present day - the study area covers a populous residential and commercial area and supports the main road infrastructure linking the Sydney CBD, Sydney Airport and Port Botany to western Sydney.

20.2.2 Historic heritage items

The review of heritage registers and databases identified 57 individual heritage items within the study area (refer to **Table 20-4** and **Figure 20-1**). Taking in account that seven items are listed on more than one register, a total of 70 listings were identified.

Table 20-4 Historic heritage items identified on heritage registers

Register	Items within study area
Commonwealth	
World Heritage List	No listed items.
National Heritage List	No listed items.
Commonwealth Heritage List	No listed items.
Register of the National Estate (non-statutory) Nine heritage items.	Alexandra Canal (ID No 103889)
	St Peters Brickpit Geological Site on Princes Highway (ID No 162040)
	St Peters Anglican Church and graveyard on Princes Highway 9 ID No 1716)
	Kingsgrove East Urban Conservation Area (ID No 102091)
	Pallamanna Parade Urban Conservation Area (Beverly Hills) (ID No 102089)
	Clemton Park Urban Conservation Area (ID No 102071)
	Bardwell Park Urban Conservation Area (ID No 102101)
	Sydenham Village (ID No 100061)

Register	Items within study area
State	
NSW State Heritage Register Five State listed heritage items	Arncliffe Railway Station Group on Firth Street (ID No 01076)
	Western Outfall Main Sewer Valda Avenue (ID No 01647)
	Timber Slab Cottage on Barden Street (ID No 01412)
	Alexandra Canal 9 ID No 016210
	St Peters Anglican Church and graveyard on Princes Highway (ID No 00032)
Sydney Water Section 170 Heritage And Conservation Register Three State listed heritage items	Western Outfall Main Sewer Valda Avenue (ID No 4572728)
	Alexandra Canal (ID No 4571712)
	Sewerage Pumping Station No. 39 (ID No 4571730)
Sydney Trains Section 170 Heritage And Conservation Register One State listed heritage items, and three listed as having local significance	Arncliffe Railway Station Group on Firth Street (ID No 4801150)
	Arncliffe Overbridge on Forest Road (ID No 4805728)
	Bexley North Railway Station (Register ID No 48101898)
	Wolli Creek Culvert (Register ID No 4305006)
Roads and Maritime Section 170 Heritage And Conservation Register Two State heritage items	Terrace group of housing at 28-44 Campbell Street (ID No 4305629)
	House at 82 Campbell Street (ID No 4305643)
Local	
Canterbury LEP	No listed items.
Hurstville LEP	No listed items.
Marrickville LEP Seventeen local heritage items, including one heritage conservation area	Timber Slab Cottage on Barden Street (I294)
	Moreton Bay Fig at 43 South Street (I303)
	Brick Kerbs and Sandstone Kerb Guttering (George Street, Henry Street, Park Road, Park Lane, Railway Lane, Rowe Lane, Reilly Lane and Stewart Lane) (I284)
	Victorian Filigree Style Sandstone Faced Residence on Railway Road (I288)
	Construction of St Mary / St Mina Coptic Orthodox Church on Railway Road (I289). Note that Marrickville Council have determined to demolish the Church. It will be removed from the Marrickville LEP.
	Alexandra Canal (I270)
	Goodsell Estate Heritage Conservation Area (C16)
	Southern Cross Hotel on Princes Highway (I277)
	A Service Garage at 316 Princes Highway (I312)
	Westpac Stores and Penfolds Wine Cellars on Princes Highway (I299)
	St Peters Anglican Church and graveyard on Princes Highway (I275)
	The Town and Country Hotel on Unwins Bridge Road (I281)
	Narara Terraces on Unwins Bridge Road (I282)
	The Waugh and Josephson Industrial Buildings on Unwins Bridge Road (I280)
	The terrace houses at 105-119 May Street (I273)
	St Peters Public School at 93A Church Street (I271)
	Remaining brick road and footpath paving and stone guttering (I283)

Register	Items within study area
Rockdale LEP Twenty-one local heritage items	House at 148 Wollongong Road (I61)
	Victorian Shop and Dwelling on Firth Street (I21)
	Arncliffe Railway Station Group on Firth Street (I1)
	Street Plantings on Firth Street (Figs) (I18)
	Glenevie Lane (I20)
	Arncliffe Post Office and residence on Firth Street (I19)
	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) (I48)
	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) (I49)
	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) (I50)
	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) (I51)
	Rosslyn Hospital on Forest Road (I24)
	St Francis Xavier Church Group on Forest Road (I22)
	St Francis Xavier Catholic Presbytery on Forest Road (I23)
	Victorian house at 73 West Botany Street (I56)
	Californian Bungalow at 21 Fairview Street (I16)
	Californian Bungalow at 7 Fairview Street (I15)
	Bard of Avon Terrace at 39 Eden Street (I13)
	Victorian house at 31 Kyle Street (I35)
	Wolli Creek Valley (I237)
	Stotts Reserve on Slade Road (I165)
	Stone Federation House at 15 East Street (I81)
Sydney LEP Eight local heritage items, including two items listed under proposed amendments to Sydney LEP (industrial and warehouse buildings)	Alexandra Canal (I13)
	Warehouse “Rudders Bond Store” on Campbell Street (I405)
	The Terrace Group at 2-34 Campbell Road (I12)
	Sewerage Pumping Station No. 39 (I18)
	Industrial Building “Frank G Spurway” on Maddox Street (I20)
	The Cooper Estate Conservation Area (C2)
	Macdonaldtown stormwater channel on Euston Road (proposed amendment ID No 3)
	Former Alexandria Spinning Mills on Maddox Street (proposed amendment ID No and 14)
Botany Bay LEP One local listed heritage item	Alexandra Canal (I1)
Total	70 listings of a total of 57 individual heritage items (including seven heritage items which are listed on two or more registers)

Seven items were found to be listed on more than one heritage register (refer to Table 4 of Technical working paper: Non-Aboriginal heritage in **Appendix R**). In the case of those heritage items with multiple listings, each heritage item has only been counted once.

The following areas are broad, landscape based heritage listings:

- Pallamanna Parade Urban Conservation Area
- Kingsgrove East Urban Conservation Area
- Clemton Park Urban Conservation Area
- Bardwell Park Urban Conservation Area

- Goodsell Estate Heritage Conservation Area
- Cooper Estate Conservation Area
- Sydenham Village.

The significance of these areas is discussed further in Section 6.0 of Technical working paper: Non-Aboriginal heritage (**Appendix R**).

While the Former Bedford Brickworks group within Sydney Park is locally listed under the Sydney LEP (I27), it sits outside the 50 metre study area delineated in **Section 20.1.1**. Furthermore, while not listed under the Sydney LEP or any other heritage register, Sydney Park itself does contain areas of archaeological potential pertaining to the former brickworks (refer Sections 5.2.6 and 6.12.2 of **Appendix R**). Due to the prominence of these items, they have been considered for potential visual impacts as a result of the project (refer Section 7.2.4 of **Appendix R**).

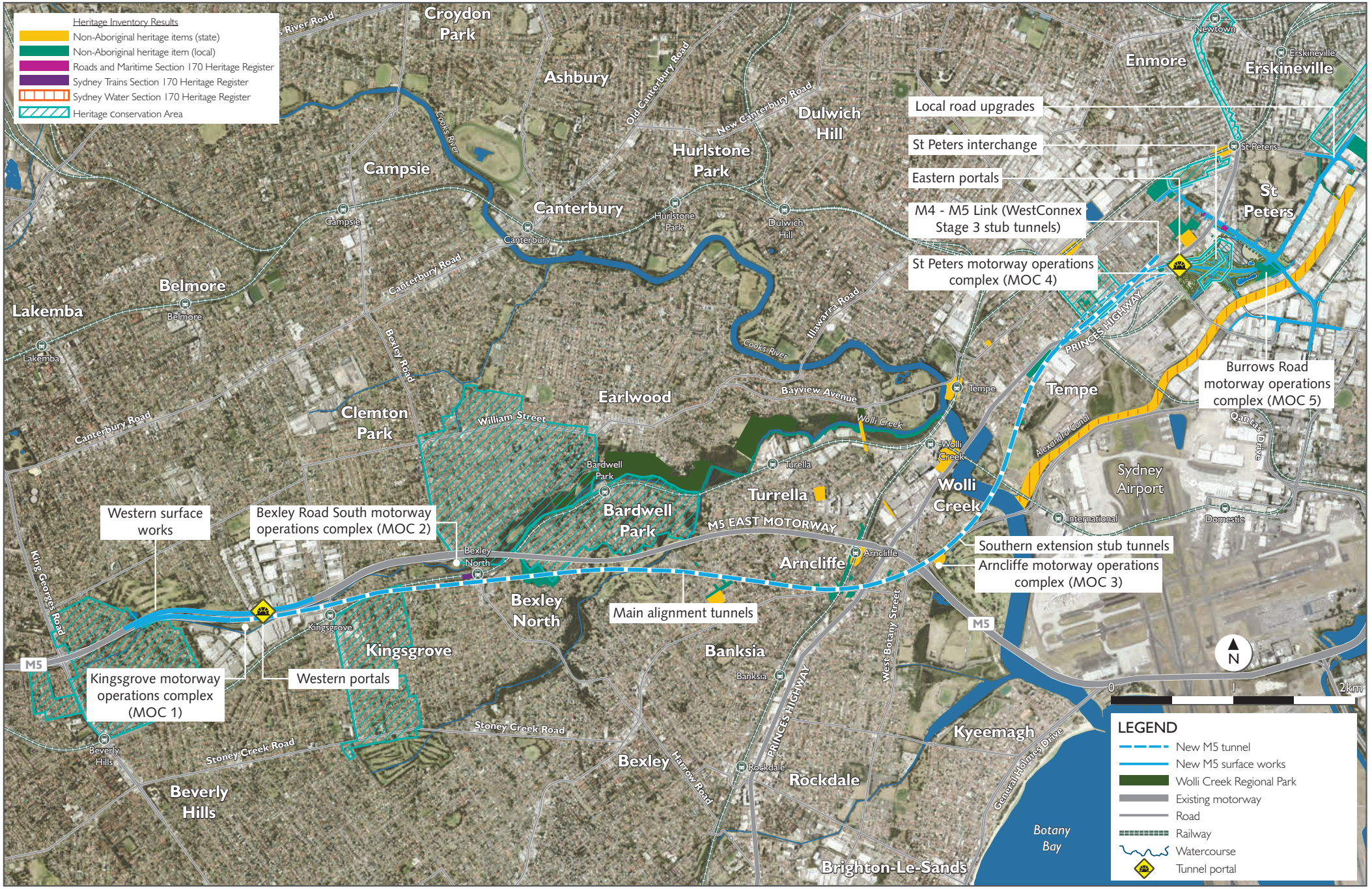


Figure 20-1 Non-Aboriginal heritage inventory results within the study area and surrounds

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20.2.3 Surface disturbance areas

The review of historical maps, plans and images focused on areas where surface disturbance is proposed. Archaeological relics or deposits located in the vicinity of the tunnel alignments are unlikely to be impacted by the project, except in areas of surface disturbance as part of the western surface works, the St Peters interchange surface works and intervening construction compound sites.

This section is divided into an examination of the non-Aboriginal archaeological potential of the western surface works, Bexley surface works, Arncliffe surface works area, St Peters interchange and local roads upgrades, which are shown on **Figure 20-2** to **Figure 20-6**.

It is also relevant to note the potential for historical tram tracks to be intercepted by ground breaking works throughout these areas. Historically, tram tracks extended throughout the Sydney area, including tracks running from the central business district toward Newtown, Alexandria, Enmore, St Peters, Marrickville, Tempe and Cooks River. As the historical retention of tram tracks and associated infrastructure beneath later developments was ad hoc, there is therefore potential to encounter tram tracks wherever those tracks were historically located.

Western surface works

This area is shown in **Figure 20-2** and **Figure 20-3**. Historical parish plans and the 1943 aerial photography of Sydney provide evidence of land grants, subdivisions and later residential development in this area. The western surface works would take place within the existing M5 East Motorway road reserve. There is no indication that potential archaeological relics or deposits remain in situ at this location.

Kingsgrove Road surface works

This area is shown in **Figure 20-3**. The Kingsgrove Road surface works would be undertaken within the current road reserve of the M5 East Motorway. There are no identified areas of archaeological potential within the areas likely to be disturbed by the Kingsgrove Road surface works.

Bexley Road surface works

This area is shown in **Figure 20-3**. The Bexley Road surface works (which would include construction and operational ancillary facilities) are located within three discrete locations on the eastern and western side of Bexley Road, north of the Bexley North Railway Station. Parish plans and the 1943 aerial photograph indicate that two of the three locations of the Bexley Road surface works remained undeveloped in 1943 (refer to Figure 8 of **Appendix R**). Any relics found at these locations would therefore post-date the early 1940s. The Bexley Road east construction compound has been historically occupied by buildings, as shown on Figure 15 of **Appendix R**. As the site is currently occupied by the M5 East Motorway trial filtration plant, the potential for remnant relics or deposits is considered to be low.

Arncliffe surface works area

This area is shown in **Figure 20-4**. Parish records show that the area around the Arncliffe surface works area was probably still Crown land before the 1830s. The 1943 aerial photographs show that the surrounding area was used for market gardening, and indicate a number of small structures within the extent of the works. However it is anticipated that relics and deposits associated with those structures would have been removed during the subsequent construction of the golf course and associated reclamation activities.

St Peters interchange

This area is shown in **Figure 20-5** and **Figure 20-6**. It was initially subject to an early colonial land grant. However the land was swampy and so remained undeveloped for a period. The 1890s parish plan shows Barwon Park, which, according to the 1951 aerial photograph became the Central Brick and Tile Company kilns. Aerial photographs between 1951 and 1997 indicate that the area containing the kilns was used to manage and stockpile wastes and was later disturbed, and that the kilns and associated structures were later demolished. It is unlikely that relics or deposits associated with the Central Brick and Tile Company remain in situ as any remains are likely to have been disturbed by subsequent waste facility related activities.

The Austral Brick Company also established and operated separate kilns and a brickpit in this area in 1975. It is unlikely that relics associated with the Austral Brick Company will remain in these areas, apart from a section on the corner of Princes Highway and Canal Road.

No substantial ground disturbance works are planned for this area as it contains the Service Garage at 316 Princes Highway, St Peters (a heritage item that is being retained). The footprint of the heritage item closely mirrors that of an historical building from the Austral operation and it is therefore unlikely that landscaping works or similar around the heritage item would encounter relics.

Local road upgrades

These areas are shown in **Figure 20-5** and **Figure 20-6**. The local roads upgrades would be largely undertaken within current road reserves and associated footpaths or in industrial areas that have been developed recently. However, some local road upgrade works would encroach onto numerous areas containing non-Aboriginal heritage items, including the following:

- Goodsell Estate Heritage Conservation Area, corner of Bedwin Road and May Street, St Peters
- Roads and Maritime owned terrace housing, Campbell Street, St Peters
- Roads and Maritime owned house, Campbell Street, St Peters
- Alexandra Canal
- Cooper Estate Heritage Conservation Area, bounded by Fountain Street, Lawrence Street, Hartley Street, Lawrence Lane, Huntley Street and Mitchell Road, Alexandria
- St Peters Brickpit Geological site, corner of Princes Highway and Canal Road.



Figure 20-2 Non-Aboriginal heritage inventory results - map 1 (Western surface works)

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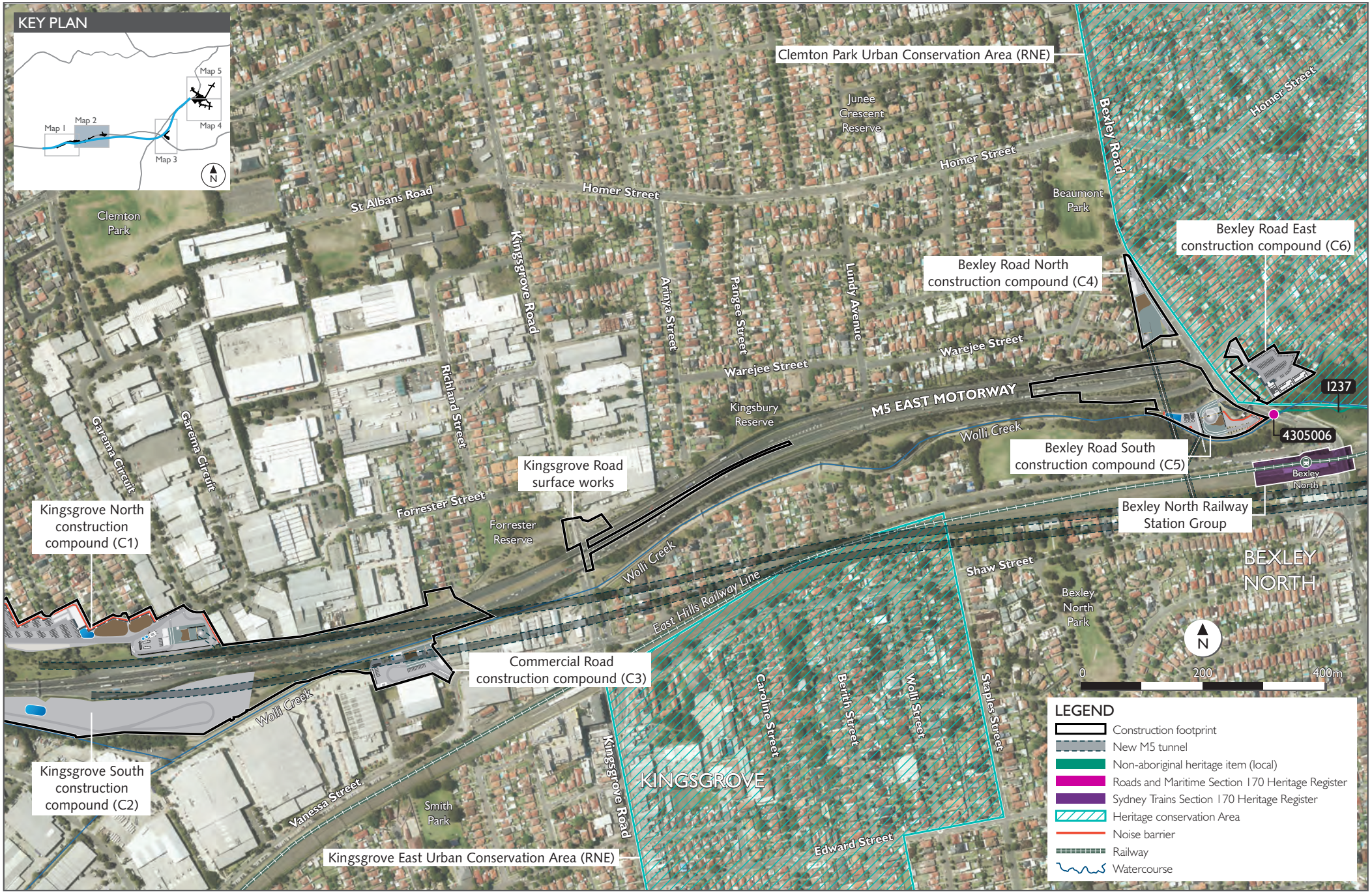


Figure 20-3 Non-Aboriginal heritage inventory results - map 2 (Kingsgrove and Bexley Road surface works)

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Figure 20-4 Non-Aboriginal heritage inventory results - map 3 (Arncliffe surface works)

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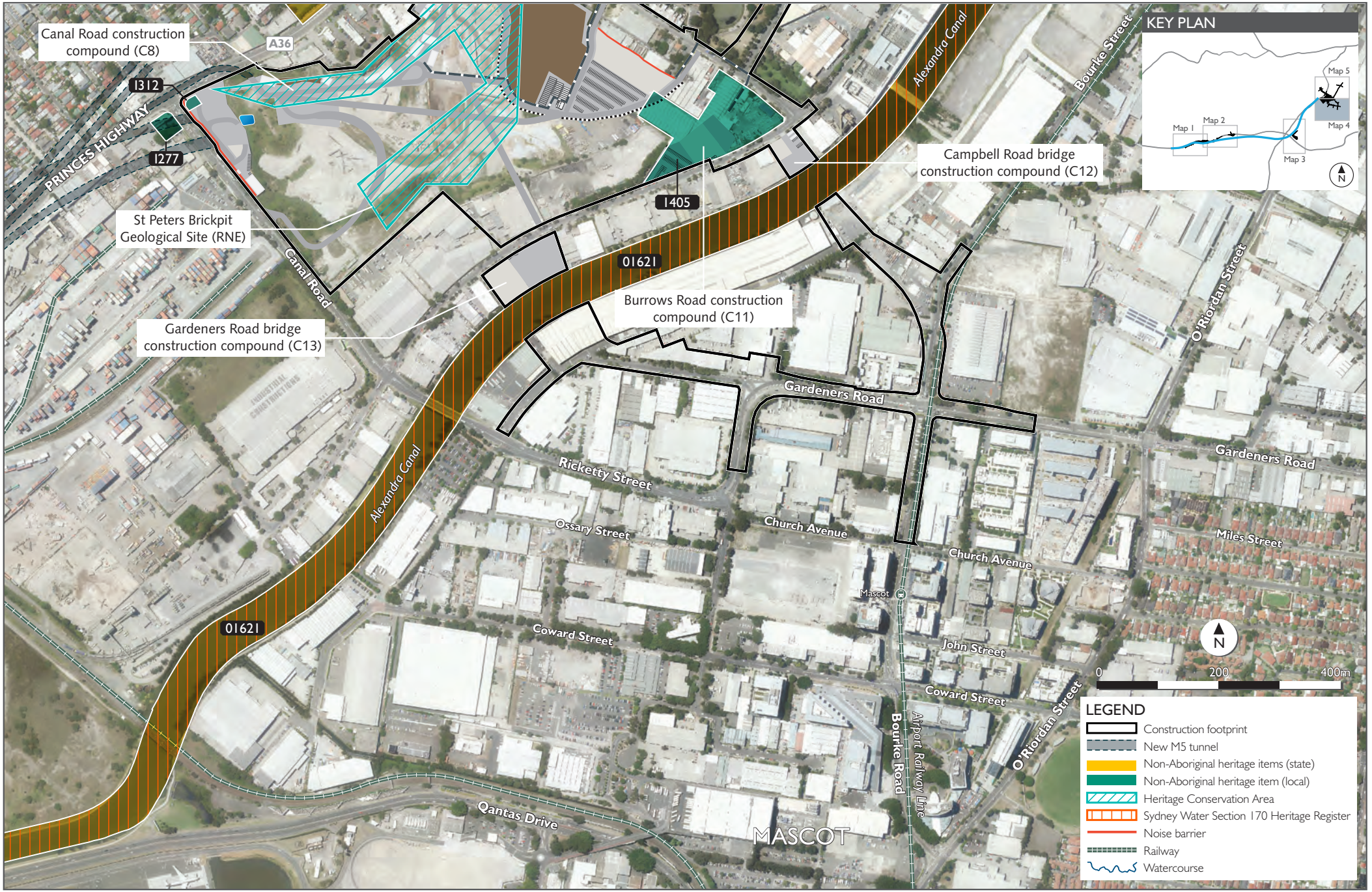


Figure 20-5 Non-Aboriginal heritage inventory results - map 4 (St Peters interchange and local roads)

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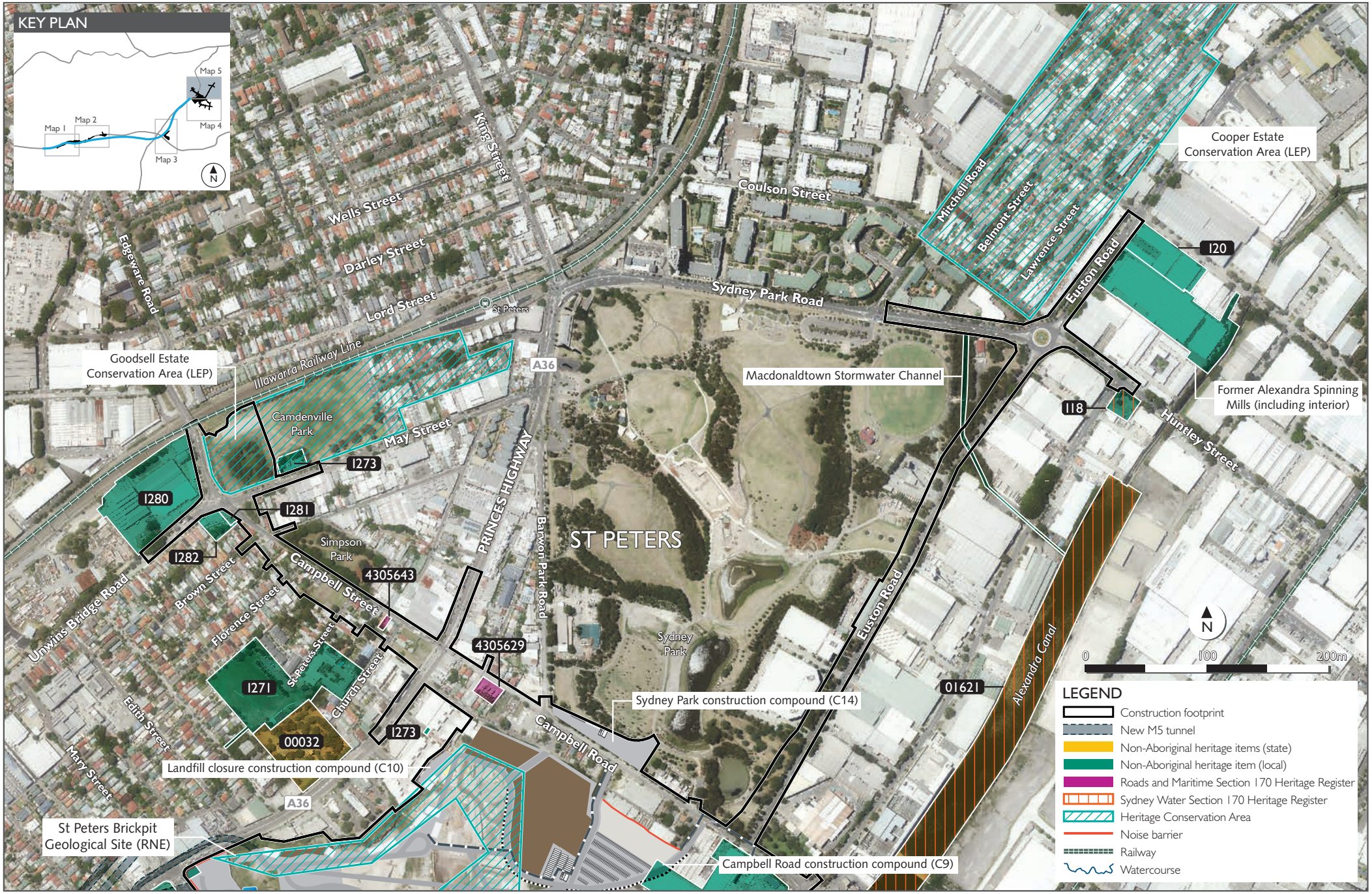


Figure 20-6 Non-Aboriginal heritage inventory results - map 5 (St Peters interchange and local roads)

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20.2.4 Significance assessment

To understand how the project would impact on non-Aboriginal heritage items within the study area it is necessary to first understand why each non-Aboriginal heritage item is significant. Assessments of significance explain why a particular heritage item is important. They also enable the boundary of the heritage site to be properly identified, and allow appropriate site management measures to be selected. For many of the non-Aboriginal heritage items within the study area, statements of heritage significance already exist and are available in the public domain. Where necessary, and based on the site inspection and historical research carried out, significance assessments were revised to ensure they were up to date.

Non-Aboriginal heritage items may be classified as having either a local or State level of heritage significance, in accordance with the guideline *Assessing Heritage Significance* (NSW Heritage Office, 2001) and the *Heritage Act 1977*. Full details of the methodology used to assess non-Aboriginal heritage significance are provided in Section 3.0 of the Technical working paper: Non-Aboriginal heritage (**Appendix R**). The resulting statements of significance for each non-Aboriginal heritage item within the study area are provided in Section 6.0 of the Technical working paper: Non-Aboriginal heritage (**Appendix R**).

Table 20-5 summarises the significance of individual non-Aboriginal heritage items found within each suburb of the study area. The locations of these non-Aboriginal heritage items along the study area are shown in **Figure 20-1**.

The Register of the National Estate no longer has a statutory purpose. Indicative places were identified as potentially being eligible for listing on the Register, but their boundaries and heritage significance were not subject to further refinement.

Table 20-5 Significance listing and reasons for heritage significance

Significance / listing	Summary of heritage significance
Kingsgrove / Beverly Hills / Clemton Park	
Register of the National Estate ID No 102091	The Kingsgrove East Urban Conservation Area (Kingsgrove) is identified on the Register of the National Estate as an area of 1930s Californian bungalows, with some 1940s and 1950s houses. Its status is as an indicative place.
Register of the National Estate ID No 102089	The Pallamanna Parade Urban Conservation Area (Beverly Hills) is identified on the Register of the National Estate as an area of 1930s Californian bungalows, with some 1940s and 1950s houses. Its status is as an indicative place.
Register of the National Estate ID No 102071	The Clemton Park Urban Conservation Area (Clemton Park) is identified on the Register of the National Estate as an area of 1930s Californian bungalows, with some 1940s and 1950s houses. Its status is as an indicative place.
Bexley North	
Local significance - Sydney Trains Section 170 Heritage and Conservation Register ID No 48101898	While not rare, the Bexley North Railway Station is part of the East Hills line, a major Great Depression period piece of public works infrastructure. It provides examples of experimentations with railway architectural styles adaptation to depression period economic conditions.
Local significance – Rockdale LEP I165	Stotts Reserve on Slade Road is a sandstone vegetation and forested area containing remnant bushland.
Bardwell Park	
Local significance – Rockdale LEP I81	Stone Federation House at 15 East Street is a federation rusticated sandstone cottage from the 1910 Maylands Estate subdivision.
Register of the National Estate ID No 102101	Bardwell Park Urban Conservation Area is an area of 1930s Californian bungalows, with some 1940s and 1950s houses.
Earlwood	
Roads and Maritime Section 170 Heritage and Conservation Register ID No 4305006	Wolli Creek Culvert on Bexley Road was a key component of upgrade works bringing Bexley Road up to standard as a newly classified Main Road serving fast growing Canterbury.
Arncliffe	
Local significance - Rockdale LEP I61	House at 148 Wollongong Road is a single storey federation arts and crafts style.
Local significance - Rockdale LEP I21	Victorian Shop and Dwelling on Firth Street evidences the district's economic growth in the mid-late 19th century (ie used as a grocery shop servicing growing population accompanying improved railway access). It also evidences strip commercial development in the Rockdale local government area in the early 20th century.
State significance – State Heritage Register ID No 01076, Sydney Trains Section 170 Heritage and Conservation Register ID No 4801150, and Rockdale LEP I1	Arncliffe Railway Station Group on Firth Street demonstrates the Illawarra Line's development from 1884 to 1925.

Significance / listing	Summary of heritage significance
Local significance - Rockdale LEP I18	Street Plantings on Firth Street (Figs) evidence the public streets beautification program in the early 20th century.
Local significance - Rockdale LEP I20	Glenevie Lane connects an urban network of streets between Firth Street and the Arncliffe Railway Station.
Local significance – Register of the National Estate ID No 19170, and Rockdale LEP I19	Arncliffe Post Office and residence on Firth Street are of rare federation style.
Local significance - Rockdale LEP I48	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) are part of rare group from the early development of Bardens Estate in 1895.
Local significance - Rockdale LEP I49	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) are part of rare group from the early development of Bardens Estate in 1895.
Local significance - Rockdale LEP I50	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) are part of rare group from the early development of Bardens Estate in 1895.
Local significance - Rockdale LEP I51	Victorian Houses and Semi-Detached Dwelling on Stanley Street (16-26) are part of rare group from the early development of Bardens Estate in 1895.
Local significance - Sydney Trains Section 170 Heritage and Conservation Register ID No 4805728	Arncliffe Overbridge on Forest Road is the largest single span brick arch road bridge on the NSW railway network.
Local significance - Rockdale LEP I24	Rosslyn Hospital on Forest Road is a prominent Victorian style villa. Its later conversion to a hospital was a significant contribution to health services development in Arncliffe.
Local significance - Rockdale LEP I22	St Francis Xavier Church Group on Forest Road shows ecclesiastical design from the interwar period, and is historically significant to the early 20th century development of Arncliffe.
Local significance - Rockdale LEP I23	St Francis Xavier Catholic Presbytery on Forest Road is a late Victorian villa.
Local significance - Rockdale LEP I56	Victorian house at 73 West Botany Street is part of the original village of West Botany.
Local significance – Rockdale LEP I16	Californian Bungalow at 21 Fairview Street is part of the original Gibbini Dappeto Estate subdivision in 1918, as Rockdale developed into a commuter suburb.
Local significance - Rockdale LEP I15	Californian Bungalow at 7 Fairview Street demonstrates the expansion of Arncliffe during the 1920s-1930s.
State significance – State Heritage Register ID No 01647, Sydney Water Section 170 Heritage and Conservation Register ID No 4572728	Western Outfall Main Sewer continues in use as part of an original system built in the 1890s to end sewage discharge to Sydney Harbour.
Local significance – Rockdale LEP I13	Bard of Avon Terrace at 39 Eden Street is early evidence of the Wincanton Estate and the late 19th century development of Arncliffe.
Local significance - Rockdale LEP I35	Victorian house at 31 Kyle Street was one of the first houses built on the Innesdale Estate.

Significance / listing	Summary of heritage significance
Wolli Creek	
Local significance - Rockdale LEP I237	Wolli Creek Valley is a rare example of native vegetation and landscape in the inner Sydney urban area, containing several rare and significant fauna and flora species. It is significant for its role in the decision to begin settlement in the area by providing water and promised good soils for crops. It was integral to the protection of the riparian corridor of Wolli Creek and acts as an essential green recreation corridor buffering densely urban surrounding areas.
Tempe	
State significance – State Heritage Register ID No 01412, and Marrickville LEP I294	Timber Slab Cottage on Barden Street was constructed around 1840, and is a rare surviving example of rudimentary timber buildings in early Sydney.
Local significance – Marrickville LEP I303	Moreton Bay Fig at 43 South Street was planted after the Tempe Estate subdivision, in either late 19th or early 20th century.
Sydenham	
Local significance - Marrickville LEP I284	Brick Kerbs and Sandstone Kerb Guttering (George Street, Henry Street, Park Road, Park Lane, Railway Lane, Rowe Lane, Reilly Lane and Stewart Lane) demonstrate the development of Sydenham. These are rare heritage features, given that the majority of guttering is now impacted / replaced by upgrade works.
Local significance - Marrickville LEP I288	Victorian Filigree Style Sandstone Faced Residence on Railway Road has an unusual stone front façade reflecting proximity to stone quarries.
Local Significance - Marrickville LEP I289	Construction of St Mary / St Mina Coptic Orthodox Church on Railway Road demonstrated the district's growing Methodist congregation. It is noted that Marrickville Council has determined to demolish the Church as no suitable use for the structure has been found.
Register of the National Estate ID No 100061	Sydenham Village is listed on the Register of the National Estate as an indicative place. It was an area of workers' cottages, built with bricks from the local brickworks. The central portion of the village was demolished as noise mitigation related to the construction of the third runway at Sydney Airport.
St Peters	
State significance – Register of the National Estate ID No 103889, State Heritage Register ID No 01621, Sydney Water Section 170 Heritage and Conservation Register ID No 4571712, Sydney LEP I13, Marrickville LEP I270 and Botany Bay LEP I1	Alexandra Canal was built on the historic Sheas Creek, which was first dredged in 1887, and was an unemployment relief scheme. The original canal extended between Sydenham to Botany Railway Bridge to the Canal Road Bridge. In 1894 plans were made to extend the Canal to Redfern. However, only part of this was constructed and the Canal halted just to the south of Huntley Street, Alexandria in 1900. During the expansion of Sydney Airport between 1947 and 1970, the Canal underwent major alterations. However the Canal was never fully utilised, being subject to silting, tidal factors and limitations on the draft of vessels that could use the passage. The closure of the Canal to shipping traffic began in the 1930s when two lifting span bridges were replaced with fixed span bridges. In the early 1940s the wharves that had serviced the Alexandra Canal were demolished as the declining use of the Canal did not warrant their maintenance.

Significance / listing	Summary of heritage significance
Local significance - Marrickville LEP C16	Goodsell Estate Heritage Conservation Area demonstrates principles and patterns of Marrickville's development, including brick and pottery industries.
Local significance – Roads and Maritime Section 170 Heritage and Conservation Register ID No 4305629	Terrace group of housing at 28-44 Campbell Street is part of rare group housing for this part of Sydney prior to the 1890s. These properties housed brickworkers after the 1870s.
Local significance – Roads and Maritime Section 170 Heritage and Conservation Register ID No 4305643	House at 82 Campbell Street is part of rare group housing for this part of Sydney prior to the 1890s. These properties houses brickworkers after the 1870s.
State significance - Sydney LEP I405	Warehouse “Rudders Bond Store” on Campbell Street is of State historical significance through its associations with Ralph Symonds Pty Ltd. The Symonds company were instrumental in the development and wide-spread use of glued structural laminated timber and laminated timber more generally, particularly during the materials shortages of World War Two and the following years.
Local significance - Sydney LEP I12	The Terrace Group at 2-34 Campbell Road was constructed around 1886 and leased to families working in nearby brickpits and factories.
Register of the National Estate ID No 162040	St Peters Brickpit Geological Site on Princes Highway has palaeontological value, and has been used for tertiary Palaeontological / geological educational purposes.
Local significance - Marrickville LEP I277	Southern Cross Hotel on Princes Highway has been a hotel site since 1906. The existing 1936 hotel shows interwar free classical style.
Local significance - Marrickville LEP I312	A Service Garage at 316 Princes Highway has detailing and architectural style unusual as applied to a mechanical workshop.
Local significance - Marrickville LEP I299	Westpac Stores and Penfolds Wine Cellars on Princes Highway were constructed in 1956, and constitute a modern industrial precinct of better quality than many of the other recent industrial developments in the area.
State significance – State Heritage Register ID No 00032, the Marrickville LEP 2011 I275, and Register of the National Estate ID No 1716.	St Peters Anglican Church and graveyard on Princes Highway is one of the earliest churches constructed as a result of the *Church Building Act 1836* and with the use of free labour in NSW. The graveyard contains many colonial settlers.
Local significance - Marrickville LEP I281	The Town and Country Hotel on Unwins Bridge Road is unusual for its close historical association with the Narara Terraces, and by together forming a unifying corner treatment of Unwins Bridge Road.
Local significance - Marrickville LEP I282	Narara Terraces on Unwins Bridge Road are unusual for their close historical association with the Town and Country Hotel, and by together forming a unifying corner treatment of Unwins Bridge Road.
Local significance - Marrickville LEP I280	The Waugh and Josephson Industrial Buildings on Unwins Bridge Road show the interwar functionalist style of the area.
Local significance - Marrickville LEP I273	The terrace houses at 105-119 May Street provided accommodation for brick and other industrial workers.
Local significance - Marrickville LEP I271	St Peters Public School at 93A Church Street is a late 19th century school building showing the development of St Peters.

Significance / listing	Summary of heritage significance
Local significance – Marrickville LEP I283	Remaining brick road and footpath paving and stone guttering.
Alexandria	
Local significance – Sydney Water Section 170 Heritage and Conservation Register ID No 4571730 Local significance - Sydney LEP I18	Sewerage Pumping Station No. 39 has multiple heritage listings. It and Water Board Pump House on Huntley Street were constructed in 1925 to combat the increasing pollution caused by Sydney's growing population.
Local significance - Sydney LEP I20	Industrial Building "Frank G Spurway" on Maddox Street shows mid-20th century industrial / commercial development.
Local significance – Sydney LEP C2	The Cooper Estate Conservation Area was subdivided in the 1880s to provide housing for industrial workers.
Local significance - proposed amendment to Sydney LEP 2012 (Industrial and warehouse buildings) ID No 3	Macdonaldtown stormwater channel on Euston Road is proposed to be included in amendments to Sydney LEP.
Local significance - proposed amendment to Sydney LEP 2012 (Industrial and warehouse buildings) ID No and 14	Former Alexandria Spinning Mills on Maddox Street is proposed to be included in amendments to Sydney LEP.

20.3 Assessment of potential impacts

Fifty seven non-Aboriginal heritage items are expected to be directly or indirectly impacted by the project. In some instances, an item would be both directly and indirectly impacted by the project. The early identification of non-Aboriginal heritage items and conservation areas during the design phase informed the project design and enabled the avoidance of heritage items where practicable.

Impacts to heritage items are discussed below. Statements of heritage impact are included in Section 9.0 of the Technical working paper: Non-Aboriginal heritage (**Appendix R**). The assessment considered the following types of impacts:

- Primary direct impacts, where the project would be located within the curtilage of the heritage item and / or involve the demolition or modification of the heritage item or its heritage significance
- Secondary direct impacts to heritage items, where the project may impact on the heritage item or its significance subject to the condition of the item, more detailed investigation, construction methodologies and / or the implementation of mitigation and management measures
- Indirect impacts to heritage items, where the project would change the visual context and surroundings of a heritage item with the potential to affect its heritage significance.

The assessment considered the degree of impact the project would have on heritage items (being negligible, minor or significant) (refer **Section 20.1.1**). The outcomes of this assessment are presented in Sections 7.0 and 9.0 of the Technical working paper: Non-Aboriginal heritage (**Appendix R**). Items where the degree of impacts has been determined as minor or significant are provided in **Table 20-6**.

As an outcome of this assessment, statements of heritage impact have been prepared for the following items which would be considered to be significantly or physically impacted by acquisition by the project following mitigation and management:

- Rudders Bond Store
- Terraces and houses on Campbell Street
- Alexandra Canal
- St Peters Brickpit Geological Site
- Service garage
- Goodsell Heritage Conservation Area.

These statements of heritage impact are summarised in **Section 20.3.1** below. Impacts to the remaining items consist primarily of potential negligible direct impacts as a result of tunnelling works. Further information regarding impacts to non-Aboriginal heritage items is provided in Sections 7.0 and 9.0 of the Technical working paper: non-Aboriginal heritage (**Appendix R**), including descriptions of impacts specific to each heritage item. Those heritage items which would be significantly impacted have been assessed further in Section 9.0 of the Technical working paper: Non-Aboriginal heritage (**Appendix R**), and are depicted in **Figure 20-7**.

Table 20-6 Summary of impact assessment

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Section 170 - Roads and Maritime	Wolli Creek Culvert #4305006	Vibration from surface works	This item is located within ten to 20 metres of the construction footprint and has the potential to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Minor secondary direct impact – vibration (surface works)
State Heritage Register Sydney LEP 2012 Marrickville LEP Botany Bay LEP Register of National Estate Section 170 Sydney Water Heritage and Conservation Register	Alexandra Canal SHR #01621 I3 (Sydney LEP) I270 (Marrickville LEP) I1 (Botany LEP) RNE # 4571712	Modification Visual Vibration (surface works)	Three new bridges would be constructed across Alexandra Canal. This has the potential to generate the following impacts on the heritage values of the Canal: • Visual, due to the introduction of three new bridges, including two road bridges and one dedicated pedestrian / cyclist bridge • Changes to the navigability of the Canal • Direct modification to the embankment, to enable new surface water discharge points and scour protection • Vibration, due to surface works occurring in close proximity to the embankments of the Canal. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Significant direct impact – modification Significant indirect impact – visual Significant direct impact – vibration (surface works)

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Marrickville LEP 2011	St Peters Public School, including interiors I271	Vibration (surface works) At-property acoustic treatment	The eastern curtilage of the heritage item is located around 50 metres from the construction footprint and has the potential to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item. The properties have also been identified for consideration of at property acoustic treatment, which would be confirmed during detailed design.	Negligible secondary direct impact – Vibration (surface works) Minor direct impacts – At-property acoustic treatment
Marrickville LEP 2011	Terrace housing, including interiors I273	Vibration (surface works) Visual	The item would be directly located to surface works associated with the local road works, and would have minor impacts to the visual setting of the heritage item. The item also has the potential to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and a program of monitoring would be undertaken to identify early potential risks to the heritage item.	Potential minor direct impact – vibration (surface works) Minor indirect impact – visual
Marrickville LEP 2011	Waugh and Josephson industrial buildings, former, showroom, offices and workshops, including interiors I280	Visual Vibration (surface works)	The item would be directly located at surface works associated with the local road works. However, at this location, the Campbell Road / Unwins Bridge Road and May Street intersection would be realigned to provide greater setback from the heritage curtilage from its eastern boundary. Widening of Unwins Bridge Road at the intersection, however, would result in a minor reduction in setback from its southern boundary. However, the building would retain its landmark qualities, as no part of it would be obscured by the works. Construction works also have the potential to directly impact due to vibration associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Potential minor direct impact – vibration (surface works) Minor indirect impact – visual

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Marrickville LEP 2011	Town and Country Hotel, including interiors I281	Visual Vibration (surface works)	Surface works associated with the local road works would be undertaken directly adjacent to the heritage item. However, at this location, the realignment of the Campbell Road / Unwins Bridge Road / Bedwin Road / May Street intersection would be realigned to provide greater setback of the building from the road carriageways. As such, the project would not have a significant impact on the visual context of the heritage item in terms of its landmark qualities. Construction works also have the potential to directly impact due to vibration associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Potential minor direct impact – vibration (surface works) Minor indirect impact – visual
Marrickville LEP 2011	Group of Victorian Filigree and Victorian Italianate terrace houses – Narara, including interiors. I282	Vibration (surface works) Visual	The item would be directly located at surface works associated with local road works, and would have minor impacts due to the visual setting. Construction works also have the potential to directly impact due to vibration associated with surface construction. However surface works would adhere to safe working distances. An existing survey condition report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Potential minor direct impact – vibration (surface works) Minor indirect impact – visual

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Marrickville LEP 2011	Service Garage I312	Vibration and settlement (tunnelling) Vibration (surface works) Visual impacts Acquisition	The heritage item would be located within the construction footprint, and directly above the eastern portal. Potential impacts may include: • Settlement during and after construction. However this would be less than ten millimetres, which is considered to be cosmetic only • Vibration impacts during tunnelling • Change in use and visual impacts associated within the integration of this item within the urban design of the interchange. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Secondary direct minor impact – vibration and settlement (tunnelling) and vibration (surface works) Significant direct impact –acquisition Minor indirect impact – visual impacts

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Marrickville LEP 2011	Goodsell Estate Heritage Conservation area C16	Acquisition Modification Change in heritage conservation area values Visual	An area of Camdenville Park, which is located within the Godsell Conservation Area would be directly impacted by the project as a result of: • The realignment of the Campbell Road / Unwins Bridge Road / Bedwin Road / May Street intersection. This would result in the permanent loss of an area along the western extent of the conservation area • Construction activities associated with the augmentation of the stormwater detention basin for additional flood storage and surface water treatment These have the potential to generate the following impacts on the heritage values of the conservation area: • Impacts to heritage values within the conservation area, which would be localised to the western curtilage of the conservation area • Visual, due to the realignment and widening of roads, and alterations to the existing stormwater detention basin which is vegetated. However, proposed landscaping would minimise the potential for adverse impacts • Direct acquisition of land within the curtilage of the conservation area, resulting in the permanent loss of this portion of land • Modification to areas within the conservation area associated with the upgrade of the stormwater detention basin. This would result in excavation of the basin of around two metres from the current level. Surface road works would also occur within or adjacent to the conservation area, which have the potential to cause vibration impacts on structures within the conservation area. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conservation area and within 50 metres of the main alignment tunnels.	Minor secondary direct impact – vibration (surface works) Minor direct impact – acquisition and modification Minor indirect impact – visual Minor indirect impact – conservation area values

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Register of National Estate	St Peters Brickpit Geological Site RNE #16240	Modification Visual impacts Vibration (surface works)	The heritage item would be directly impacted as a result of the St Peters interchange and the construction of a shared pathway along the northern boundary of the St Peters interchange.	Significant direct impact – modification Significant indirect impact – visual Significant secondary direct impact – vibration (surface works)
Roads and Maritime Heritage and Conservation Register	Terrace group – 28-44 Campbell Street #4305629	Demolition	The project would involve the demolition of this item to enable the widening of Campbell Street. This impact cannot be avoided.	Significant direct impact –demolition
Roads and Maritime Heritage and Conservation Register	House #4305643	Demolition	The project would involve the demolition of this item to enable the widening of Campbell Road. This impact cannot be avoided.	Significant direct impact – demolition

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Sydney LEP 2012	Terrace group I12	Visual Vibration (surface works) At-property acoustic treatment	The item is located directly adjacent to the surface works associated with the widening of Campbell Road and opposite the St Peters interchange. A new pedestrian bridge would also be constructed to the north-west of the heritage curtilage. Construction compounds would be located in the vicinity of the heritage item. Permanent structures and the road widening would change the visual setting of this heritage item. Construction works also have the potential to directly impact due to vibration associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item. The properties have also been identified for consideration of at property acoustic treatment, which would be confirmed during detailed design.	Minor secondary direct impact – vibration (surface works) Minor indirect impact –visual Minor direct – At-property acoustic treatment
Sydney LEP 2012 Sydney Water Section 170	Water Board pump house, including Interior and substructure I18 #4571730	Visual Vibration (surface works)	Surface works associated with the local road works would occur in proximity to the heritage item. However, works associated with the project would be within an existing road corridor. As such, there would be no significant change to the visual setting of the heritage item. There is the potential for the item to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Minor secondary direct impact – vibration (surface works) Minor indirect impact – visual

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Sydney LEP 2012	Industrial Building, 'Frank G Spurway' I20	Visual Vibration (surface works)	Surface works associated with the local road works would occur in proximity to the heritage item. However, works associated with the project would be within an existing road corridor. As such, there would be no significant change to the visual setting of the heritage item. There is the potential for the item to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Minor secondary direct impact – vibration (surface works) Minor indirect impact – visual
Sydney LEP 2012	Warehouse 'Rudders Bond Store' I1405	Demolition	The project would involve the demolition of this item. This impact cannot be avoided.	Significant direct impact –demolition
Proposed amendment to Sydney LEP 2012 (Industrial and warehouse buildings)	Macdonaldtown Stormwater Channel #3	Visual Vibration (surface works)	Surface works associated with the local road works would occur within the curtilage of the stormwater canal, which presently passes under Euston Road. The project would require the widening of Euston Road, which would involve additional sections of the canal being covered. The works would not require a direct modification of the canal structure, but would cause direct impacts as a result of: • Change to the visual setting of the item • Impacts from vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Minor secondary direct impact – vibration (surface works) Minor indirect impact – visual

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Proposed amendment to Sydney LEP 2012 (Industrial and warehouse buildings)	Former Alexandria Spinning Mills #14	Visual Vibration (surface works)	Surface works associated with the local road works would occur in proximity to the heritage item. However, works associated with the project would be within an existing road corridor. As such, there would be no significant change to the visual setting of the heritage item. There is potential for the item to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item.	Minor secondary direct impact – vibration (surface works) Negligible indirect impact – visual

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Register of the National Estate	Clemton Park Urban Conservation Area #102071	Changes in heritage conservation area values Vibration from surface works Visual	Impacts to heritage values within the conservation area would be localised to specific areas already associated with major transport network infrastructure, or which have been previously disturbed by previous road infrastructure projects (such as the M5 East Motorway, and the M5 East Motorway filtration trial). Visual impacts due to Bexley Road South motorway operations complex would be visible and may affect certain properties. Temporary visual impacts may also occur while the Bexley Road North construction compound (C4), the Bexley Road South construction compound (C5) and the Bexley Road East construction compound (C6) are used during construction. However, there would be no direct impacts in the sense that there would be no demolition of houses or structures in the urban conservation area. The works within the urban conservation area are restricted to the current motorway road reserve, land used to support the M5 East Motorway or vacant land. Buildings that are within 50 metres of the construction footprint have the potential to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conservation area. Landscaping would provide screening of the Bexley Road South motorway operations complex from the Clemton Park Urban Conservation Area, once established.	Negligible direct impact – change in heritage values Negligible impact – visual Minor secondary direct impact – vibration (surface works)

LEP and / or other register	Item	Impact type	Comment	Degree of impact
Register of the National Estate	Pallamanna Parade Urban Conservation Area #102089	Change in heritage conservation values Vibration from surface works Visual	The preferred project corridor at this location follows the existing motorway alignment and passes through the conservation area. The curtilage of this urban conservation area was determined prior to the construction of the M5 East Motorway and has not been updated since. Impacts to heritage values within the conservation area would be localised to specific areas already associated with major transport network infrastructure. The M5 East Motorway would be widened to cater for the western portal and associated ancillary facilities. This would extend into the heritage conservation area. Visual impacts due to changes from new noise walls and the Kingsgrove motorway operations complex which would be visible above the noise walls may affect certain properties. However, there would be no direct impacts in the sense that there would be no demolition of houses or structures in the urban conservation area. Landscaping would provide screening of the project from the heritage conservation area, once established. For these reasons, visual impacts would be low to negligible. Buildings that are within 50 metres of the construction footprint have the potential to be directly impacted due to vibration impacts associated with surface construction. However surface works would adhere to safe working distances. An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the heritage conservation area that are within safe working distances. Temporary visual impacts may also occur when the Kingsgrove North construction compound (C1), the Kingsgrove South construction compound (C2) and the Commercial Road construction compound (C3) are used during construction.	Negligible direct impact – change in heritage values Low to negligible indirect impact – visual Negligible secondary direct impact – vibration (surface works)

20.3.1 Direct impacts

There are 57 non-Aboriginal heritage items outlined in **Table 20-5** which would be directly or indirectly impacted by the project. Of these:

- Three items would be demolished as a result of the project:
  - Warehouse 'Rudders Bond Store' (ID No I1405 under the Sydney LEP)
  - Terrace group – 28-44 Campbell Street, St Peters (ID No 4305629 under the Roads and Maritime Section 170 Heritage and Conservation Register)
  - House – 82 Campbell Street, St Peters (ID No 4305643 under the Roads and Maritime Section 170 Heritage and Conservation Register)
- Modifications ranging from a minor to significant level would be required at four items, being:
  - Alexandra Canal (ID No 103889 under the Register of the National Estate, ID No 01621 under the State Heritage Register, ID No 4571712 under the Sydney Water Section 170 Heritage and Conservation Register, ID No I13 under the Sydney LEP, ID No I1 under the Botany LEP 2013, ID No I270 under the Marrickville LEP 2011)
  - St Peters Brickpit Geological Site (RNE #16240)
  - Service Garage – 316 Princes Highway (Marrickville LEP 2011 I312) (the modification includes change of use, as a result of acquisition of the property)
  - Goodsell Estate Conservation Area (Marrickville LEP 2011 C16).
- Eight heritage conservation areas would be partially and directly impacted, with the majority of heritage conservation areas being exposed to negligible impacts only. Landscaping of the project within these areas would minimise the potential impacts. Some of these conservation areas may be impacted by secondary direct impacts (as the tunnel passes under these heritage conservation areas). The overall heritage value of the heritage conservation areas would not be significantly impacted by the project. The three heritage conservation areas that would be partially and directly impacted within the minor to low range of impact are:
  - Pallamanna Parade Urban Conservation Area (ID No 102089 under the Register of the National Estate)
  - Clemton Park Urban Conservation Area (ID No 102071 under the Register of the National Estate)
  - Goodsell Conservation Area (ID No C16 under the Marrickville LEP).

Relevant mitigation measures for these three heritage conservation areas are contained in **Table 20-7**.

Twenty three items would be directly impacted due to construction vibration from surface works. These impacts are anticipated to have a negligible to minor risk of affecting the significance of the heritage items. Structural damage vibration limits for non-Aboriginal heritage properties and recommended safe working distances for vibration intensive plant are provided in Section 7.2.1 of the Technical working paper: non-Aboriginal heritage (**Appendix R**). The overall heritage value of these heritage items would not be significantly impacted by the project.

Thirty four items would be directly impacted due to vibration, settlement and groundwater drawdown as a result of tunnelling works. These items are primarily located within the preferred project corridor and include items consisting of mainly residential houses. Impacts to these items are anticipated to be minor to negligible. Four of these items would also be directly impacted by construction vibration due to surface works. The overall heritage value of the heritage items would not be significantly impacted by the project.

There is also the potential for direct impacts due to potential eligibility for at-property acoustic treatment. Two of the 57 items have also been identified as being potentially eligible for consideration of property acoustic treatment (St Peters Public School, and the terrace group of housing at 2-34 Campbell Road, St Peters). This would be confirmed during detailed design, in consultation with landowners, and with consideration of potential impacts to heritage values. Treatment would be sympathetic to the heritage values of each item and would be undertaken in accordance with the Burra Charter, which stipulates that changes reducing cultural significance should be reversible.

Further information about mitigation measures to manage noise and vibration impacts as a result of the project is provided in **Section 12.5.3**.

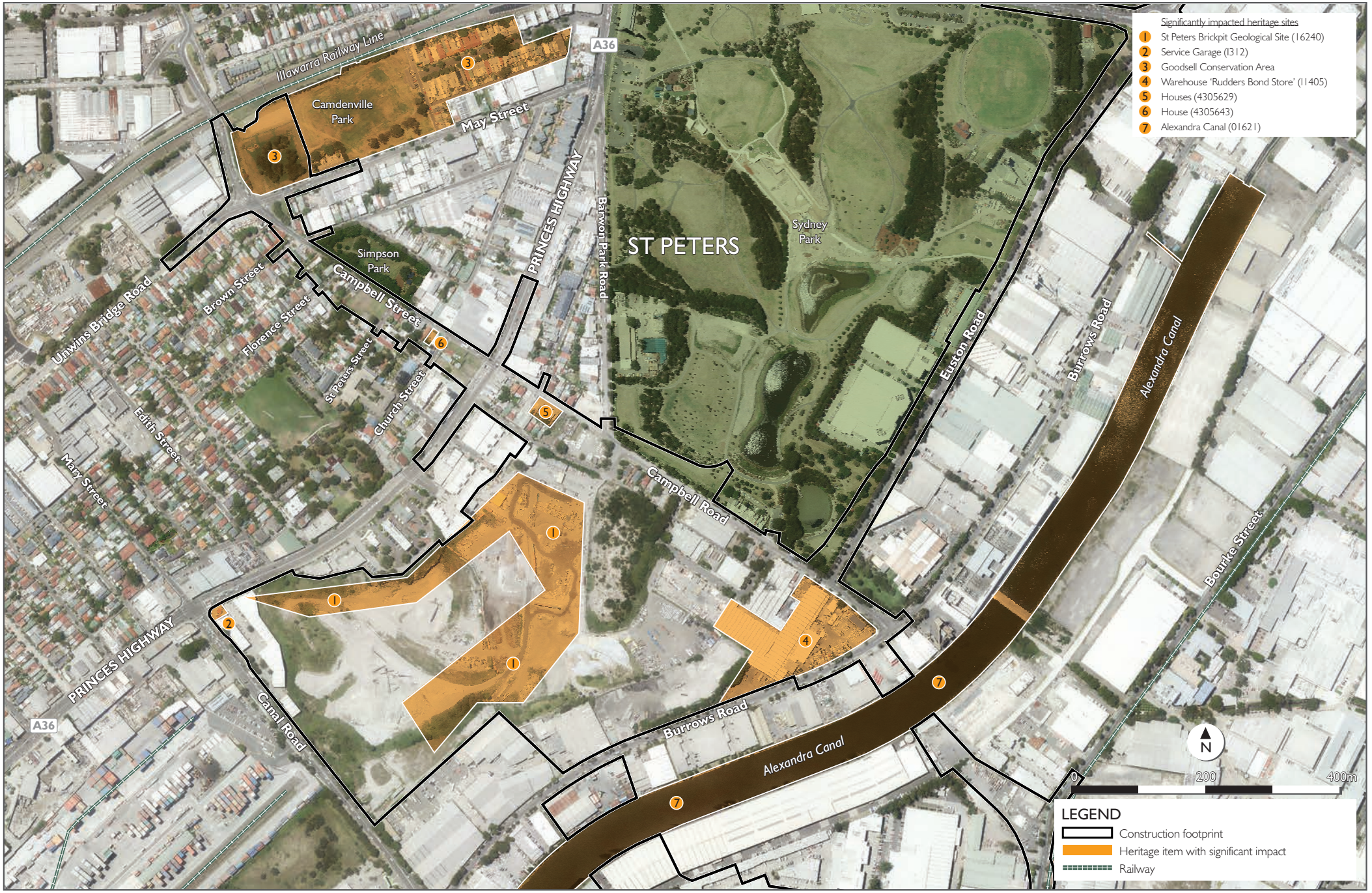


Figure 20-7 Non-Aboriginal heritage items with significant impacts

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Tunnelling works – settlement and vibration impacts

Section 5.5 of the Technical working paper: Noise and vibration (**Appendix J**) provides an assessment of potential construction vibration impacts as a result of works at surface and below ground (tunnelling). It concludes that, for tunnelling activities, the predicted vibration levels at heritage items are estimated to be around two millimetres per second or less, which is below the recommended maximum level of vibration that would be applicable to heritage structures set within the German Standard DIN 4150 - Part 3 - Structural Vibration in Buildings – Effects on Structures.

The ground settlement as a result of the project, and its potential impacts on heritage structures would be dependent on the geotechnical conditions, the depth of the tunnelling activity, the number of storeys of the building, and the position, condition and masonry of the structure itself. **Section 19.3.9** (Groundwater) provides an assessment of the potential impacts of ground settlement on structures.

The calculated settlement for the project is generally less than 20 millimetres for the majority of the tunnel alignment. Locations of peak settlement are at the portals and at the Y-junction caverns. It is expected that settlement would stabilise within two months of the roadheader passing under a structure.

All heritage structures have a predicted settlement of less than 20 millimetres and are assessed as having a building damage category of “Negligible”. Examples of visible potential impacts would be cosmetic and could include hairline cracks.

It is noted that these results are preliminary and do not take into account the specifics of properties themselves. Further assessments would be undertaken during detailed design to determine the level of potential impact on structures and to identify appropriate mitigation and management measures to minimise these impacts. For some properties, this may involve undertaking an existing condition survey and a program of monitoring (refer **Section 12.4.1** – Noise and vibration).

For the majority of listed street tree groups, potential impacts as a result of the project would be minor and / or negligible due to the depth of the tunnel at these locations.

Surface works – vibration impacts

For surface works, such as at the local road surface works, cosmetic damage to buildings would be unlikely where buildings are distanced from the project by two metres to 25 metres (depending on the vibration-generating equipment being used and the location of that equipment within each construction area). Safe working distances for vibration intensive plant equipment are outlined in Section 7.2.1 of **Appendix R**. Sections 8.5 and 10.0 of **Appendix R**, along with recommended mitigation measures such as condition surveys and monitoring where works within these setbacks cannot be avoided.

Statements of heritage impact

Detailed statements of heritage impacts have been prepared and are provided in full in Section 9.0 of the Technical working paper: Non-Aboriginal heritage (**Appendix R**). Summaries of those statements of heritage impact are provided here for those items that would be directly impacted either through demolition or modification as a result of the project.

Warehouse ‘Rudders Bond Store’

Due to the location of the Rudders Bond Store within the proposed location of the St Peters interchange, there is no potential to retain the store or its associated office. The demolition of this store and office would be a major negative impact, resulting in the irreversible loss of State significance heritage fabric and value. This would be mitigated through the salvage and reuse of at least a section of the store (focusing on the significant laminated timber columns, mitigating the impacts to the item’s aesthetic, technical and rarity significance). Such mitigation measures would be considered further during detailed design to confirm whether they are reasonable and feasible. An archival recording of the store and associated office would also be undertaken prior to demolition / salvage works.

Terraces and houses on Campbell Street

The terraces at 28-44 and 82 Campbell Street, St Peters, are listed on Road and Maritime's Section 170 Heritage and Conservation Register (ID # 4305629 & ID #4305643).The demolition of the terraces and houses would be unavoidable, and is considered to be a moderate level of negative impact. The loss of heritage fabric would be mitigated through archival recordings prior to demolition. The style of the terraces is not rare within the Marrickville and Sydney local government areas. Furthermore, similar examples of such terraces within the project area would not be directly impacted on as part of the project (eg those within the Goodsell Estate Heritage Conservation Area and the Cooper Estate Heritage Conservation Area, as well as the Narara Terraces and others).

Alexandra Canal

As part of the project, three new bridges would be constructed over the Alexandra Canal, including:

- A new bridge over the Alexandra Canal as part of the Campbell Road extension
- A new pedestrian and cycle bridge extending from east of Alexandra Canal, to over the on and off ramps at the St Peters interchange
- A new bridge over the Alexandra Canal as part of the Gardeners Road extension.

Crossings would provide a clear span across the Canal to avoid the construction of piers within the Canal. To achieve this, the abutment piers for the road bridges would be located one metre from the top of the existing sandstone embankment walls. Construction works would be managed to prevent direct impacts to the sandstone embankments on either side of the Canal. The crossings would also result in direct vibration and indirect visual impacts to the Canal.

Stormwater discharge points would also be constructed into the Canal at the Campbell Road bridge. These outlets would require the removal of sections of the embankment walls which have been identified as being of high significance, including State heritage significance.

In terms of major negative impacts to the Alexandra Canal, the stormwater discharge points proposed as part of the project would impact on the Canal's aesthetic significance by requiring the removal of two intact sections of sandstone walls. However, these impacts would be mitigated by reinstating the blocks and reusing them to finish the discharge points. The stormwater design has also been sympathetically considered to enable the necessary discharge via only two points, thereby limiting impacts to this fabric.

The construction of the additional crossings would have a minor impact on the Canal's significance. These crossings would open up further views of the Canal and allow for a greater appreciation of the industrial heritage of the Canal.

Overall, while impacts are proposed to the fabric of the Alexandra Canal, these can be mitigated through increased public access to and interpretation along the Campbell Road pedestrian / cycle bridge, and by reinstating sandstone removed to insert the proposed discharge points.

St Peters Brickpit Geological Site

The St Peters interchange would be located on land that includes the current St Peters Brickpit Geological Site. The construction of the St Peters interchange would therefore result in alterations to this heritage item, including cut and fill. Ultimately the project would result in geological formations in the Brickput being obscured by landscaping. However the project would not necessarily require the removal of these geological formations. In terms of minor negative impacts, the construction of the St Peters interchange would therefore result in the removal or concealment of the currently exposed cuttings at the St Peters Brickpit Geological Site.

In terms of major positive impacts, the project would result in the potential for improved access and interpretation of this heritage item within the St Peters interchange, including by allowing for greater public knowledge of the site. This improved interpretation would contribute to a greater understanding of the geological and palaeontological history of the Sydney Basin.

Service garage

Whilst no direct impacts are actually proposed to the fabric of the service garage, it would be acquired as part of the project and cease to operate as a service garage. It is proposed to be retained with possible re-use opportunities (eg commercial / retail). The aesthetic and rarity values of this heritage item would therefore not be impacted on. Any potential modifications required for the change of use would be assessed at a future time, once approved. As the service garage has operated in its capacity since at least 1946, there would be some loss of significance associated with a changed use and this is considered to be a minor negative impact.

Goodsell Heritage Conservation Area

Local road upgrades would include the realignment of the intersection of Bedwin Road, Unwins Bridge Road, Campbell Street and May Street. The project would therefore require the acquisition of the south western corner of the Goodsell Heritage Conservation Area. This section proposed for acquisition is currently part of the Camdenville Park and is a fenced area providing a depression for the collection of stormwater runoff. However, the project would nevertheless result in an amendment to the curtilage of the Goodsell Heritage Conservation Area, involving the augmentation of this stormwater basin to cater for the operation of the project.

Ultimately the statement of heritage impact prepared for this heritage conservation area has concluded that the project would not impact on its overall heritage significance.

20.3.2 Indirect impacts

Of the 57 heritage items, 21 items may be indirectly impacted by the project, due to temporary and / or permanent visual impacts. Of the 21 items, 20 would also have the potential to be directly impacted as outlined in **Section 20.3.1**.

Visual character

The introduction of new elements within the study area has the potential to indirectly visually impact heritage items, particularly if the visual characteristics of these elements are unsympathetic with those of the heritage items. In addition, new elements may obstruct significant views to heritage items or places, when viewed from public or private land. It is also the case that the heritage significance of the items in the study area is such that views from an item do not necessarily contribute to its heritage significance. The individual contribution of views into and out from heritage properties and the long-term impact of construction, if any, would be considered in identifying ways to appropriately manage such impacts.

The project aims to use urban design techniques such as architectural design, building materials and colour palettes to merge new infrastructure into the existing visual environment where feasible to do so. In the majority of cases, impacts to the heritage items as a result of visual effects are therefore anticipated to be minor (refer **Sections 14.3.1** and **14.3.2**– Visual impact and urban design). Further, visual impacts to affected heritage items would be reduced in part by distance and the screening effect of surrounding residential developments and proposed landscaping. Existing vistas and view lines from heritage items would be considered during detailed design, and rehabilitation strategies sympathetic to the heritage item would be determined. In these cases, the overall heritage value of the heritage items would not be significantly impacted by the project.

However, the impact to Alexandra Canal is considered to be significant due to the introduction of new crossings of the Canal. For this reason the item was carried forward for further consideration in a statement of heritage impact.

Further information on indirect visual impacts to heritage items, and recommended measures to mitigate these impacts, are provided in **Section 14.4** (Visual impact and urban design).

Noise

There is also the potential for direct impacts due to potential eligibility for at-property acoustic treatment. Two of the 57 items have also been identified as being potentially eligible for consideration of property acoustic treatment. This would be confirmed during detailed design, in consultation with landowners, and with consideration of potential impacts to heritage values.

Traffic and access

Impacts to traffic and access are outlined in more detail in **Section 9.3.1** and **9.3.2** (Traffic and transport). No roads on which heritage listed items are located are anticipated to be permanently closed. Other than those heritage listed properties which are to be acquired, permanent altered access arrangements would not be required for heritage properties as a result of the project.

The nearby temporary closure of Brown Street and Florence Street (refer **Sections 9.3.1** and **9.3.2**) may result in additional traffic using Unwins Bridge Road. While some properties along Euston Road and Gardeners Road would require temporary driveway modifications, this would not impact on heritage listed items.

The Alexandra Canal bridge design, where reasonable and feasible, would be set back from the edge of the Canal to allow unimpeded pedestrian access during operation. The increased number of crossings, and particularly the pedestrian / cycle bridge adjacent to the Campbell Road bridge would increase access to and visibility of the Canal during operation of the project.

For the St Peters Brickpit, the public access created by the St Peters interchange could allow for greater public knowledge of the geological and palaeontological significance of the site and the Sydney basin more generally, through the implementation of interpretive management measures (refer **Table 20-7**).

Whilst it does not lie directly within the project area, a further assessment was undertaken of potential traffic impacts to the King Street / Enmore Road Heritage Conservation Area (listed under both the Sydney LEP 2012 and Marrickville LEP 2011). This heritage conservation area is identified as being of State heritage significance, despite not being listed on the State Heritage Register.

Consultation during the preparation of the EIS identified a concern that the project would impact King Street and its retail function, thereby impacting the heritage significance of the King Street / Enmore Road Heritage Conservation Area. The project would not modify King Street, including by way of speed limits or on-street parking arrangements. Traffic modelling (refer **Section 9.3.2**) has indicated that the future operation of King Street is expected, in most cases, to experience reduced peak hour volumes when compared to a scenario where the project were not to proceed. The exception to this would occur in the 2031 cumulative scenario, where morning peak hour volumes southbound would increase by around 35 per cent compared to the scenario where the project does not proceed. However these predictions are in the opposite direction to the dominant morning peak hour traffic, and they are also within the design carrying capacity of the road. No resulting impacts would occur to the heritage value of the King Street / Enmore Road Heritage Conservation Area. As such, this heritage conservation area has not been carried forward for further assessment in this chapter.

20.3.3 Cumulative impacts

The cumulative impact of the project to heritage values would be moderate. These potential impacts are to be managed to reduce the risk of actual impacts to the identified items.

20.4 Environmental management measures

The early identification of non-Aboriginal heritage items and conservation areas during the design phase informed the project design and enabled the avoidance of heritage items where practicable.

The mitigation and management measures provided in **Table 20-7** have been developed to avoid, reduce and manage identified potential impacts to non-Aboriginal heritage. These measures would be developed further on a case by case basis during detailed design, with consideration of finalised areas of disturbance. The final suite of mitigation and management measures would be documented within the Construction Environmental Management Plan.

Heritage specialists would work with the construction contractor and design team to ensure that appropriate mitigation measures are implemented and impacts to heritage items minimised. The heritage significance of particular sites and localities would also be interpreted through signage and other means, where reasonable and feasible and as part of the urban landscape strategy.

The level of effectiveness in mitigating the impact to individual items and conservation areas has been ranked in the following manner:

- Highly effective – the measure completely mitigates the impacts to the item's / area's heritage significance
- Moderately effective – the measure largely mitigates the impacts to the item's / area's heritage significance, but the impact is not fully mitigated
- Somewhat effective – the measure only partly mitigates the impacts to the item's / area's heritage significance
- Ineffective – the measure is not effective in mitigating the impacts to the item's / area's heritage significance.

An assessment of the effectiveness of the proposed management measures is contained in Section 8.9 and Appendix A of the Technical working paper: Non-Aboriginal heritage (**Appendix R**). The management measures selected for the project were mostly found to be highly effective, except in the following instances:

- For the Alexandra Canal, where mitigation measures to manage visual and modification impacts would be moderately effective
- For the Service Garage at 316 Princes Highway, where mitigation measures to manage the change of use and acquisition impacts would be somewhat effective
- For the terrace group of housing at 28-44 Campbell Street and the house at 82 Campbell Street, where mitigation measures to manage demolition would be somewhat effective
- For the Warehouse 'Rudders Bond Store,' where mitigation measures to manage demolition would be somewhat effective.

Mitigation and management measures relevant to non-Aboriginal heritage items are also included in other sections of this EIS as follows:

- Construction vibration in **Section 12.5.3** (Noise and vibration)
- Ground settlement in **Sections 19.3.9** and **19.5** (Soils and water quality)
- Dust in **Section 10.11** (Air quality)
- Landscaping in the vicinity of non-Aboriginal heritage items in **Sections 14.4** (Visual impact and urban design)
- Revegetation of the temporary construction footprint in the vicinity of non-Aboriginal heritage items in **Section 14.4** (Visual impact and urban design) and **Section 21.4** (Biodiversity).

Table 20-7 Environmental management measures – non-Aboriginal heritage

Impact	No.	Environmental management measure	Timing
Construction			
General	NAH01	Protocols would be developed for anticipated categories of unexpected non-Aboriginal heritage finds, such as tram infrastructure, late 19th to early 20th refuse, and brick works. In the event of an unexpected cultural heritage find outside of these specific protocols, the *Standard Management Procedure – Unexpected Archaeological Finds* (Roads and Maritime, 2015a) would be followed. This would include notification to the NSW Heritage Division of OEH (highly effective).	Pre-construction and construction
	NAH02	Construction personnel would be made aware of non-Aboriginal heritage sites as part of the site induction. These sites would be identified on sensitive area plans and in the CEMP (highly effective).	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
	NAH03	As part pf the construction heritage management plan, an overarching historical archaeological research design would be prepared prior to commencement of construction in consultation with the NSW Heritage Division of OEH. It would describe clear significance thresholds to possible archaeological items that may be uncovered during works and designate when monitoring, testing and / or salvage and excavation should occur in relation to the project works and timing. Post-excavation reporting, including artefact analysis and additional historical research (where necessary), would be required for any historical archaeological investigations undertaken (moderately effective).	Detailed design
	NAH04	A construction heritage management plan would be prepared prior to construction in consultation with the NSW Heritage Division of OEH. The plan would detail how construction impacts on heritage would be minimised and managed including training and induction processes for construction personnel. Inductions are to cover built heritage, landscape and historical archaeological sites and their management, and provide heritage guidance on how to avoid / manage impacts. The induction would be prepared in consultation with a suitably qualified heritage specialist and historical archaeologist. As a minimum, the plan would include the following: • Induction protocols for staff and project personnel to undertake a cultural heritage induction, to assist them in understanding and complying with their legal obligations under the *Heritage Act 1977* • A list, plan and GIS layer showing the location of identified heritage items • A significance assessment and statement of significance for each item • Detail the mitigation measures identified and when the measures are to be implemented • Provide protocols and procedures to be enacted during construction to ensure the protection of items of heritage significance • An unexpected finds procedure in the event that further sites are identified during works • The separate procedure for the discovery of skeletal remains (highly effective).	Pre-construction
	NAH05	Impacts to built heritage, heritage landscapes and historical archaeological sites, will to the greatest extent practicable, be avoided and minimised. Where impacts are unavoidable, works shall be undertaken in accordance with the strategy outlined in the construction heritage management plan (moderately effective).	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
Removal of heritage listed structures	NAH06	In relation to the house at 82 Campbell Street and terrace group at 28-44 Campbell Street the following would be undertaken: • The buildings would be subject to a full archival recording following the *NSW Heritage Division guidelines How to Prepare an Archival Recording* (NSW Heritage Office, 2003) and *Photographic recording of heritage items using film or digital capture* (NSW Heritage Office, 2006) • Consideration should be given as to whether elements of the houses could be salvaged and used to maintain or restore other properties managed by Roads and Maritime (somewhat effective).	Detailed design
	NAH07	In relation to Rudders Bond Store, the following would be undertaken: • The bond store would be subject to a full archival recording following the *NSW Heritage Division guidelines How to Prepare an Archival Recording* (NSW Heritage Office, 2003) and *Photographic recording of heritage items using film or digital capture* (NSW Heritage Office, 2006) • Consideration would be given as to whether the laminated timber columns could be salvaged and re-erected and clad elsewhere within the St Peters interchange or the local area. The cladding and brick walls are not considered to be of heritage significance and are not included within the reuse proposal • Investigate options for documenting the history of the Ralph Symonds company and presenting it to a national audience, in partnership with stakeholders such as the City of Sydney and Powerhouse Museum. The focus would be on their development of innovative timber construction methods during and after World War II (somewhat effective).	Detailed design / pre-construction

Impact	No.	Environmental management measure	Timing
Change of use	NAH08	In relation to the Service Garage at 316 Princes Highway, the following would be undertaken: • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item • A photographic archival recording is undertaken prior to the current use ceasing. The archival recording should conform to the guidelines provided in *How to prepare archival records* (NSW Heritage Office, 2003) and *Photographic recording of heritage items using film or digital capture* (NSW Heritage Office, 2006). The archival recording should be lodged with the relevant local libraries and the State Library of NSW. • The oral history should be prepared, which seeks to contact past and present employees as well as others with memories of the service station. The oral history should be lodged with the relevant local libraries and the State Library of NSW (somewhat effective).	Pre-construction
Potential for direct impacts due to vibration associated with surface construction	NAH09	Detailed mitigation and management measures would be developed for each heritage item directly impacted by the project with regard to vibration (surface and tunnelling) and settlement once final disturbance areas have been identified through detailed design. These mitigation and management measures would be included in the construction environmental management plan(s) for the project (highly effective).	Detailed design
Potential for direct impacts due to vibration associated with surface construction	NAH10	Surface works would adhere to safe working distances, and an existing condition survey report and program of monitoring would be undertaken to identify early potential risks at the following non-Aboriginal heritage items: • Wolli Creek Culvert • St Peters Public School, including interiors • Terrace housing, including interiors (I273) • Waugh and Josephson industrial buildings, former, showroom, offices and workshops, including interiors • Town and Country Hotel, including interiors • Group of Victorian Filigree and Victorian Italianate terrace houses – Narara, including interiors • Terrace group I12 • Water Board pump house, including Interior and substructure • Industrial Building, 'Frank G Spurway' • Former Alexandria Spinning Mills (highly effective).	Pre-construction and construction
Visual impacts, as well as vibration impacts to the Macdonaldtown Stormwater Channel #3	NAH11	An existing condition survey report and program of monitoring would be undertaken to identify early potential risks at the Macdonaldtown Stormwater Channel #3 (highly effective).	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
Acoustic impacts to non-Aboriginal heritage items	NAH12	The following non-Aboriginal heritage properties would be considered for at property acoustic treatment: • St Peters Public School, including interiors • Terrace group I12 (highly effective). Acoustic treatments would be confirmed during detailed design, and would consider the principles of *The Burra Charter (the Australia ICOMOS charter for places of Cultural Significance)* (ICOMOS (Australia), 2013).	Detailed design
Impacts to the Goodsell Estate Heritage Conservation Area as a result of vibration, acquisition and modification, as well as visual impacts and impacts conservation area values.	NAH13	Management measures for the Goodsell Estate Heritage Conservation Area would include: • Landscaping, to mitigate the impacts of realigning and widening roads, as well as alterations to the existing stormwater detention basin • Surface works would adhere to safe working distances • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conversation area and within 50 metres of the main alignment tunnels (highly effective).	Pre-construction, construction and post-construction
Impacts to the Clemton Park Urban Conservation Area as a result of vibration, changes in heritage area conservation values, and visual impacts.	NAH14	Management measures for the Clemton Park Urban Conservation Area would include: • Surface works would adhere to safe working distances • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conservation area • Landscaping would provide screening of the Bexley Road South motorway operations complex from the Clemton Park Urban Conservation Area, once established (highly effective).	Pre-construction, construction and post-construction
Impacts to the Pallamanna Parade urban Conservation Area as a result of vibration, changes in heritage area conservation values, and visual impacts.	NAH15	Management measures for the Pallamanna Parade Urban Conservation Area would include: • Surface works would adhere to safe working distances • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conservation area • Landscaping would provide screening of the project from the Pallamanna Parade Urban Conservation Area, once established (highly effective).	Pre-construction, construction and post-construction

Impact	No.	Environmental management measure	Timing
Impacts to heritage values due to construction of stormwater discharge points	NAH16	The following management measures would be implemented with respect to Alexandra Canal: • Monitoring during works to ensure vibration is not impacting the Alexandra Canal walls • Preparation of an archival recording of the Canal, involving both scale drawings and photography, prior to the removal of sandstone blocks • Numbering of sandstone blocks so that those displaced by the discharge points can be replaced in their previous locations • Stockpiling displaced sandstone blocks for use in repairs of other sections of the Alexandra Canal • Installation of heritage interpretation regarding the Canal in accordance with an interpretation plan (moderately effective).	Detailed design and construction
Heritage interpretation	NAH17	An interpretation plan would be prepared and implemented for: • Alexandra Canal and the industrial heritage of the area. This shall include installation of a heritage interpretation regarding the Canal in accordance with an interpretation plan • The St Peters Brickpit geological site, including: – Integrate the geological interpretation into the Sydney Park brickworks in consultation with City of Sydney, as the industrial counterpart to the geological history to tell a more complete story of historical land use in the area – Integrate the geological / palaeontological discovery of the *Paraclytosaurus davdi* – Retain an exposed section of the fresh shales and siltstones, including features associated with deposition of the sedimentary rocks, and later formed fractures such as joints and faults, if safe to do so for both landform stability and ongoing access for interpretation (moderately effective).	Detailed design and construction
Impact to geological and palaeontological values	NAH18	An archival recording of the St Peters brickpit geological site would be undertaken prior to and during the construction (highly effective).	Pre-construction
	NAH19	An assessment and / or consultation with a palaeontologist to determine whether the project impact area has potential to contain further specimens of scientific interest (highly effective).	Pre-construction
Visual	NAH20	Approaches to appropriately manage impacts of the project to the individual contribution of views into and out from heritage properties and the long-term impact of construction would be detailed in a CEMP (highly effective). Individually tailored landscape treatments would be developed during detailed design to mitigate visual impacts at 2-34 Campbell Road, St Peters.	Pre-construction Detailed design
Impacts on archaeology	NAH21	The construction heritage management plan would include detailed procedures / strategies for the conservation and curation of any historical artefacts recovered during works (moderately effective).	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
Urban design and landscaping	NAH22	Urban design and landscaping would be undertaken to manage visual impacts to the following additional non-Aboriginal heritage items: • Terrace housing (I273) • Southern Cross Hotel (I277) • Water Board pump house (I18) (highly effective).	Construction and post-construction

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21 Biodiversity

A Technical working paper: Biodiversity (**Appendix S**) has been prepared to assess the potential impacts of the project on biodiversity. This chapter provides a summary of the technical working paper, including:

- Biodiversity features present within and surrounding the construction and operational footprints of the project
- An assessment of the impacts of the project on biodiversity during construction and operation, including how impacts have been avoided and minimised
- Environmental management measures to minimise and manage impacts to biodiversity as a result of the project
- The biodiversity offsets for residual impacts which cannot be satisfactorily mitigated.

During the preparation of this environment impact statement, the project has been referred to the Commonwealth Minister for the Environment (2015/7520) under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) because of the potential for the project to impact on the following matters of national environmental significance:

- A population of Green and Golden Bell Frogs (*Litoria aurea*), known to inhabit the Kogarah Golf Course at Arncliffe
- An area of the Cooks River Castlereagh Ironbark Forest vegetation community in Beverly Grove.

On 11 August 2015, the Commonwealth Minister for the Environment determined that the project has the potential to significantly impact on a matter of national environmental significance and is therefore a 'controlled action' in accordance with the EPBC Act. Approval of the project is required from the Commonwealth Minister for the Environment in addition to the planning approvals required under State legislation (refer to **Chapter 2** for additional detail regarding the assessment process for the project).

Under the Bilateral Agreement relating to environmental assessment (February 2015) between the Commonwealth Government and the NSW Government, this environmental impact statement has been adopted for the purpose of meeting the assessment requirements of both the Commonwealth EPBC Act and the *NSW Environmental Planning and Assessment Act 1979* (EP&A Act). The requirements of the bilateral agreement have been considered and taken into account as part of this environmental impact statement.

The Commonwealth Department of the Environment has issued assessment requirements with respect to matters of national environmental significance, which have been included as part of the amended Secretary Environmental Assessment Requirements (SEARs) for the project, issued by the NSW Department of Planning and Environment on 26 August 2015. The assessment requirements issued by the Commonwealth Department of the Environment also included guidelines for preparing Assessment Documentation relevant to the EPBC Act, which are provided in **Appendix A**.

Table 21-1 sets out the SEARs as they relate to biodiversity and where in the environmental impact statement (EIS) these have been addressed.

Table 21-1 SEARs – biodiversity

SEARs	Where addressed
An assessment of the potential ecological impacts of the proposal, with specific reference to vegetation and habitat clearing, connectivity, edge effects, weed dispersal, riparian and aquatic habitat impacts, soil and water quality impacts and operational impacts. The assessment must:	
• Make specific reference to impacts on landscape values, biodiversity values of native vegetation and threatened species or populations, including worst case estimates of vegetation clearing and operational impacts	The impacts of the project on biodiversity during construction and operation, including impacts on landscape values, biodiversity values of native vegetation and threatened species or populations, including worst case estimates of vegetation clearance and operational impacts are described in **Section 21.3.1** and **Section 21.3.2**
• Demonstrate a design philosophy of impact avoidance on ecological values, and in particular, ecological values of high significance, and be consistent with the 'avoid, minimise or offset' principle	An assessment of the impacts of the project on biodiversity during construction and operation, including how impacts have been avoided and minimised throughout the design process in accordance with the hierarchy of 'avoid, minimise or offset' is described in **Section 21.3.1** and **Section 21.3.2**.
• Be undertaken in accordance with the Framework for Biodiversity Assessment (OEH, 2014b) and the NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014c), and by a person accredited in accordance with section 142B(1)(c) of the Threatened Species Conservation Act, 1995. Impacts on species, populations and ecological communities that will require further consideration and provision of information specified in section 9.2 of the Framework for Biodiversity Assessment include those identified by the OEH. Species specific surveys shall be undertaken for those species and in accordance with the survey requirements specified by the OEH; and in relation to aquatic biodiversity be consistent with the draft Policy and Guidelines for Fish Habitat Conservation and Management – Update 2013 (DPI, 2013).	The assessment of impacts of the project on biodiversity has been undertaken in accordance with the *Framework for Biodiversity Assessment and the NSW Biodiversity Offsets Policy for Major Projects* by a person accredited in accordance with section 142B(1)(c) of the *Threatened Species Conservation Act 1995* (TSC Act). A summary of how the biodiversity assessment report prepared for the project meets the minimum requirements of the FBA is provided in Appendix H of **Appendix J**. Species specific surveys have been undertaken as part of the biodiversity assessment for the project, as summarised in **Section 21.1.4** and detailed in Chapter 7 of **Appendix J**. The assessment of impacts of the project have been undertaken in accordance with the *Policy and guidelines for fish habitat conservation and management (update 2013)* (Department of Primary Industries (DPI), 2013).

SEARs	Where addressed
• The assessment of potential ecological impacts is to comply with the requirements of the Guidelines for preparing Assessment Documentation relevant to the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) — WestConnex New M5 Project (EPBC 2015/7520). The assessment is to contain detailed identification and assessment of direct and indirect impacts on threatened species and ecological communities that will, are likely to, or may be significantly impacted by the proposal, including but not limited to: – Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion – Green and Golden Bell Frog (*Litoria aurea*) – Turpentine Ironbark Forest in the Sydney Basin Bioregion – Bynoe's Wattle (*Acacia bynoeana*) – Downy Wattle (*Acacia pubescens*) – Deane's Paperbark (*Melaleuca deanei*) – Hairy Geebung (*Persoonia hirsuta*) – Spiked Rice-flower (*Pimelea spicata*) – Magenta Lilly Pilly (*Syzygium paniculatum*) – Black-eyed Susan (*Tetratheca juncea*).	The assessment of the impacts of the project on biodiversity during construction and operation has been undertaken in accordance with the requirements of the Guidelines for preparing Assessment Documentation relevant to the EPBC Act — WestConnex New M5 Project (EPBC 2015/7520, available at http://www.environment.gov.au/cgi-bin/epbc/epbc_ap.pl?name=current_referral_detail&proposal_id=7520). A description of how the biodiversity assessment has met the assessment requirements and guidelines provided is described in Appendix I of **Appendix S**. The biodiversity assessment has identified and assessed direct and indirect impacts of the project on threatened species and ecological communities that will, are likely to, or may be significantly impacted by the project, including those threatened species and communities prescribed in the assessment requirements issued by the Commonwealth Department of the Environment. As assessment of the potential impacts of the project on these threatened species and ecological communities is provided in **Section 21.3**.

21.1 Assessment methodology

The biodiversity assessment and the identification of appropriate biodiversity offsets (where required) for the project has been undertaken in accordance with the requirements of the NSW Biodiversity Offsets Policy for Major Projects (the biodiversity offsets policy) (OEH, 2014c) and the Framework for Biodiversity Assessment (FBA) (OEH, 2014b).

The Bilateral Agreement relating to environmental assessment (February 2015) between the Commonwealth Government and the NSW Government, has endorsed the FBA as providing an appropriate basis for undertaking biodiversity assessment, including Commonwealth listed threatened species and ecological communities.

The FBA applies predominantly to terrestrial biodiversity. Impacts of the project on aquatic environments and aquatic biodiversity has been undertaken in accordance with the Policy and guidelines for fish habitat conservation and management (update 2013)(DPI, 2013) as prescribed by the SEARs (refer to **Table 21-2**) and the biodiversity offsets policy.

Additional detail regarding the approach to the biodiversity assessment is provided in Section **21.1.1**.

The biodiversity assessment included:

- Identification of a biodiversity study area to adequately identify and assess potential impacts of the project on biodiversity values
- A desktop assessment including database searches and a literature review to identify threatened species, populations and ecological communities listed under the TSC Act and *Fisheries Management Act 1994* (FM Act), as well as matters of national environmental significance listed under the EPBC Act known to occur or potentially occurring within the biodiversity study area
- Field surveys to verify the results of the desktop review
- An assessment of the potential impacts of the project on biodiversity values present within the biodiversity study area
- Identification of measures to avoid, minimise and offset potential impacts to biodiversity within the biodiversity study area, and the preparation of an offset strategy where impacts could not be fully mitigated.

21.1.1 Approach to biodiversity assessment

The NSW Biodiversity Offsets Policy for Major Projects and the Framework for Biodiversity Assessment

The NSW Biodiversity Offsets Policy for Major Projects (the biodiversity offsets policy) (OEH, 2014c) provides a standardised approach to the assessment and offsetting of impacts to biodiversity from projects declared to be 'state significant' under the EP&A Act.

Under the biodiversity offsets policy, the SEARs for all projects declared to be state significant are required to apply the FBA to assess impacts on biodiversity and to identify reasonable measures and strategies that can be taken to avoid and minimise these impacts. The FBA sets out a repeatable process for assessing biodiversity impacts and for determining the biodiversity offset requirements for those impacts. The FBA:

- Provides specific instructions for avoiding and minimising impacts on biodiversity and requires proponents to clearly explain why impacts cannot be avoided or minimised any further
- Identifies impacts that may be considered severe enough to prevent a project going ahead, known as 'impacts that require further consideration'.

The biodiversity assessment and offset process which has been followed for the project in accordance with the FBA is shown in **Figure 21-1**.

The assessment of the biodiversity impacts of the project in accordance with the FBA has been carried out in two stages:

- Stage 1 – preparation of a biodiversity assessment report, including
  - Identification of existing biodiversity values within a study area, including landscape features, native vegetation communities and threatened species within the biodiversity study area
  - Identification of impacts of a project on the biodiversity values present
  - Demonstrable evidence that direct impacts to biodiversity values present have been avoided and minimised where possible
  - Identification of impacts to biodiversity values which require further consideration
  - Identification of the biodiversity offsets required based on the identified impacts to biodiversity as a result of the project
- Stage 2 – preparation of a biodiversity offset strategy to outline how the project intends to offset the impacts of the project identified in the biodiversity assessment report

The FBA applies only to terrestrial impacts. The assessment of impacts to aquatic biodiversity and requirements for avoiding, minimising and offsetting these impacts has been informed by the *Policy and guidelines for fish habitat conservation and management (update 2013)* (DPI, 2013) and was conducted separately to the biodiversity assessment report.

The Bilateral Agreement relating to environmental assessment (February 2015) between the Commonwealth Government and the NSW Government, has endorsed the FBA as providing an appropriate basis for undertaking biodiversity assessment. In addition, the supplementary SEARs for the project requires consideration of a number of assessment guidelines, which are listed below.

Additional assessment guidelines

Additional assessment guidelines which have been considered as part of the assessment has included:

- *Policy and guidelines for fish habitat conservation and management* (update 2013), (DPI, 2013)
- Commonwealth Approved Conservation Advice (including listing advice) for Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion (Department of the Environment, 2014b)
- Commonwealth *Significance Impact Guidelines for the Green and Golden Bell Frog* (Department of the Environment, 2009).
- Commonwealth Approved *Conservation Advice for Litoria aurea* (Green and Golden bell Frog) (Department of the Environment, 2014a)
- *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (NSW Office of Water, 2012b).

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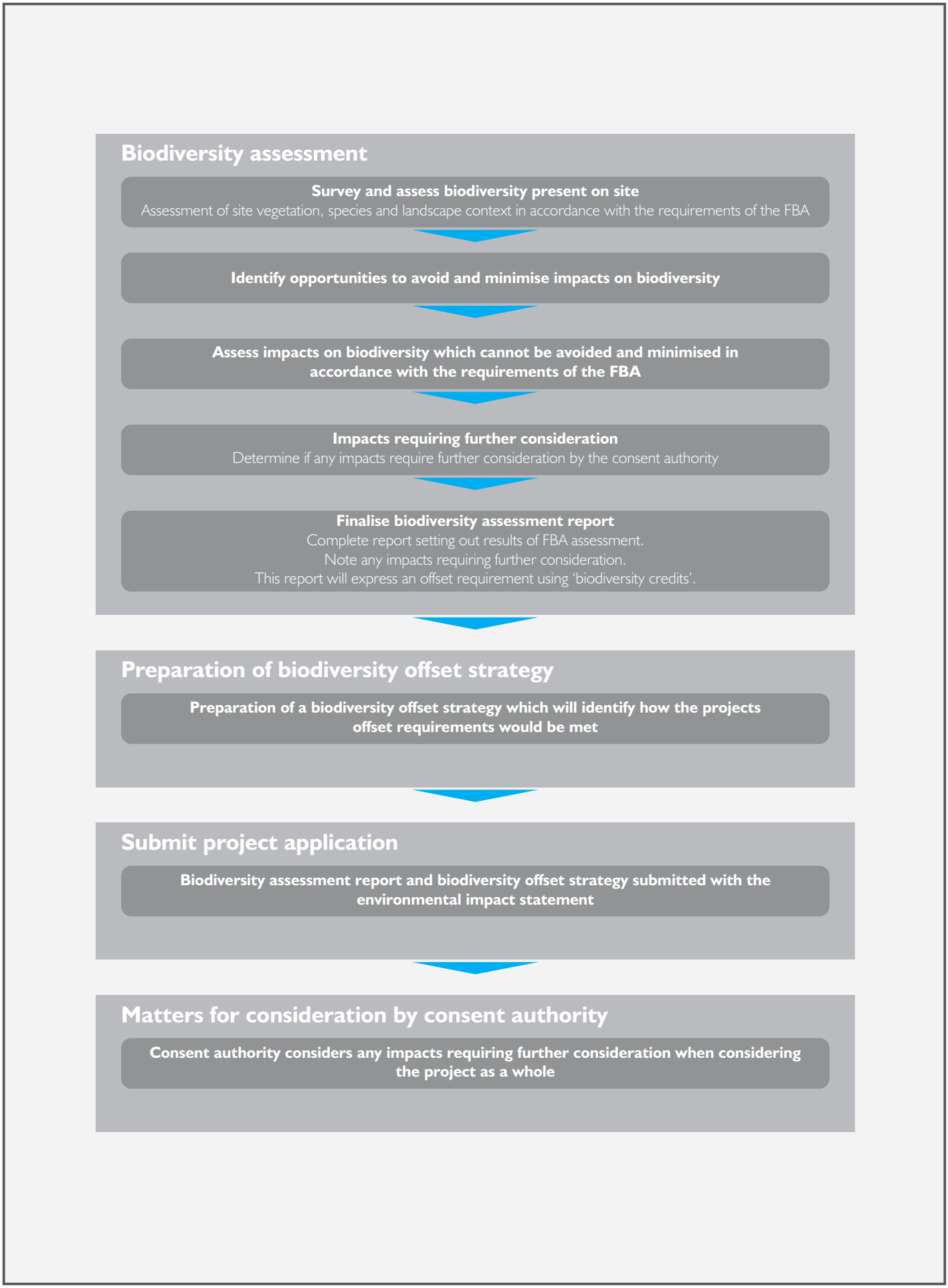


Figure 21-1 Biodiversity assessment and offset process

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21.1.2 Biodiversity study area

The biodiversity study area for the project comprises the project construction and operational footprints (refer to **Figure 5-2** to **Figure 5-8** and **Figure 6-1** to **Figure 6-4** for additional detail). The biodiversity assessment has conservatively assumed that all land within the construction and operational footprints would be cleared to accommodate the project. While complete vegetation clearance is unlikely to be required within these footprints, the actual final extent of vegetation clearance may change within the footprints during detailed design. As such, total vegetation clearance has been assumed to ensure the 'worst case scenario' has been assessed.

The biodiversity study area includes existing motorways, residential areas, urban landscaped areas, golf courses and remnant native vegetation in varying conditions with various levels of connectivity. The biodiversity study area is shown in **Figure 21-2** and consists of:

- The area around the western surface works, including Beverly Grove Park, Canterbury Golf Course and parts of the M5 East Motorway
- The area around the Kingsgrove Road and Bexley Road surface works, including Kingsgrove Avenue Reserve, parts of Wolli Creek Regional Park and the M5 East Motorway
- The Arncliffe surface works area, comprising Kogarah Golf Course
- The area around the St Peters interchange and local road upgrades, including the former Alexandria Landfill and Sydney Park.

The project corridor as assessed for Matters of national environmental significance, groundwater dependent ecosystems (GDEs) and riparian ecosystems is shown on Figure 1 of **Appendix S** (Biodiversity Assessment Report).

In accordance with the FBA, the assessment of landscape-scale biodiversity values has been undertaken using a 550 metre buffer around the anticipated worst-case construction and operational disturbance footprints. The biodiversity assessment buffer is shown on **Figure 21-2**.

21.1.3 Desktop assessment

Existing information about the biodiversity study area has been obtained from a range of sources including threatened species databases, aerial photographs and previous studies relevant to the project corridor. A review of various vegetation and soil datasets relevant to the biodiversity study area has also been conducted.

Database searches

Database searches carried out as part of the biodiversity assessment included:

- OEH Atlas of NSW Wildlife (10 kilometre radius search), carried out in November 2014
- EPBC Act Protected Matters Search Tool (10 kilometre radius search), carried out in December 2014
- NSW DPI Fisheries threatened and protected species record viewer, carried out in June 2015
- NSW DPI Fisheries Key Fish Habitat Map, carried out in June 2015
- Bureau of Meteorology Groundwater Dependent Ecosystem Atlas, carried out in June 2015.

Previous mapping applicable to the biodiversity study area has also been reviewed, including the VIS online vegetation classification database (OEH, 2015b) Sydney Metropolitan Catchment Management Authority vegetation mapping, Native Vegetation Maps of the Cumberland Plain, Western Sydney (NPWS, 2002) and the Soil Landscapes of the Sydney 1:100,000 Sheet (Chapman and Murphy, 1989).

Literature review of previous reports and field investigations

Several known sites of high conservation and biodiversity value are present in the biodiversity study area and have been the subject of previous field investigations and reports. Reports relevant to the biodiversity study area were reviewed, including:

- *Beverly Grove Vegetation Plan of Management* (NGH Environmental, 2014)
- *Beverly Grove Bushland Flora Survey – M5 East Motorway Corridor* (Cumberland Flora and Fauna Interpretive Services, 1997)
- *Management Plan for the Green and Golden Bell Frog at Arncliffe* (White, 1998)
- *Draft Recovery Plan for the Green and Golden Bell Frog* (DEC, 2005c)
- *Green and Golden Bell Frog Management Plan for Cooks Cove* (Cumberland Ecology, 2006)
- *Plan of Management: Green and Golden Bell Frog Key Population of the Lower Cooks River* (DECC, 2008b)
- *Biodiversity Assessment for the Proposed Widening of Marsh Street, Wolli Creek* (AMCS, 2014).
- Annual monitoring reports for the Green and Golden Bell Frog artificial habitat at the Kogarah Golf Course, Arncliffe (Biosphere, 2002 to 2015).

Likelihood of occurrence assessment

The database searches identified threatened species, populations, communities and habitats with the potential to occur or known to occur within the biodiversity study area. The likelihood of occurrence for the relevant threatened species, populations, communities and habitats identified was assessed based on information obtained from database searches and literature reviews. The likelihood of occurrence assessment was used to guide and inform the field surveys that were undertaken for the project.

21.1.4 Field surveys

A field survey program was developed and implemented for the project, based on the outcomes of desktop assessment (refer to **Section 21.1.3**) and the existing urban/ suburban nature of the biodiversity study area.

The field surveys undertaken for the project were conducted over a total of 12 days between November 2014 and May 2015. Details of field surveys, survey effort, survey extent and timing of field work is provided in **Appendix S**, and in summary included:

- Surveys of vegetation communities within the biodiversity study area to verify the existing vegetation mapping (OEH, 2013) and to confirm the presence/ absence and quality of natural vegetation, including threatened ecological communities
- Targeted surveys in accordance with the methodology prescribed in the FBA, including:
  - Vegetation condition survey plots (50 metre by 20 metre quadrats and 50 metre transects), including hollow bearing trees, length of fallen wood, canopy cover, midstorey cover, and groundcover for native and exotic species
  - Floristic surveys (20 metre by 20 metre quadrats and 20 metre transects) to identify flora species within vegetation communities, and to assist in the identification of those vegetation communities by comparing characteristic species
- Random meander surveys for threatened species potentially occurring in the study area
- A targeted migratory wader bird survey at Eve Street wetland to identify the presence of migratory birds
- Opportunistic sightings of fauna species during vegetation surveys

- Fauna habitat assessments to identify potential habitat for threatened fauna species, including rock habitats, foraging substrates and the presence of termite mounds
- Hollow bearing tree surveys
- An assessment of aquatic habitat, focusing on fish, aquatic vertebrates and marine vegetation as defined in the FM Act. The aquatic habitat assessment comprised a rapid assessment of instream habitat and riparian condition from the bank to characterise watercourses.

In some cases, the survey periods for this assessment did not align with the preferred seasonality requirements for certain threatened species. In these circumstances, the presence of threatened species has been conservatively assumed based on identified habitat values.

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Figure 21-2 Biodiversity study area

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21.2 Existing environment

21.2.1 Landscape scale biodiversity features

The landscape scale biodiversity features identified within the biodiversity study area are summarised in **Table 21-2** and shown in **Figure 21-3**.

Table 21-2 Biodiversity landscape features within the biodiversity study area

Landscape feature	Description
Interim Biogeographic Regionalisation for Australia (IBRA) bioregion and sub-region	The biodiversity study area (refer to **Figure 21-2**) is located within the Sydney Basin Bioregion which extends north to the Hunter Valley, west to Mudgee and south to Batemans Bay. The biodiversity study area is situated across the Cumberland and Pittwater sub-regions of the Sydney Basin bioregion (refer to **Figure 21-3**). The biodiversity study area is located in a highly urbanised setting with notable remnant vegetation located within Beverly Grove Park, Wolli Creek Regional Park and in Arncliffe as part of the Rockdale wetlands corridor, south of the Kogarah Golf Course.
Mitchell Landscapes	The majority of the project is located across the Sydney-Newcastle barriers and beaches landscape, with smaller areas being located within the Ashfield plains, Woronora Plateau and Port Jackson Basin landscapes. The Mitchell Landscapes present across the biodiversity study area are shown in **Figure 21-3**.
Rivers, streams and estuaries	Three principal watercourses traverse the biodiversity study area; Wolli Creek, the Cooks River and Alexandra Canal. All three watercourses are classified as Key Fish Habitat under the *Fisheries Management Act 1994* (FM Act). However, urban and industrial development has modified most of the aquatic and riparian habitat of these watercourses. Rivers, streams and estuaries within the biodiversity study area are shown in **Figure 21-3**.
Wetlands	No coastal wetlands protected under *State Environmental Planning Policy No 14 – Coastal Wetlands* (SEPP 14) are located within the biodiversity study area. There are a number of artificial waterbodies scattered across the biodiversity study area, some of which are known to support a variety of wetland fauna, including the Green and Golden Bell Frog at Arncliffe. Towra Point Nature Reserve is the closest RAMSAR listed site, located about nine kilometres south of the biodiversity study area. Waterbodies within the biodiversity study area are shown in **Figure 21-3**.
Groundwater dependent ecosystems (GDEs)	The Cooks River and the Cooks River Castlereagh Ironbark Forest are identified on the NSW Groundwater Atlas as being highly likely to be dependent on groundwater. An additional three groundwater dependent ecosystems have been identified outside of the biodiversity study area, but within the extent of land impacted by groundwater drawdown: • Bardwell Valley Parkland and Broadford Street Reserve • Stotts Reserve, Bexley North • This forest is between the southern bank of Wolli Creek and the rail line behind Wolli Creek Station Additional information regarding groundwater dependent ecosystems is provided in Section 21.2.7.
Vegetation cover	Around 103 hectares of native vegetation is located within the biodiversity study area, accounting for about eight per cent of the total footprint of the study area. Vegetation communities within the biodiversity study area are shown in **Figure 21-4** to **Figure 21-7**.
Wildlife corridors	No formal state or regional biodiversity links are present within the study area. Local wildlife corridors are present, but do not meet the definition of state or regional biodiversity links. Additional detail regarding wildlife corridors is provided in **Section 21.2.5**.

21.2.2 Terrestrial flora

Existing vegetation across the biodiversity study area varies in terms of extent, connectivity and quality. Most of the biodiversity study area is characterised by established suburban development, with remnant patches of vegetation associated with suburban residential properties and infrastructure corridors. Much of the vegetation around Sydney, including within the biodiversity study area, has been cleared or disturbed to varying extents. It is common for fragmented vegetation communities to be present along highways and major roads where they have been preserved as part of the road reserve or as part of riparian buffers and gully systems associated with sandstone landforms.

The most significant areas of vegetation include Wolli Creek Regional Park, to the north of the project, and Cooks River Castlereagh Ironbark Forest at the westernmost end of Beverly Grove Park, Beverly Hills.

The biodiversity study area spans all four surface water sub-catchments of the Cooks River catchment; the Cooks River, Alexandra Canal, Eastern Channel and Wolli Creek sub-catchments (refer to **Figure 16-1**). Surface water quality across the biodiversity study area is variable as a result of the suburban nature of the surface water catchments, with the quality of water, watercourses and riparian areas influenced by the extent of adjacent development. Further discussion of surface water quality is provided in **Chapter 16** (Soils and water quality).

Vegetation communities

Native vegetation communities

Vegetation communities within the biodiversity study area were identified through database searches and literature reviews, and verified through field surveys carried out for the project (refer to **Section 21.1.4**). Four plant community types as defined by the OEH vegetation information system database were identified in the biodiversity study area:

- Broad-leaved Ironbark *Melaleuca decora* shrubby open forest on the clay soils of the Cumberland Plain, Sydney Basin Bioregion (Broad-leaved *Melaleuca decora* shrubby open forest)
- Paperbark Swamp Forest of the Coastal Lowlands of the NSW North Coast Bioregion and Sydney Basin Bioregion (Paperbark Swamp Forest)
- Turpentine Grey Ironbark open forest on shale in the Sydney Basin (Turpentine Grey Ironbark Forest)
- Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in sandstone gullies of western Sydney, Sydney Basin (Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest).

The vegetation communities mapped within the biodiversity study area are shown in **Figure 21-4** to **Figure 21-7**.

Some areas could not be accessed during ecological field surveys because they are located on private property. Vegetation on private properties has not been verified through field surveys, but is expected to contain limited native vegetation communities. It is expected that most flora within areas that have not been verified would largely contain planted or managed vegetation.



Figure 21-3 Biodiversity landscapes within the study area

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Threatened ecological communities

As summarised in **Table 21-3**, three of the four vegetation communities identified in the biodiversity study area are associated with threatened ecological communities. Specifically:

- Vegetation mapped as Broad-leaved *Melaleuca decora* shrubby open forest around the western surface works area meets the EPBC Act and TSC Act definition of Cooks River Castlereagh Ironbark Forest in the Sydney Basin Bioregion (Cooks River Castlereagh Ironbark Forest) (refer to **Figure 21-4**). Cooks River Castlereagh Ironbark Forest is listed as a critically endangered ecological community under the EPBC Act and an endangered ecological community under the TSC Act
- Turpentine Grey Ironbark Forest, also known as Sydney Turpentine Ironbark Forest is a threatened ecological community, listed as a critically endangered ecological community under the EPBC Act and an endangered ecological community under the TSC Act. Patches of Sydney Turpentine Ironbark Forest have been mapped as occurring south of the Kingsgrove South construction compound (C2) within Beverly Hills Park and within Canterbury Golf Course (refer to **Figure 21-4**). These patches of vegetation did not meet the threshold criteria to be identified as a threatened ecological community under the EPBC Act, due to their small size of only 0.6 hectares. The vegetation did, however, meet the definition of this community under the TSC Act.
- Paperbark Swamp Forest is a component of Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions (Swamp Sclerophyll Forest), listed as an endangered ecological community under the TSC Act. Paperbark Swamp Forest is located within the biodiversity study area around the Arncliffe surface works within the Kogarah Golf Course between the fairways. This vegetation is under-scrubbed with a clear understorey and exotic groundcover, consistent with vegetation management on golf course fairways. Given the extent of clearing of the understorey, vegetation classified as paperbark swamp forest within the biodiversity study area does not meet the threshold criteria to be identified as the Swamp Sclerophyll Forest threatened ecological community.

Other vegetation communities

Areas of planted native, introduced and exotic species (urban native and exotic vegetation) have been mapped within parklands and areas of open space adjacent to the M5 East Motorway. Around 7.45 hectares of urban native and exotic vegetation has been mapped across the biodiversity study area. Mapped areas of urban native and exotic vegetation are shown in **Figure 21-4** to **Figure 21-7**.

Urban native and exotic vegetation within the biodiversity study area is typically located in areas where the soil profile has been modified. Urban native and exotic vegetation within parklands, including playground and maintained sports fields generally comprises large established trees, with no shrub layer or evidence of regenerating overstorey species. Vegetated areas adjacent to the M5 East Motorway mapped as urban native and exotic vegetation primarily consists of regenerating canopy species above a shrub layer but with no large established trees.

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Table 21-3 Native vegetation communities within the biodiversity study area

Plant community type	Associated threatened ecological community				Description of vegetation community within biodiversity study area		
	Threatened ecological community	EPBC Act listing	TSC Act listing	EEC present in biodiversity study area	Location	Area (ha)	Condition
Broad-leaved Ironbark *Melaleuca decora* shrubby open forest	Cook River Castlereagh Ironbark Forest	CE	E	Yes. Vegetation community meets the threshold criteria to be identified as a threatened ecological community under the EPBC Act and the TSC Act.	Area around the western surface works (refer to **Figure 21-4**)	1.4	Moderate to good
Paperbark swamp forest	Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	N/A	E	No. Vegetation within the biodiversity study area does not meet the threshold criteria to be identified as a threatened ecological community under the TSC Act. This vegetation community is not listed under the EPBC Act	Area around the Arncliffe surface works (refer to **Figure 21-6**)	1.82	Moderate to good
Turpentine Grey Ironbark open forest *	Sydney Turpentine Ironbark Forest	CE	E	One patch of Sydney Turpentine Ironbark Forest was identified in the biodiversity study area assessment buffer, outside of the worst case construction and operational footprints. The patch did not meet the threshold criteria to be identified as a threatened ecological community under the EPBC Act, due to its small size of only 0.6 hectares but it did meet the TSC Act definition.	South of the M5 East Motorway, outside of the worst case construction and operational footprints, but within the assessment buffer (refer to **Figure 21-4**)	0	Moderate to good
Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest	NA	N/A	N/A	This vegetation community is not listed under the TSC Act or the EPBC Act.	Area around the Bexley surface works (refer to **Figure 21-5**)	0.09	Moderate to good

CE – critically endangered, E – endangered

*Sydney Turpentine Ironbark Forest is located within the 550 metre biodiversity assessment buffer but outside of the construction and operational footprint



Figure 21-4 Vegetation communities around the western surface works area

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Figure 21-5 Vegetation communities around the Bexley Road surface works area

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Figure 21-6 Vegetation communities around the Arncliffe surface works

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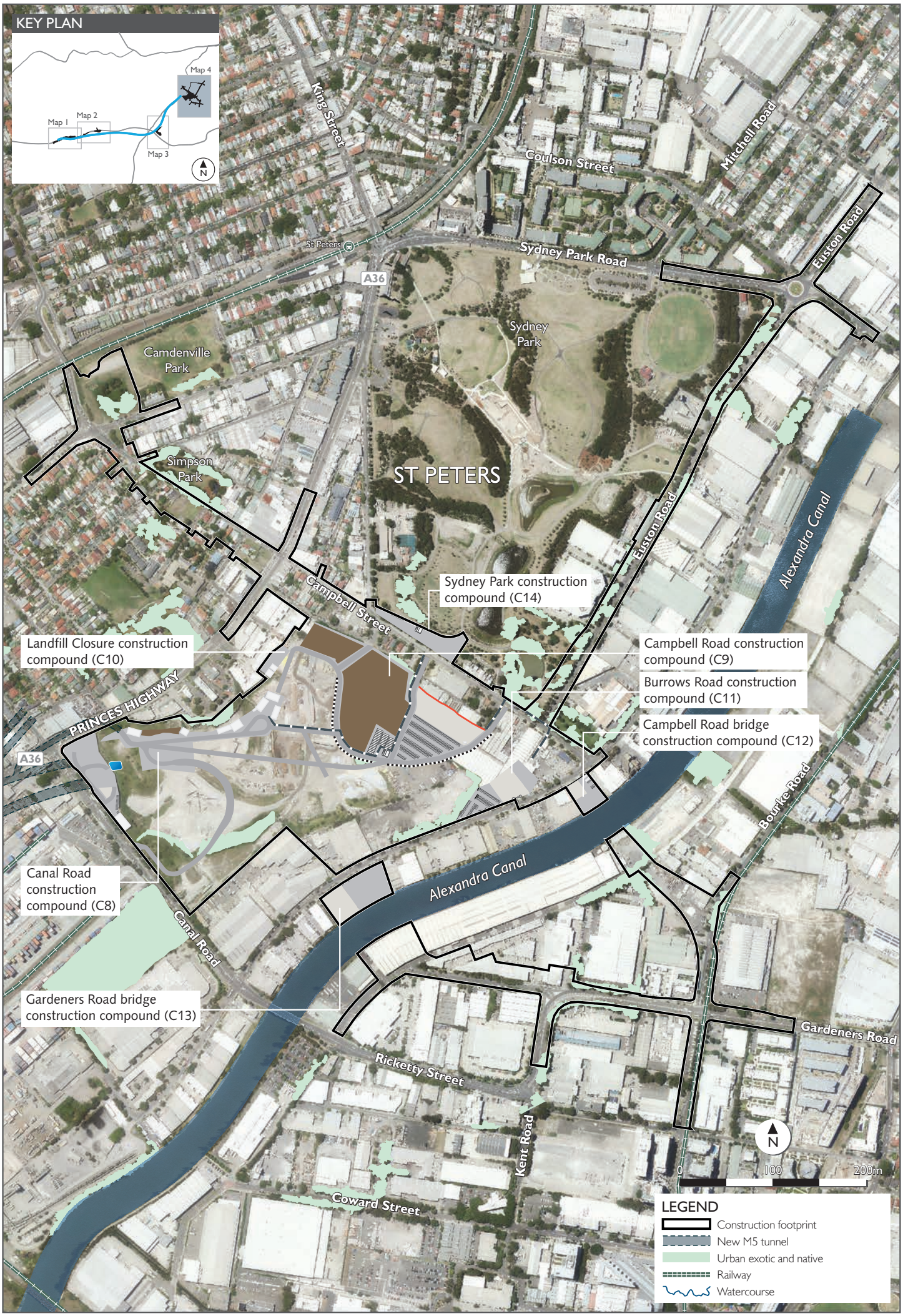


Figure 21-7 Vegetation communities around the St Peters interchange and local road upgrades

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Threatened flora

A database search of the EPBC Protected Matters Search Tool and the NSW Wildlife Atlas identified 50 threatened flora species and four threatened flora populations listed as vulnerable, endangered or critically endangered under the EPBC Act and / or TSC Act as occurring or potentially occurring within 10 kilometres of the project. A full list of these species is provided in Technical working paper: Biodiversity (**Appendix S**).

In accordance with the FBA methodology, no threatened flora species were identified in the credit calculator as ecosystem credit species. The credit calculator identified 22 threatened flora species and three threatened flora populations as candidate species, in accordance with the FBA (refer to **Section 21.1.1** for additional detail). These species and populations and their conservation status under the EPBC and / or TSC Act and are listed in **Table 21-4**.

Persoonia hirsuta (Hairy Geebung), *Pimelia spicata* (Spiked Rice-flower) and *Tetratheca juncea* (Black-eyed Susan), have been specified in the Commonwealth guidelines for the project (refer to **Appendix A**) as potentially being at risk from the project. However, the field surveys undertaken as part of the biodiversity assessment did not record these species within the biodiversity study area. Further, any potential habitat present within the biodiversity study would be highly modified and unlikely to support these species. As such, these species are not considered likely to occur and therefore excluded from **Table 21-4**.

The identified candidate species were compared against the habitat features present within the biodiversity study area to determine whether the species are likely to be present and subsequently if there is a requirement for a targeted survey to be conducted. Field surveys did not record any threatened flora species or populations within the biodiversity study area. No candidate species listed in **Table 21-4** are likely to occur in the biodiversity study area due to the degraded condition of the vegetation. In accordance with the FBA methodology, these species were excluded from further consideration and assessment.

Table 21-4 Threatened flora species and populations with the potential to occur within the biodiversity study area

Scientific Name	Common Name	Statutory listing	
		EPBC Act	TSC Act
Threatened flora			
Acacia bynoeana	Bynoes Wattle	V	E
Acacia pubescens	Downy Wattle	V	V
Caladenia tessellata	Thick Lip Spider Orchid	V	E
Callistemon linearifolius	Netted Bottle Brush	-	V
Darwinia biflora	-	V	V
Dillwynia tenuifolia	-	-	V
Epacris purpurascens var. purpurascens	-	-	V
Grammitis stenophylla	Narrow-leaf Finger Fern	-	E
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	V	V
Gyrostemon thesioides	-	-	E
Haloragodendron lucasii	-	E	E
Hibbertia puberula	-	-	E
Hibbertia sp. Bankstown	-	CE	CE
Hibbertia superans	-	-	E
Leucopogon exolasius	Woronora Beard Heath	V	V
Maundia triglochinoides	-	-	V
Melaleuca deanei	Deanes Paperbark)	V	V
Persoonia nutans	Nodding Geebung	E	E
Pimelea curviflora subsp. curviflora	NA	V	V
Pterostylis saxicola	Sydney Plains Greenhood	E	E
Syzygium paniculatum	Magenta Lilly Pilly	V	E
Tetratheca glandulosa	-	-	V

Scientific Name	Common Name	Statutory listing	
		EPBC Act	TSC Act
Threatened flora populations			
Acacia prominens (Gosford wattle) population, Hurstville and Kogarah local government areas		-	E
Plum-leaf Pomaderris population, Parramatta, Auburn, Strathfield and Bankstown Local Government Areas		-	E
Wahlenbergia multicaulis (Tadgells Bluebell) population, Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield local government areas		-	E

CE = critically endangered, E = endangered, V = vulnerable

Exotic species

Field surveys carried out for the project (refer to **Section 21.1.4**) identified abundant weeds within the biodiversity study area, with some areas containing prolific weed infestations. A total of 38 weed species were recorded across the biodiversity study area. Of these, 14 noxious and environmental weeds were identified and are summarised in **Table 21-5**.

A comprehensive list of weeds identified within the biodiversity study area is provided in the Technical working paper: Biodiversity (**Appendix S**).

Table 21-5 Noxious and environmental weeds identified during field surveys

Scientific name	Common name	Listed as noxious in local government areas	Class*	Weed of National Significance
Acetosa sagittata	Turkey Rhubarb	-	×	×
Araujia sericifera	Moth Vine	-	×	×
Asparagus aethiopicus	Asparagus Fern	Canterbury and Rockdale	4	✓
Cestrum parqui	Green Cestrum	Canterbury and Rockdale	3	×
Cinnamomum camphora	Camphor Laurel	-	×	×
Cotoneaster glaucophyllus	Cotoneaster	-	×	×
Erythrina crista-gall	Cockspur Coral Tree	-	×	×
Ipomoea indica	Morning Glory	-	×	×
Lonicera japonica	Japanese Honeysuckle	-	×	×
Lantana camara	Lantana	Canterbury and Rockdale	4	✓
Ligustrum lucidum	Large-leaved Privet	Canterbury and Rockdale	4	×
Ligustrum sinense	Small-leaved Privet	Canterbury and Rockdale	4	×
Ochna serrulata	Mickey Mouse Plant	-	×	×
Rubus fruticosus aggregate species	Blackberry	Canterbury and Rockdale	4	×

*Noxious weeds classes as defined under the *Noxious Weeds Act 1993*
Class3: The plant must be fully and continuously suppressed and destroyed.
Class 4: The growth of the plant must be managed in a manner that reduces its numbers spread and incidence and continuously inhibits its reproduction.

21.2.3 Terrestrial fauna

Table 21-6 presents the threatened fauna species and populations with the potential to occur within the biodiversity study area. These species have been identified using the FBA credit calculator as part of the application of the FBA methodology for the project.

The FBA credit calculator identified 17 threatened fauna species as ecosystem credit species (ie species which can be reliably predicted as potentially occurring at a location based on the landscape-scale biodiversity features and plant community types present). An additional 10 threatened flora species and one threatened flora population were identified in the FBA credit calculator as species credit species; ie species which may potentially be present within the biodiversity study area, but are not able to be reliably predicted based on vegetation communities present.

The 'likelihood of occurrence' assessment determined that the Green and Golden Bell Frog (*Litoria aurea*) is the only threatened species known to occur in the biodiversity study area. No other threatened fauna are likely to occur in the biodiversity study area due to the limited and degraded nature of suitable habitat present.

Table 21-6 Threatened fauna species and populations with the potential to occur within the biodiversity study area

Scientific Name	Common Name	Statutory listing		FBA Species type	
		EPBC Act	TSC Act	Ecosystem credit	Species credit
Threatened fauna					
Anthochaera phrygia	Regent Honeyeater	CE	CE		✓
Burhinus grallarius	Bush Stone Curlew	-	E	✓	
Callocephalon fimbriatum	Gang-gang Cockatoo	-	V	✓	
Cercartetus nanus	Eastern pygmy possum	-	V		✓
Chalinoblus dwyeri	Large-eared Pied Bat	V	V		✓
Chthonicola sagittata	Speckled Warbler	-	V	✓	
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	-	V	✓	
Daphoenositta chrysoptera	Varied Sittella	-	V	✓	
Falsistrellus tasmaniensis	Eastern False Pipistrelle	-	V	✓	
Glossopsitta pusilla	Little Lorikeet	-	V	✓	
Grantiella picta	Painted Honeyeater	V	V	✓	
Hieraaetus morphnoides	Little Eagle	-	V	✓	
Hoplocephalus bungaroides	Broad-headed Snake	V	E		✓
Lathamus discolour	Swift Parrot	E	E	✓	
Litoria aurea	Green and Golden Bell Frog	V	E		✓
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	-	V	✓	
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	-	V	✓	
Meridolum corneovirens	Cumberland Plain Land Snail	V	E		✓
Mormopterus norfolkensis	Eastern Freetail-bat	-	V	✓	
Petaurus norfolcensis	Squirrel Glider	-	V		✓
Phascolarctos cinereus	Koala	V	V		✓
Pseudomys novaehollandiae	New Holland Mouse	V	-	✓	
Pseudophryne australis	Red-crowned Toadlet	-	V		✓
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	-	V	✓	
Scoteanax rueppellii	Greater Broad-nosed Bat	-	V	✓	
Stagonopleura guttata	Diamond Firetail	-	V	✓	
Varanus rosenbergi	Rosenberg's Goana	-	V		✓
Threatened fauna populations					
Gang-gang Cockatoo population, Hornsby and Ku-ring-gai Local Government Areas (LGAs)		NA	E		✓

CE = critically endangered, E = endangered, V = vulnerable

Terrestrial fauna habitat

The following section provides a description of flora and fauna habitats within the biodiversity study area. No critical habitat has been declared for any of the species or ecological communities within the biodiversity study area.

Grey-headed Flying Fox habitat

Grey-headed Flying Fox (*Pteropus poliocephalus*) roosting camps are generally located within 20 kilometres of a regular food source and are commonly found in gullies, close to water, in vegetation with a dense canopy (DECCW, 2009b). Individual camps may have tens of thousands of animals and are used for mating, birth and the rearing of young.

No Grey-headed Flying Fox breeding or roosting habitat is located within the construction and operational footprint of the project. The closest Grey-headed Flying Fox camp is located about 500 metres north of the Bexley Road surface works.

Grey-headed Flying Foxes feed on the nectar and pollen of native trees, in particular *Eucalyptus*, *Melaleuca* and *Banksia*, and fruits of rainforest trees and vines. They also forage in cultivated gardens and fruit crops and can inflict severe crop damage (DECCW, 2009b). Native vegetation communities within the biodiversity study area (refer to **Section 21.2.2**) provide potential foraging habitat for the Grey-Headed Flying Fox. No potential breeding or foraging habitat is located within the biodiversity study area.

Hollow bearing trees

Nine trees within the biodiversity study area were identified as containing hollows, as summarised in **Table 21-7**. These trees were scattered throughout the biodiversity study area around the western surface works, Bexley Road surface works and the local road upgrades.

Table 21-7 Hollow bearing tree survey results

ID	Location	Hollow type	Potential fauna	Evidence of use	TBH* (cm)	Notes
1	Around the western surface works area	Fissure	Bat	No	110	One possible hollow was recorded during field surveys. There is the potential for additional smaller hollows to be present.
2	Around the western surface works area	Hole on branch/ fissure	Bat	No	110	One hollow was recorded about six metres from the ground level. There is the potential for additional smaller hollows to be present.
3	Around the Bexley Road surface works area	Fissure	Bat, small bird	No	140	One hollow about one metre from the ground level and a split trunk were recorded during the field survey. Tree hollow was identified as being unlikely to be used.
4	Around the Bexley Road surface works area	Nest box	Possum	No	75	One nest box recorded on the tree. The nest box was recorded as being just outside the construction and operational footprint.
5	Around the local road upgrades	Branch	Small bird	No	70	One possible hollow was recorded during field surveys about three metres above ground level. The possible hollow was recorded as being unlikely to be used.
6	Around the local road upgrades	Branch (dead)	Bat	No	60	The hollow may be a branch hollowed out by termites; however, this hollow is low-lying and unlikely to be used
7	Around the local road upgrades	Spout	Medium bird or possum	Possible	90	Possible scratches and chew marks recorded on tree. Presence of hollow was unconfirmed.
8	Around the local road upgrades	Spout	Bat	Unknown	40	Potential for hollow to be present in tree spout. This was unconfirmed during field surveys.
9	Around the local road upgrades	Trunk / fissure	Possum, bat, small bird	Unknown	120	Dual trunk tree, which could potentially be used by fauna. Presence of hollow unconfirmed during field surveys.

TBH – Tree diameter at breast height

21.2.4 Green and Golden Bell Frog key population and habitat

The Green and Golden Bell Frog (*Litoria aurea*) Key Population of the Lower Cooks River (the Arncliffe key population) is located within the construction and operational footprint of the project at the Kogarah Golf Course, Arncliffe. The Arncliffe key population is one of two key populations around Botany Bay, and one of four in south-eastern Sydney. The Arncliffe key population around the Marsh Street wetlands was previously the subject of major road works and infrastructure development associated with the construction of the M5 East motorway in 1998. Compensatory habitat in the form of two breeding ponds (the RTA Ponds) were established in the north-western corner of Kogarah Golf Course on Roads and Maritime land and a frog underpass connecting the new breeding ponds with Marsh Street wetlands was also established. In addition, a long-term monitoring and management program was established and is still operating successfully.

Monitoring of the Arncliffe key population has been undertaken by Dr. Arthur White since 1998, with regular annual monitoring undertaken from 2004 onwards. This monitoring has indicated that the population centres around the compensatory habitat at the Kogarah Golf Course. Green and Golden Bell Frog habitat within the construction and operational footprint is shown on **Figure 21-8**. Adult Green and Golden Bell Frogs have been recorded at the Kogarah Golf Course during each annual monitoring period, with recordings concentrated mostly around the fifth and six fairways, and Crescent Lake. Annual monitoring results from 2004 to 2015 indicate that the Arncliffe key population was at its largest in 2012 with 110 adults recorded. In the 2014 / 2015 monitoring period, the Arncliffe key population was estimated to be around 30 to 50 adults. The current population is unlikely to persist without constant management and is considered to have poor long-term viability (White pers. comms, 2015).

The current population is limited to the RTA Ponds by the presence of the Plague Minnow (*Gambusia holbrooki*), an introduced fish species which eats frogspawn and attacks the tadpoles of native frog species, and the chytrid fungus, which infects frogs causing the disease 'Chytridiomycosis', both of which are located in nearby waterbodies. The infection of frogs with the chytrid fungus is listed as a key threatening process under the EPBC Act and TSC Act and is discussed further in **Section 21.3.1**. Regular maintenance is undertaken within the RTA Ponds to manipulate the water levels to manage vegetation and Green and Golden Bell Frog predators, namely the Plague Minnow. Additionally, the RTA ponds are regularly subject to salt water flushing to manage and prevent the introduction and spread of the chytrid fungus at this location.

Monitoring of the Arncliffe key population identified that the population is centred around the artificially created RTA Ponds and breeding has not been identified outside this area since 2000 (White pers. comms, 2015). The RTA Ponds are considered to be the key source for adult frogs for the local population, which disperse across the Kogarah Golf Course. Kogarah Golf Course contains a range of habitats for the Green and Golden Bell Frog, which are summarised in **Table 21-8**.

Table 21-8 Green and Golden Bell Frog habitat types within Kogarah Golf Course

Habitat type	Description
Breeding habitat	The permanent and semi-permanent RTA Ponds in the north-western corner of the Kogarah Golf Course. Two other ponds within the golf course have provided breeding habitat, although breeding events are rare, presumably due to predation by the Plague Minnow (*Gambusia holbrooki)*. The key source of adults and juveniles are the RTA Ponds (which are actively managed for Plague Minnow and chytrid fungus by Roads and Maritime)
Foraging habitat	Native and exotic grassed areas, tussock vegetation and emergent sedges and reeds which border the RTA Ponds, as well as the drainage channel and reed beds along the southern boundary of the golf course.
Sheltering habitat	Areas around the RTA Ponds, consisting of foraging habitat as well as rock piles, fallen timber, and other sheltering sites.
Dispersal habitat	The Kogarah Golf Course fairways provide movement habitat between breeding and foraging habitat. There is an artificial frog passage that travels under the M5 East Motorway to facilitate movement between the Kogarah Golf Course and the Marsh Street wetland, which is not regularly used (DECC, 2008b). .

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Figure 21-8 Green and golden bell frog habitat within the biodiversity study area

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21.2.5 Wildlife corridors

Wildlife corridors are connections across the landscape that link areas of habitat. Wildlife corridors generally comprise native vegetation and connect two or more areas of similar wildlife habitat. Corridors are critical for the maintenance of ecological processes, including allowing for the movement of animals and the continuation of viable ecological processes. Landscape connections between larger areas of habitat through wildlife corridors enable migration, colonisation and breeding of flora and fauna.

Corridors can comprise either discontinuous areas of habitat, such as wetlands and roadside vegetation, continuous lineal strips of vegetation and habitat, such as riparian strips and ridge lines, or parts of a larger habitat area selected for its known or likely importance to local fauna.

Based on their ecological value, the following areas are considered to have potential functionality as local scale wildlife corridors:

- Vegetation along Wolli Creek, including Wolli Creek Regional Park
- Vegetation along the F6 reserved road corridor, including the Eve Street Marsh
- Vegetation along Bardwell Creek, including Kingsgrove Park, Bardwell Valley Parklands, Broadford Street Reserve and Coolibah Reserve
- Vegetation along the Cooks River north of its confluence with Wolli Creek, including parts of Wentworth Park and Gough Whitlam Park.

While the abovementioned corridors provide local connectivity, they do not represent regional and/ or state significant corridors of significance. No regional or state wildlife corridors have been identified within the biodiversity study area.

21.2.6 Aquatic biodiversity

Aquatic habitat

Three principal watercourses traverse or are located in the vicinity of the biodiversity study area:

- Wolli Creek (passed under by the main alignment tunnels)
- The Cooks River (passed under by the main alignment tunnels)
- Alexandra Canal (crossed by two bridges as part of the local road upgrades)

All watercourses within the biodiversity study area are declared as Key Fish Habitat by the New South Wales Department of Primary Industries. The condition and aquatic habitats for each watercourse are outline in the following sections. Additional detail regarding the local and regional hydrology of the project is provided in **Chapter 16** (Soils and water quality).

There are no wetlands protected under *State Environmental Planning Policy No 14 – Coastal Wetlands* (SEPP 14) within or nearby the biodiversity study area. The closest Ramsar wetland to the project is the Towra Point Nature Reserve, about nine kilometres south of the biodiversity study area.

In addition to natural watercourses, constructed detention basins and artificial waterbodies provide potential habitat for aquatic flora and fauna, including wetland species. The primary purpose of detention basins is to slow stormwater flows to minimise water pollution and impacts to the hydrology of receiving waters. As the detention basins are isolated, they are unlikely to be inhabited by fish, though other fauna may be found at these locations.

The *Sydney Water Environmental Indicators Compliance Report Volume 3* (Woodlots, 2004) provided a comparison between Wolli Creek, Alexandra Canal and Cooks River, classifying them as highly disturbed systems in relation to the ANZECC Water Quality Guidelines (ANZECC, 2000). Results indicated poor water quality overall with a number of parameters failing to comply with respective guidelines (refer to **Section 16.2.7** for additional detail).

Threatened aquatic flora and fauna

Six threatened species / populations listed under the EPBC Act and / or FM Act potentially occur in the Sydney Metropolitan catchment area, excluding marine sharks (discussed collectively as part of migratory and marine fauna). This includes:

- Two dragonflys with an aquatic life history stage, The Sydney Hawk dragonfly (*Austrocordulia leonardi*) and Adam's Emerald Dragonfly (*Archaeophya adamsi*). These two species of dragonfly are unlikely to occur in the study area as they have only been recorded in creeks with intact riparian / aquatic vegetation and in forested catchments
- One migratory fish; the Australian Grayling (*Protoroctes maraena*). The Australian Grayling uses good quality, freshwater habitat, which is not present in the biodiversity study area or in associated upstream catchments of the Cooks River and Wolli Creek
- One coastal/estuarine fish, the Black Rock Cod (*Epinephelus daemelii*). The black rockcod prefers rocky shores, caves and reefs which are not present in the biodiversity study area
- One coastal/estuarine ray, the Green Sawfish (*Pristis zijsron*), which is presumed extinct
- A population of the seagrass *Posidonia australis* occurs in southern Botany Bay (Fisheries NSW), but is not known to occur within or near the biodiversity study area.

Although some marine vegetation occurs in Wolli Creek and Cooks River, no seagrass, mangroves or saltmarsh were observed in the study area during land-based surveys of Wolli Creek, Cooks River and Alexandra Canal. The proposed crossings across Alexandra Canal near the St Peters interchange and local road upgrades. The contaminated and degraded nature of the canal means that it is unlikely to be viable habitat for seagrasses and other aquatic flora and fauna.

21.2.7 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) are defined as ecosystems whose current species composition, structure and function are reliant on a supply of groundwater as opposed to surface water supplies from overland flow paths. The majority of ecosystems in Australia have little to no dependence on groundwater, although the full understanding of the role of groundwater in maintaining ecosystems is generally poor. The exception to this is wetland communities, for which it is thought that most have some level of dependence on groundwater resources. Shallow groundwater can support riparian vegetation either permanently or seasonally. Groundwater needs to be sufficiently shallow to support vegetation where root systems of vegetation communities are able to access groundwater.

A search of the GDE Atlas (Bureau of Meteorology) indicated that there are two GDEs within the biodiversity study area. GDEs within the biodiversity study area include:

- Cooks River Castlereagh Ironbark Forest within Beverly Grove Park. There is about 1.8 hectares of this threatened ecological community, containing several native vegetation communities which are indicative of shallow groundwater tables and waterlogged soils. The GDE Atlas marks the Cooks River Castlereagh Ironbark Forest as being highly likely to have an inflow dependence on groundwater. The extent of this vegetation community is shown on **Figure 21-4**
- The Cooks River, which is likely to be an inflow dependent GDE.

An additional three groundwater dependent ecosystems have been identified outside of the biodiversity study area, but within the extent of land impacted by groundwater drawdown:

- Seventeen hectares of Hinterland Sandstone Gully Forest with a moderate to high potential to be dependent on groundwater within Bardwell Valley Parkland and Broadford Street Reserve
- About 3.5 hectares of Coastal Sandstone Ridgetop Woodland within Stotts Reserve, Bexley North. This vegetation has a moderate to high potential to be dependent on groundwater
- About 3.4 hectares of Estuarine Fringe Forest between the southern bank of Wolli Creek and the rail line behind Wolli Creek Station, with a low to moderate potential to be dependent on groundwater

GDEs within the biodiversity study area and within the extent of land impacted by groundwater drawdown are shown on **Figure 21-9**.

Additional detail regarding existing groundwater conditions in the biodiversity study area is discussed in **Chapter 19** (Groundwater).

Other native vegetation has been identified within the project groundwater drawdown modelling extent; however, the vegetation is not considered to be associated with a dependence on groundwater. These areas include:

- Landing lights, Eve Street and Marsh Street wetlands, which are all located in alluvium
- Tempe wetlands near Alexandra Canal – the canal is tidal and associated with tidal flows along the Cooks River.

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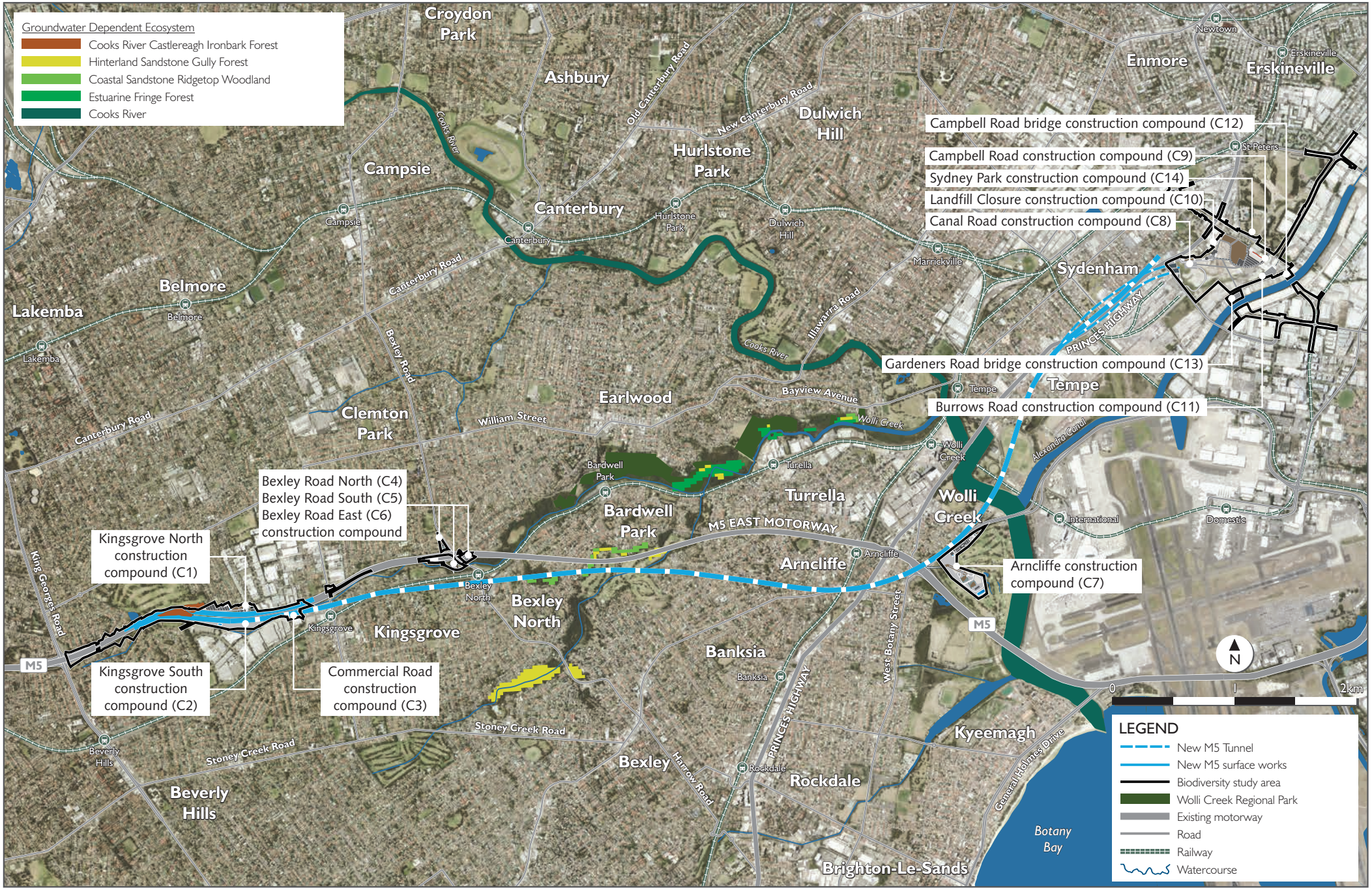


Figure 21-9 Groundwater dependent ecosystems relevant to the project

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21.3 Assessment of potential impacts

Impacts to terrestrial and aquatic flora and fauna within the biodiversity study area during construction and operation of the project may include:

- Impacts on vegetation communities and threatened ecological communities
- Impacts on threatened flora, threatened fauna or their habitats
- Impacts on migratory and marine species
- Impacts to hydrology and aquatic biodiversity, and permanent changes to hydrology
- Introduction and spread of weeds, pathogens and animal pests
- Fauna injury and mortality
- Disruption of wildlife connectivity and increased habitat fragmentation
- Impacts on groundwater dependent ecosystems
- Indirect impacts from noise and vibration, lighting and dust
- Impacts on relevant key threatening processes.

An assessment of the potential impacts of the project during construction and operation are detailed in **Section 21.3.1** and **Section 21.3.2** respectively. Environmental management measures to avoid, minimise, mitigate and offset these impacts are discussed in **Section 21.4**.

21.3.1 Construction

The project has been designed with the aim of avoiding impacts to known areas of ecological sensitivity, where feasible. However, some impacts on areas of ecological sensitivity were unavoidable. An assessment of the potential impacts of the project on biodiversity during construction of the project is described in the following sections.

Impacts on vegetation communities and threatened ecological communities

Clearance of vegetation would be unavoidable due to the required footprint of the project. Notwithstanding, opportunities to avoid and minimise the extent of vegetation clearing would continue to be considered during detailed design of the project.

For the purpose of this assessment, a worst case construction footprint has been assumed (which is larger in area than the subsequent operational footprint for the project). The project would require the clearance of around 10.76 hectares of vegetation, including 3.31 hectares of native vegetation and 7.45 hectares of urban native and exotic vegetation.

Table 21-9 provides a breakdown of the vegetation communities that would be directly impacted by the worst case construction footprint.

Table 21-9 Directly impacted vegetation within the biodiversity study area

Plant community type	Threatened ecological community associated with plant community type	EPBC Act listing	TSC Act listing	Area (ha)
Broad-leaved Ironbark *Melaleuca decora* shrubby open forest on the clay soils of the Cumberland Plain, Sydney Basin Bioregion	Cooks River Castlereagh Ironbark Forest	CE	E	1.40
Paperbark swamp forest of the coastal lowlands of the NSW North Coast Bioregion and Sydney Basin Bioregion	Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	NA	E	1.82
Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in sandstone gullies of western Sydney, Sydney Basin	NA	NA	NA	0.09
Total native vegetation (hectares)				**3.31**
Urban native and exotic vegetation	N/A	N/A	N/A	7.45
Total vegetation to be removed (hectares)				**10.76**

CE – critically endangered, E – endangered

Cooks River Castlereagh Ironbark Forest community

About 1.87 hectares of Cooks River Castlereagh Ironbark Forest (as defined under the TSC Act and EPBC Act) is located within and adjacent to the Kingsgrove North construction compound (C1) site within Beverly Grove Park. This patch of vegetation is currently managed for conservation purposes by Roads and Maritime.

Vegetation at this location meets the definition of the Cooks River Castlereagh Ironbark Forest threatened ecological community under the TSC Act and EPBC Act as it:

- Occurs in the Interim Biogeographic Regionalisation for Australia (IBRA) Cumberland Subregion at less than 100 metres above sea level
- Contains native flora species representative of clay and shale influenced soils
- Contains representative species across all vegetation layers including the Prickly-leaved Paperbark (*Melaleuca nodosa*), White Feather Honeymyrtle (*Melaleuca decora*), Woollybutt (*Eucalyptus longifolia*), Green Wattle (*Acacia decurrens*), *Bursaria spinosa*, Wiry Panic (*Entolasia stricta*) and Weeping Grass (*Microlaena stipoides*)
- Is greater than the minimum patch size area (0.5 hectares) and more than 50 per cent of the perennial understorey vegetation cover comprises native species.

It is estimated that 1828 hectares of Cooks River Castlereagh Ironbark Forest remains in existence within the Sydney Basin bioregion (Tozer et al, 2006, 2010). The project is anticipated to require the clearing of 1.4 hectares of Cooks River Castlereagh Ironbark Forest, which is equivalent to less than 0.1 per cent of the estimated remaining remnant area of this community within the Sydney Basin Bioregion.

A detailed assessment of the significance of clearing up to 1.4 hectares of Cooks River Castlereagh Ironbark Forest is presented in the Technical working paper: Biodiversity (**Appendix S**). The assessment of significance against the EPBC Act significant impact criteria (Commonwealth Department of the Environment, 2015) determined that despite the provision of mitigation measures, there is likely to be a significant impact on this threatened ecological community. This reflects the limited remaining areas of this community within the Sydney Basin bioregion and its status as a critically endangered ecological community under the EPBC Act and as an endangered ecological community under the TSC Act.

Impacts to the Cooks River Castlereagh Ironbark Forest threatened ecological community would be offset in accordance with the FBA. Additional information regarding the biodiversity offsets strategy for the project is provided in **Section 21.4.1** and **Appendix T**.

Impacts on threatened flora

As discussed in **Section 21.2.2**, the FBA credit calculator predicted that 24 threatened flora species and three threatened fauna populations are potentially associated with vegetation communities present in the biodiversity study area. No threatened flora species or populations were recorded within the construction and operational footprints of the project during field surveys. Impacts to threatened flora species and populations are therefore not anticipated as a result of the project.

The following species listed under the EPBC Act have been identified by the Commonwealth Department of the Environment as occurring or potentially occurring within the region:

- Bynoe's Wattle (*Acacia bynoeana*)
- Downy Wattle (*Acacia pubescens*)
- Deane's Paperbark (*Melaleuca deanei*)
- Hairy Geebung (*Persoonia hirsuta*)
- Spiked Rice-flower (*Pimelea spicata*)
- Magenta Lilly Pilly (*Syzygium paniculatum*)
- Black-eyed Susan (*Tetratheca juncea*).

The project is not anticipated to impact these species as suitable areas of potential habitat that are to be cleared within the biodiversity study area are degraded or have been substantially modified and are unlikely to support these species. Targeted surveys conducted as part of the field survey program did not record these species within the biodiversity study area.

Impacts on threatened fauna

The FBA credit calculator identified 17 threatened fauna species as ecosystem credit species (ie species which can be reliably predicted as potentially occurring at a location based on the landscape-scale biodiversity features and plant community types present (refer to **Section 21.2.3**). The 'likelihood of occurrence' assessment determined that these species are unlikely to be present in the biodiversity study area due to the limited and degraded nature of suitable habitat present.

As discussed in **Section 21.2.3**, the Green and Golden Bell Frog (*Litoria aurea*) is the only threatened species known to occur in the biodiversity study area. No other threatened fauna are likely to occur in the biodiversity study area.

The project would remove up to 7.82 hectares of foraging, dispersal and sheltering habitat for the Arncliffe key population at Kogarah Golf Course. The breeding habitat provided by the RTA Ponds (refer to **Section 21.2.4**) would not be directly disturbed by the project, and a buffer/ exclusion zone of around 32 metres would be provided between the RTA Ponds and the Arncliffe construction compound.

The removal of foraging, dispersal and sheltering habitat would decrease the viability of the population at this location. Although previous records have identified individual frogs located at the Marsh Street and Eve Street wetlands there have not been any record of frogs breeding in these habitats suggesting that these habitats are unsuitable.

Impacts to the Green and Golden Bell Frog key population at Arncliffe are expected to be temporary for the duration of construction. Land to be used for construction and not within the footprint of the Arncliffe motorway operations complex (MOC3) would be rehabilitated at the completion of construction. This rehabilitation would take into account the habitat requirements of the Green and Golden Bell Frog.

Impacts to the RTA Ponds as a result of noise, lighting and dust during construction are described below (refer to relevant sections). Noise, lighting and dust impacts would be temporary and are unlikely to have a significant impact on the Arncliffe Key Population with the implementation of specific mitigation measures to manage these impacts as part of the Green and Golden Bell Frog Plan of Management. No residual impacts to the Arncliffe Key Population are anticipated as a result of noise, lighting and dust.

Several mitigation and management measures have been developed and would be implemented to minimise impacts to the Green and Golden Bell Frog population, including a program to create additional breeding habitat at Marsh Street and the establishment of a captive breeding program. These mitigation measures have been included as part of a Green and Golden Bell Frog Plan of Management. The Green and Golden Bell Frog Plan of Management includes mitigation and management measures to be implemented to minimise impacts associated with construction and operation of the project. The Green and Golden Bell Frog Plan of Management includes:

- Management measures to be implemented at the Arnciffe construction compound (C7) and RTA Ponds to minimise and manage impacts to the Green and Golden Bell Frog habitat and key population during construction.
- Management measures relating to the enhancement of existing habitat at the Marsh Street Wetland
- Supplementary management measures for consideration to mitigate and minimise impacts to the Green and Golden Bell Frog.

Impacts on migratory and marine species

Based on database searches and literature reviews, 63 migratory and marine species protected under the EPBC Act and the international agreements of the China-Australia Migratory Bird Agreement (CAMBA), the Japan-Australia Migratory Bird Agreement (JAMBA) and the Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA) have been identified as having been previously recorded within 10 kilometres of the biodiversity study area. A comprehensive list of these species is provided in Appendix A of the Technical working paper: biodiversity (**Appendix S**).

Suitable habitat for migratory and marine species is not present or is unlikely to be present within the biodiversity study area. Further, impacts to aquatic habitat downstream of the project are not expected. As such, impacts to migratory and marine species from construction of the project are unlikely.

Impacts to threatened fauna habitat

No critical habitat within the biodiversity study area for any listed threatened species, communities or populations.

There is known and potential threatened fauna habitat within the biodiversity study area, including for the Green and Golden Bell Frog and the Grey-headed Flying Fox, as well as hollow-bearing trees with habitat value for fauna species. Impacts to threatened fauna habitat during construction of the project are discussed in the following sections.

Impacts to Green and Golden Bell Frog habitat

The Arncliffe surface works would require the clearance of around 7.82 hectares of Green and Golden Bell Frog foraging, sheltering and dispersal habitat, equivalent to about 20 per cent of the currently available habitat within the Kogarah Golf Course. The clearance of this habitat is expected to impact on the viability of the Arncliffe key population of Green and Golden Bell Frogs. Some of this impact would be temporary during construction, with disturbed land not required for the Arncliffe motorway operations complex (MOC3) rehabilitated at the completion of construction. This rehabilitation would take into account the habitat requirements of the Green and Golden Bell Frog, with the aim of returning disturbed residual land to habitat values equivalent to or better than currently exists.

A Green and Golden Bell Frog Plan of Management has been developed to mitigate the impacts of the project on the population and its associated habitat. The plan of management includes measures to create additional habitat adjacent to the Arncliffe surface works area and to increase the amount of tussocky grasses and swales around the RTA Ponds to increase the quality of habitat. Additional information regarding the Green and Golden Bell Frog Plan of Management is provided in **Section 21.4**.

It is a commitment in the Green and Golden Bell Frog Plan of Management to undertake water quality monitoring of the breeding ponds. More detail on the water quality monitoring regime including frequency, sampling locations and parameters will be provided in the Habitat Creation and Captive Breeding Plan due for completion by March 2016.

Impacts to Grey-headed Flying Fox habitat

While no direct impacts to known Grey-headed Flying Fox camps (roosting habitat) would occur, there would be direct impacts to potential foraging habitat for this species. About 10.76 hectares of native and exotic vegetation would be directly impacted by construction of the project. Some of the vegetation to be cleared may be used as foraging habitat by Grey-headed Flying Fox (*Pteropus poliocephalus)*, associated with the Grey-headed Flying Fox camp at Turrella, located about one kilometre north of the Bexley Road surface works.

An assessment of significance concluded that the clearance of potential Grey-headed Flying Fox foraging habitat is unlikely to present a significant adverse impact to this species (refer Appendix G of **Appendix S**).

Removal of hollow bearing trees

A total of nine trees were identified as containing hollows during field surveys conducted for the project (refer to **Section 21.2.3**). Eight of these trees are likely to require clearance during construction. Hollows identified within the biodiversity study area are not considered large enough to provide roosting or breeding habitat for large forest owls or large cockatoos.

The removal of hollow bearing trees during construction of the project is unlikely to have an impact on threatened fauna. Pre-clearance surveys of all potential hollows would be conducted prior to clearance to ensure no fauna is present.

Impacts to hydrology and aquatic biodiversity

The project has the potential to result in temporary impacts to hydrology due to the following construction activities:

- Dewatering, treatment and discharge of groundwater during construction of the main alignment tunnels, on-ramps and off-ramps
- An increase in runoff during construction as a result of increased paved areas
- Changes to current flow regimes caused by alterations to existing detention basins and culverts, and the installation of new culverts and drainage infrastructure as part of the project
- Groundwater drawdown

Groundwater captured during construction would be pumped to four construction water treatment plants, located at:

- Kingsgrove North construction compound (C1)
- Commercial Road construction compound (C3)
- Bexley Road South construction compound (C5)
- Canal Road construction compound (C8).

Groundwater would then be treated to the 80 per cent protection level criteria as specified in the ANZECC guidelines prior to discharge to Wolli Creek, the Cooks River and Alexandra Canal (refer to **Chapter 16** (Soils and water quality) for additional information).

Groundwater collected during tunnelling would be treated prior to discharge to local watercourses to meet the requirements of the environment protection licence to be issued for the project. Reference criteria for each watercourse were developed to provide guidance on the quality of water that must be produced by groundwater treatment plants to make that water suitable for discharge into the receiving environment. These criteria were defined based on available data and in accordance with the relevant ANZECC criteria.

It is expected that the environment protection licence will require the project to meet the 80 per cent protection level criteria as specified in the ANZECC guidelines (refer to **Chapter 16** (Soils and water quality) for additional information).

An increase in paved areas and tunnel water discharge to local watercourses may result in increased erosion and sedimentation. Temporary controls would be implemented within construction compounds to manage erosion and sedimentation and to maintain water quality within and adjacent to construction compounds. These controls are detailed in **Chapter 16** (Soils and water quality) and **Chapter 18** (Surface water and flooding).

The condition of aquatic habitats downstream of the project varies from slightly modified to substantially modified. Upper reaches of watercourses are generally more heavily disturbed than further downstream. Potential impacts to aquatic habitats as a result of construction works may include:

- Groundwater discharge
- Weed invasion
- Polluted surface water runoff
- Erosion, sedimentation and increases in turbidity.

Impacts to aquatic fauna in the upper reaches of watercourses which traverse the biodiversity study area are unlikely, given the already degraded condition of these environmental and the lack of available habitat. Higher quality environments downstream could be affected during construction by:

- Increased surface water volumes and velocities, which may contribute to bank erosions and sedimentation
- Transport of weeds and nutrients, which may increase the potential for algal blooms to occur.

Impacts to aquatic habitat may also reduce the availability or desirability of habitat for macroinvertebrates.

Impacts to aquatic habitats during construction would be avoided by reducing the speed of discharge flows into watercourses, removing sediment and nutrients prior to the discharge of water into watercourses and stabilising banks, where necessary. Further information regarding these environmental management measures is provided in **Chapter 16** (Soils and water quality) and **Chapter 18** (Surface water and flooding).

Spread of weeds

Weeds are abundant within the biodiversity study area, with some areas containing prolific weed infestations. Given the high presence of weeds in the biodiversity study area, it is likely that disturbance of vegetation could result in conditions conducive to the spread and intensification of weeds. If not appropriately mitigated and managed, this may indirectly affect native flora and fauna in adjoining areas by further reducing habitat quality, increasing competition for resources, and altering the structure and composition of vegetation communities.

The implementation of management measures outlined in **Section 21.4** would minimise the potential for the spread of weeds from construction activities.

Introduction and spread of pathogens

Several pathogens of concern occur within New South Wales and have the potential to impact on native flora and fauna. The movement of equipment over large areas for construction of the project has the potential to facilitate the spread of pathogens. Pathogens of concern within the biodiversity study area include:

- Chytrid fungus (*Batrachochytrium dendrobatidis*)
- Myrtle Rust (*Uredo rangelli*)
- Phytophthora (*Phytophthora cinnamomi*).

Chytrid fungus is a water-borne fungus which affects amphibian species, and the infection of frogs by the fungus causing the disease 'Chytridiomycosis' is listed as a key threatening process under the EPBC Act and the TSC Act. The Chytrid fungus is likely to be present at the RTA Ponds (White A, pers. comm 2015) adjacent to the Arncliffe construction compound (C7), which provides breeding habitat for the Green and Golden Bell Frog (*Litoria aurea*). Water and salinity levels within the RTA Ponds are maintained to manage and prevent the spread of the Chytrid fungus.

Given that the Chytrid fungus is likely to be present adjacent to the construction footprint at Arncliffe, construction of the project is not expected to further exacerbate the effects of the Chytrid fungus on the Green and Golden Bell Frog. A hygiene protocol would be implemented as part of the Construction Environmental Management Plan(s) for the project to minimise the potential spread of Chytrid fungus. Environmental management measures to mitigate and manage the spread of pathogens during construction of the project are provided in **Section 21.4**.

Myrtle Rust has the potential to affect native vegetation including bottlebrush (Callistemon species), tea tree (Melaleuca species) and eucalyptus (Eucalyptus species) species but is unlikely to be present in the biodiversity study area. The introduction and establishment of Myrtle rust is listed as a key threatening process under the EPBC Act and TSC Act.

Phytophthora has not been previously identified in the biodiversity study area, but has the potential to be spread over large areas by water, vehicle and machinery movement as well as human and animal movement. Once introduced, Phytophthora represents a significant threat to flora, including native vegetation, through root rot. Dieback caused by Phytophthora is a listed key threatening under the EPBC Act and TSC Act.

The management and prevention of introducing Myrtle Rust and Phytophthora into the biodiversity study area during construction of the project would be managed through the implementation of the environmental management measures detailed in **Section 21.4**.

Introduction and spread of animal pests

Annual monitoring of the Arncliffe Key Population has identified Plague Minnow (*Gambusia holbrooki*) an introduced fish species which eats frogspawn and attacks the tadpoles of native frog species, within waterbodies at the Kogarah Golf Course. The water level within the RTA Ponds is manipulated to actively manage and prevent the presence of this species. Construction of the project would not interrupt the management of the water level of the RTA Ponds, and is unlikely to result in the introduction of the Plague Minnow into the RTA Ponds.

Given the highly urbanised nature of the biodiversity study area, it is highly likely that animal pests would be present, including the European Rabbit (*Oryctolagus cuniculus*), European Red Fox and Feral Cat (*Felis catus*).

The potential for construction of the project to increase the abundance of animal pests, introduce them into new areas or increase predation pressures on native fauna is limited because:

- No tracks or cleared corridors would be established that may facilitate the movement of pest species
- The project would not involve the introduction of other conditions in which animal pest species may thrive and result in an increase in population spread of these species.

Fauna injury and mortality

The injury and / or mortality of fauna during construction of the project may occur as a result of vegetation clearance or direct collisions with vehicles and equipment within construction sites. More mobile species such as birds may be able to move away quickly and easily; however, others may be slower to relocate or may not vacate the area at all, which could result in the injury or mortality of the individual.

Construction works around the Arncliffe surface works area may result in the injury of Green and Golden Bell Frogs which utilise the RTA Ponds and associated habitat. To prevent movement of individual Green and Golden Bell Frogs into or near the Arncliffe construction compound, a frog exclusion fence would be constructed along the boundary of the RTA Ponds. This fence would be transparent and provide some noise attenuation at the ponds to minimise impacts to the breeding habitat. Further, a pre-clearing procedure would be established and implemented prior to any vegetation clearance. In addition, an unexpected discovery procedure would be implemented to minimise the potential for Green and Golden Bell Frog injury and mortality.

Appropriate mitigation measures to minimise the injury and mortality of fauna species during construction are provided in **Section 21.4**.

Wildlife connectivity and habitat fragmentation

Barrier effects may occur as a result of new and relocated noise barriers preventing wildlife movement between vegetation fragments. As the construction and operational footprints of the project generally align with the existing M5 East Motorway corridor where barriers are already present, it is not expected that the project would increase the existing barrier effect. Around the St Peters interchange, the implications of barrier effects associated with the construction of new road infrastructure and noise barriers would be limited due to the low habitat values in the area.

Habitat fragmentation as a result of the project would be minimal given that the majority of the project is located underground. Land surrounding the western surface works, St Peters interchange and local road upgrades is urbanised and native vegetation present is limited to relatively small and highly modified patches with limited connectivity with larger patches of remnant vegetation. The project would not sever or otherwise compromise any state or regional biodiversity links.

Edges created by clearing vegetation for construction works could potentially impact on surrounding vegetation communities. The edge effect may impact on adjacent native vegetation through the increased presence of weeds, particularly around the edges of the disturbance footprint. Edges provide an opportunity for the establishment of weeds which then compete with native species. The potential impacts associated with the spread of weeds have been discussed above.

Impacts to groundwater dependent ecosystems

Impacts to groundwater inflows to the Cooks River

The Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2015) identifies the Cooks River as being highly likely to have an inflow dependence on groundwater, meaning that the Cooks River estuary receives groundwater passively through its bed. Some of this groundwater may flow underneath the Kogarah Golf Course at Arncliffe, which could be intercepted during tunnelling. The volume and rate of groundwater flow into the Cooks River is unknown; however, the hydraulic connection to the Cooks River is likely to be limited by the concrete and brick lining along the banks.

Although the Cooks River is highly likely to receive groundwater, there are no known ecosystem components which would be significantly impacted by a reduction in groundwater as a result of groundwater interception from tunnelling.

Impacts to the Cooks River Castlereagh Ironbark Forest

Construction of the project is expected to require the clearance of 1.4 hectares of Cooks River Castlereagh Ironbark Forest, which contains several native vegetation communities which are indicative of shallow groundwater table and waterlogged soils. The Groundwater Dependent Ecosystem Atlas marks the Cooks River Castlereagh Ironbark Forest as being highly likely to have an inflow dependence on groundwater.

The residual Cooks River Castlereagh Ironbark Forest around the western surface works area may be affected by groundwater drawdown from tunnelling (refer to **Table 21-10**).

Impacts to GDEs from groundwater drawdown

The maximum amount of groundwater drawdown is expected to be about five to ten metres. Drawdown would be the greatest directly above the main alignment tunnels, and would decrease towards the drawdown boundary. Five GDEs (including the Cooks River and the Cooks River Castlereagh Ironbark Forest) have the potential to be impacted as a result of groundwater drawdown. **Table 21-10** provides a summary of impacts to GDEs as a result of groundwater drawdown.

Table 21-10 Summary of impacts to GDEs from groundwater drawdown

GDE	Area (hecatares)	Location	Summary of impact	Significance of impact
Cooks River Castlereagh Ironbark Forest	1.8	Western surface works within the construction footprint	Vegetation to be retained is likely to be highly groundwater dependent. Lowering of the water table at this location is likely to place this vegetation under stress.	Moderate
Cooks River	NA	Adjacent to the Arncliffe (C7) construction compound	Drawdown may reduce the flow of water from aquifer to river. The current flow rate at this location is unknown, but is unlikely to be significant because large reaches of the bank and bed are lined with concrete or brick.	Low
Hinterland sandstone gully forest	17	Within Bardwell Valley Parkland and Bradford Street Reserve outside of the construction footprint but within the groundwater drawdown extent	Drawdown could lower groundwater to a point where it is below the roots of dependent trees. As this GDE is near the edge of the drawdown boundary, the impact is not expected to be significant	Low
Coastal sandstone ridgetop woodland	3.5	Within Stotts Reserve, Bexley North outside of the construction footprint but within the groundwater drawdown extent	Stotts Reserve is located directly above the main alignment tunnel. Drawdown could be up to 10 metres, and if trees are dependent on groundwater, a large part of the reserve could show signs of stress in prolonged dry periods.	Moderate
Estuarine fringe forest	3.4	Between the southern bank of Wolli Creek and the rail line behind Wolli Creek Station, outside of the construction footprint but within the groundwater drawdown extent	This tract of vegetation is on the bank of Wolli Creek, near the edge of the drawdown boundary. It is unlikely that drawdown would have a significant impact.	Low

Noise and vibration

Indirect impacts to biodiversity may occur as a result of changes in noise and vibration levels during construction of the project, with construction works being conducted during the day and outside of standard construction hours. Fauna species most susceptible to indirect impacts from construction noise and vibration would include nocturnal species and species which are reliant on sound to communicate, such as diurnal and nocturnal birds and bats, and other nocturnal mammals.

Given the existing noise environment for the project is characterised by high levels of road traffic noise (refer to **Chapter 12** (Noise and vibration) for additional detail), construction noise and vibration is unlikely to have a considerable impact on diurnal and nocturnal fauna. Environmental management measures to minimise and manage construction noise and vibration are described in **Section 12.4**.

The Green and Golden Bell Frog Plan of Management for the project would include specific mitigation and management measures to minimise indirect noise and vibration impacts at the RTA Ponds, including the installation of transparent, noise-proof fencing along the boundary.

Lighting

The introduction of lighting during out-of-hours construction works may impact flora and fauna species. Fauna species most susceptible to indirect lighting impacts would include nocturnal birds and bats. Construction lighting could affect sleeping patterns of nocturnal species and may also discourage prey species.

Altering the light regimes could affect plant growth and changes to micro-climates as a result of overshadowing or increased light could increase the likelihood of weed invasion. Mitigation measures to manage the introduction of weeds are provided in **Section 21.4**.

The Green and Golden Bell Frog Plan of Management for the project would include specific mitigation and management measures to minimise indirect lighting impacts at the RTA Ponds, including the use of low sodium and / or directional lighting to avoid light spill into the RTA Ponds.

Impacts to biodiversity during construction as a result of lighting are expected to be minor and temporary and would not significantly impact flora and fauna within the biodiversity study area. Mitigation measures to manage lighting are described in **Chapter 14** (Visual impacts and urban design).

Dust

Dust has the potential to be generated during construction as a result of clearing, disturbance of soils, movement of machinery. Dust that settles on vegetation accumulates on leaf surfaces and reduces essential photochemical processes, decreasing plant health and reducing habitat quality. Dust deposition on vegetation also affects fauna that use these plants as a source of food or habitat.

Impacts to biodiversity as a result of construction dust are expected to be minor and temporary and would not significantly impact flora within the biodiversity study area. Mitigation measures to manage construction dust are described in **Chapter 10** (Air quality).

Impacts on relevant key threatening processes

The project has the potential to contribute to key threatening processes as defined by the EPBC Act, TSC Act and FM Act in relation to threatened species, communities, populations and their habitats as summarised in **Table 21-11**.

Table 21-11 Key threatening processes and potential impacts on biodiversity

Key threatening process	Statutory listing	Relevance to the project
Clearing of native vegetation	EPBC Act and TSC Act	Clearing of vegetation including native vegetation will be undertaken as part of the project. The loss of native vegetation will be offset in accordance with the FBA and Biodiversity offsets policy.
Infection of amphibians with chytrid fungus resulting in chytridiomycosis	EPBC Act and TSC Act	The Chytrid fungus is likely to be present at the RTA Ponds (White A, pers. comm 2015) adjacent to the Arncliffe construction compound (C7), which provides breeding habitat for the Green and Golden Bell Frog (*Litoria aurea*). Construction of the project is not expected to further exacerbate the effects of the Chytrid fungus on the Green and Golden Bell Frog. A hygiene protocol would be implemented as part of the Construction Environmental Management Plan(s) for the project to minimise the potential spread of Chytrid fungus. Environmental management measures to mitigate and manage the spread of pathogens during construction of the project are provided in **Section 21.4**. The potential to exacerbate the risk of this key threatening process within the biodiversity study would be low.
Infection of native plants by *Phytophthora cinnamomi* Dieback caused by the root-rot fungus[1] *Phytophthora cinnamomi*	TSC Act EPBC Act	Phytophthora has not been previously identified in the biodiversity study area, but has the potential to be spread over large areas by water, vehicle and machinery movement as well as human and animal movement. The management and prevention of introducing Phytophthora into the biodiversity study area during construction of the project would be managed by the implementation of the environmental management measures detailed in **Section 21.4**. The potential to exacerbate the risk of this key threatening process within the biodiversity study would be low.
Introduction and establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae	TSC Act	Myrtle Rust is unlikely to be present in the biodiversity study area, but has the potential to affect native vegetation including bottlebrush (Callistemon species), tea tree (Melaleuca species) and eucalyptus (Eucalyptus species) species. The management and prevention of introducing Myrtle Rust into the biodiversity study area during construction of the project would be managed by the implementation of the environmental management measures detailed in **Section 21.4**. The potential to exacerbate the risk of this key threatening process within the biodiversity study area would be low.
Invasion and establishment of exotic vines and scramblers (TSC Act)	TSC Act	Exotic vines and scramblers are present within the biodiversity study area including areas along road and track edges within the study area. The movement of vehicles and equipment during construction has the potential to introduce and / or spread exotic vines and scramblers. Disturbance of areas of intact vegetation during construction could also increase the risk of weed infestations. Appropriate mitigation measures would be implemented to limit the spread of weeds and reduce the risk of exacerbating weed infestations within and adjoining the biodiversity study area as a result of the project. With the implementation of appropriate mitigation measures listed in **Section 21.4**, the risk of exacerbating this key threatening process would be low.

Key threatening process	Statutory listing	Relevance to the project
Invasion, establishment and spread of *Lantana camara* (TSC Act)	TSC Act	*Lantana camara* is present within the biodiversity study area including within Smooth-barked Apple – Red Bloodwood – Sydney peppermint heathy open forest and within the Broad-leaved Ironbark Melaleuca decora shrubby open forest on the clay soils of the Cumberland Plain. Movement of vehicles and equipment could result in the introduction and spread of *Lantana camara* into unaffected areas. Appropriate mitigation measures would be implemented to limit the spread of weeds and reduce the risk of exacerbating weed infestations within and adjoining the biodiversity study area as a result of the project. With the implementation of appropriate mitigation measures listed in **Section 21.4**, the risk of exacerbating this key threatening process would be low.
Loss of Hollow-bearing Trees (TSC Act)	TSC Act	The project would result in the permanent removal or lopping of up to eight hollow bearing trees. The eight hollows present within these trees are low quality and unlikely to be suitable for many hollow dependent fauna. The loss of hollow-bearing trees resulting from the project would be offset through the installation of nest boxes in accordance to the Guideline for Biodiversity Offsets (OEH, 2014c) and through vegetation offsets discussed in **Section 21.4**.
Human-caused climate change (FM Act)	EPBC Act, TSC Act and FM Act	The combustion of fuels associated with construction of the project would contribute to anthropogenic emissions of greenhouse gases. The increase in greenhouse gases as a result of the project may affect climatic habitat elsewhere in New South Wales over the long term. The project may result in better performance of the M5 Motorway corridor, reducing stop-start conditions, which may decrease emissions (refer to Chapter 22 (Greenhouse Gas) for further detail).

[1] It is now understood that *Phytophthora cinnamomi* is not a fungus. This was the name of the key threatening process when it was registered under the EPBC Act.

21.3.2 Operation

Permanent changes in hydrology

Changes to hydrology during operation of the project may result from:

- The capture, treatment and discharge of groundwater and deluge water from the main alignment tunnels and the New M5 on and off ramps
- Operational drainage infrastructure for new sections of roadway to maintain the quality of surface water runoff
- Extensions to existing and construction of new watercourse crossings.

Discharge of tunnel groundwater and deluge water

Groundwater inflows would be captured in tunnel drainage infrastructure during operation of the project. Collected groundwater from the main alignment tunnels would be treated at the operational water treatment plant within the Arncliffe motorway operations complex (MOC3). The capture and treatment of groundwater during operation of the project is described in **Chapter 16** (Soils and water quality) and **Chapter 19** (Groundwater).

Groundwater collected during tunnelling would be treated prior to discharge to local watercourses to meet the requirements of the environment protection licence to be issued for the project. Reference criteria for each watercourse were developed to provide guidance on the quality of water that must be produced by groundwater treatment plants to make that water suitable for discharge into the receiving environment. These criteria were defined based on available data and in accordance with the relevant ANZECC criteria. (ANZECC & ARMCANZ, 2000).The discharge water quality level would be determined in consultation with the NSW Environment Protection Authority during the detailed design phase of the project. Additional detail relating to the water treatment plant and discharges, including potential geomorphologic impacts is provided in **Chapter 16** (Soils and water quality).

The Cooks River flows for around 23 kilometres between Bankstown and Botany Bay. It is semi-tidal due to its connection with Botany Bay at Mascot and the tidal limit is about 7.5 kilometres upstream of the biodiversity study area near Croydon Park. The Cooks River is highly modified and largely channelised, with poor surface water quality. The Cooks River catchment is regarded as one of the most polluted urban river catchments in Australia and has been historically affected by stormwater pollution, industrial and domestic wastewater discharge, rubbish dumping and anthropogenic modification.

No threatened aquatic fauna or flora listed under the TSC Act, FM Act or EPBC Act have been identified as likely to occur within the Cooks River. Given the degraded nature of the watercourse and the limited fish habitat present, the project is unlikely to have a significant impact on aquatic ecology as a result of the discharge of tunnel groundwater and deluge water.

The discharge of treated groundwater into the Cooks River would result in a relatively insignificant increase in water flow volumes and would not impact the geomorphology or water quality of the river.

Operational stormwater impacts

Increases in impervious surfaces (such as motorway operations complexes, and new and upgraded surface roads) would result in increased runoff during operation of the project. Runoff has the potential to alter the flow regimes of local watercourses and increase the risk of soil erosion, sedimentation of watercourses and degradation of water quality. Catchments impacted by surface infrastructure would include:

- The Wolli Creek catchment from runoff at the Kingsgrove motorway operations complex (MOC1) and Bexley Road South motorway operations complex (MOC2) and the western surface works
- The Cooks River catchment from runoff at the Arncliffe motorway operations complex (MOC3)
- The Eastern Channel catchment from runoff associated with the local road upgrades
- The Alexandra Canal catchment from runoff at the St Peters motorway operations complex (MOC4), Burrows Road motorway operations complex (MOC5) and from the local road upgrades.

To accommodate the increases in impervious surfaces, existing drainage infrastructure would be augmented and additional infrastructure would be constructed. Modifications to drainage infrastructure and water treatment facilities are described in **Section 5.8.3** and **Chapter 18** (Flooding and drainage). Modifications to drainage infrastructure and water treatment facilities would mitigate the potential impacts of increased surface water runoff. It is unlikely that increased runoff from the operation of the project would have a significant impact on the aquatic ecological environment during operation.

Watercourse crossings

Around the western surface works, two existing culverts at Kooemba Road would be extended by around 30 metres and a new box culvert would be constructed at Kirrang Street. The extension of existing culverts would be generally consistent with the design and function of existing infrastructure and would not significantly alter the ability of the culverts to be accessed and traversed by native fauna. The new culvert under Kirrang Street is intended to provide drainage relief and is not intended to provide or replace any existing fish passage.

As part of the local road upgrades, the existing bridge along Euston Road over the Munni Street stormwater channel would be widened as part of the local road upgrades. The extension of the bridge would be generally consistent with the design and function of existing infrastructure and would not significantly alter the ability of the stormwater channel to be accessed and traversed by native fauna.

Three bridges would be constructed over Alexandra Canal; the Gardeners Road bridge, Campbell Road bridge and the Campbell Road bridge pedestrian and cyclist bridge. No bridges over Alexandra Canal would require piers, therefore the potential for scour within this watercourse is unlikely.

Construction of new bridges and culverts would be located within substantially modified watercourses and are not expected to change flow patterns. Additional detail is provided in **Chapter 18** (Flooding and drainage).

Injury and mortality

The local road upgrades (refer to **Section 5.7** for additional detail) would widen the carriageways of several roads around St Peters, which would increase the likelihood of vehicle strike during operation as fauna would need to travel further to cross these roads. The presence of noise barriers along the M5 East Motorway along the western surface works would limit the number and quality of potential fauna crossings.

Although operation of the project may potentially result in some injury or mortality of fauna species, the project is unlikely to cause a significant increase in fauna incidents relative to the existing situation as the majority of the project is located underground. Environmental management measures to minimise the injury or mortality of fauna species during operation of the project are provided in **Section 21.4**.

Noise and vibration

Changes to the noise and vibration environment within the biodiversity study area could indirectly impact native fauna, including threatened species. Threatened species most at risk from changes to noise and vibration impacts include nocturnal and diurnal birds and bats.

Operational noise, which would be continuous, is unlikely to significantly impact on threatened fauna species given that the majority of the project would be located underground. Potential increased traffic due to the surface road widening is unlikely to significantly alter the local acoustic environment, which is already substantially characterised by road traffic noise.

Lighting

Changes to the availability of light as a result of vegetation clearance may impact flora and fauna species. Altering the light regimes could affect plant growth and changes to micro-climates as a result of overshadowing or increased light could increase the likelihood of weed invasion.

Changes to light availability within areas of vegetation to be retained are expected to be minor and would not significantly impact flora within the biodiversity study area.

Permanent facilities would be constructed adjacent to the RTA Ponds within the Arncliffe motorway operations complex (MOC3). The visual impact assessment undertaken as part of the project identified that there would be overshadowing of the RTA Ponds at 9.00 am during the winter solstice (the shortest day and longest night of the year, during winter) from the Arncliffe motorway operations complex (MOC3); however, all overshadowing would disappear by midday. The visual impact assessment also indicated that there would be no shading of the RTA ponds during the summer solstice (the longest day and shortest night of the year).

As basking habitat would be available during the critical period of breeding (January and February) for this population, overshadowing from the Arncliffe motorway operations complex (MOC3) would not significantly impact on the Arncliffe Key Population or the quality of the breeding habitat of the RTA Ponds.

Only minimal lighting would be provided at the Arncliffe motorway operations complex (MOC3) at night during operation for safety and security purposes. This lighting would be directed towards buildings and car parking areas at the motorway operations complex and would be screened with maturing landscape vegetation, where possible. Lighting of the Arncliffe motorway operations complex (MOC3) during operation at night is not expected to significantly impact on the Arncliffe Key Population or RTA Ponds.

Mitigation measures to manage the light spill and the introduction of weeds are provided in **Section 14.4** (Visual impacts and urban design) and **Section 21.4**.

21.4 Environmental management measures

Potential impacts to biodiversity have been taken into account as part of the design development of the project. The project design has avoided impacts to high quality vegetation and a vegetated riparian corridor in the Wolli Creek Valley, a small area of Sydney Turpentine Ironbark Forest in Kingsgrove, a Grey-headed Flying Fox camp and habitat at Turella and areas of native coastal reedland and mangroves at the confluence of Wolli Creek and the Cooks River.

Despite avoiding impacts on biodiversity where feasible to do so, there will nonetheless be some impacts to biodiversity as a result of construction and operation of the project. These unavoidable impacts would include impacts to threatened ecological communities and threatened species. Environmental management measures to minimise and manage impacts to biodiversity during construction and operation are provided in **Table 21-12**. Mitigation and management measures relevant to biodiversity are also included in other sections of this environmental impact statement as follows:

- Noise and vibration management measures in **Section 12.4** (Noise and vibration)
- Lighting mitigation in **Section 14.4** (Visual impacts and urban design)
- Erosion and sediment control measures in **Section 16.4** (Soils and water quality).

Biodiversity offset proposed in relation to residual impacts to threatened ecological communities and threatened fauna, in accordance with the biodiversity offsets policy and FBA are described in **Section 21.4.1**.

Table 21-12 Environmental management measures – biodiversity

Impact	No.	Environmental management measure	Timing
Construction			
General construction impacts	B01	A Flora and Fauna Management Plan will be developed before construction. The Plan will identify potential impacts to biodiversity and describe mitigation measures and environmental controls to be implemented during construction, including measures to protect biodiversity features which will be retained.	Construction
Vegetation clearance	B02	The removal of established vegetation will be minimised, where possible.	Construction
	B03	Pre-clearance activities will be carried out in accordance with Guide 1 Pre-clearing process of Roads and Maritime's Biodiversity Guidelines (RTA, 2011). Pre-clearing surveys will be undertaken by a suitably qualified ecologist to identify the presence of: • Hollow-bearing trees • Threatened flora and fauna.	Construction
	B04	Trees will be removed in accordance with Guide 4 – Clearing of Vegetation and Removal of Bushrock of Roads	Construction

Impact	No.	Environmental management measure	Timing
		and Maritime's Biodiversity Guidelines (RTA, 2011).	
	B05	Where vegetation clearance is required, exclusion zones will be established in accordance with Guide 2 Exclusion Zones of Roads and Maritime's Biodiversity Guidelines (RTA, 2011).	Construction
	B06	Where reasonable and feasible, mature and hollow-bearing trees will be retained. Where this is not reasonable and feasible, nest boxes will be installed to mitigate the impacts of removing hollow bearing trees in accordance with Table 8.1 of Guide 8 – Nest boxes of Roads and Maritime's Biodiversity Guidelines (RTA, 2011) at least one month prior to the commencement of construction	Construction
	B07	Locally indigenous species will be included as part of landscaping and rehabilitation works to promote native fauna habitat.	Construction
Impacts to native flora and fauna	B08	Should unexpected threatened flora or fauna be located at any time during construction, relevant works will cease in the area to prevent further harm to the individual. Should this occur, a suitably qualified ecologist will be engaged to advise on appropriate mitigation and management measures.	Construction
	B09	Any fauna handling would be undertaken by an appropriately licenced ecologist in accordance with Guide 9 – Fauna handling of Roads and Maritime's biodiversity guidelines (RTA, 2011).	Construction
Impacts to the Green and Golden Bell Frog	B10	The Green and Golden Bell Frog Plan of Management Plan will be finalised and implemented to minimise and manage impacts to the Arncliffe key population. The Green and Golden Bell Frog Plan of Management Plan would be approved by the Commonwealth Department of the Environment and OEH, and would include: • Management measures to be implemented at the Arnciffe construction compound (C7) and RTA Ponds to minimise and manage impacts to the Green and Golden Bell Frog habitat and key population during construction. • Management measures relating to the enhancement of existing habitat at the Marsh Street Wetland • Supplementary management measures for consideration to mitigate and minimise impacts to the Green and Golden Bell Frog. would include	Construction
Impacts to hydrology and aquatic biodiversity	B11	Measures to mitigate potential water quality impacts during construction are outlined in **Section 16.4** and **Section 18.4**.	Construction
	B12	Works within or near aquatic habitats and riparian areas will be managed in accordance with Roads and Maritime's Guide 10 – Aquatic habitats and riparian zones.	Construction
	B13	Works within aquatic habitats or riparian zones would be undertaken to limit impacts on aquatic flora and fauna, and their habitats, and impacts on riparian areas. This would be undertaken in accordance with Guide 10 of the Biodiversity Guidelines.	Construction
	B14	Where possible, construction activities would minimise disturbance to waterways and riparian land	Construction
	B15	Stockpiles would be located outside riparian corridors.	Construction
Spread of weeds	B16	Weeds within the construction footprint will be actively managed prior to the clearance of vegetation. All weed material cleared from within the construction footprint of the	Construction

Impact	No.	Environmental management measure	Timing
		project will be disposed of at a facility licensed to receive green waste.	
	B17	Vegetation within the road reserve adjacent to areas to be cleared will be managed in accordance with Guide 6 – Weed Management and Guide 10 – Aquatic Habitats and Riparian Zones of Roads and Maritime's Biodiversity Guidelines (RTA, 2011) to reduce the introduction and spread of noxious weed species.	Construction
	B18	Landscaping and revegetation works will be undertaken using weed-free topsoil in accordance with the project's urban design concept plan.	Construction
Introduction and spread of pathogens	B19	A hygiene protocol will be implemented as part of the Construction Environmental Management Plan(s) for the project to prevent the spread and exacerbation of the Chytrid Fungus in accordance with Guide 7 – Pathogen Management of Roads and Maritime's Biodiversity Guidelines (RTA, 2011).	Construction
	B20	A risk assessment process will be used for each construction compound to determine the need to clean machinery prior to entering	Construction
	B21	Pathogens will be identified as part of pre-clearing inspections. In the event that pathogens are identified within the construction footprint, appropriate mitigation measures will be identified by an ecologist and implemented as part of the Construction Environmental Management Plan(s) in accordance with Guide 7 – Pathogen Management of Roads and Maritime's Biodiversity Guidelines (RTA, 2011).	Construction
Operation			
General	OpB01	A management plan will be developed and implemented to identify and mitigate potential ongoing impacts to biodiversity, including procedures for: • Management of weeds • Management, maintenance and rehabilitation of riparian land disturbed by the project and riparian areas associated with the discharge of treated water • Maintenance of nest boxes	Operation

21.4.1 Biodiversity offsets

Mitigation and management measures would be implemented to minimise impacts to biodiversity where feasible, as described in **Table 21-12** above. However, residual impacts to threatened ecological communities and threatened fauna as a result of construction and operation of the project would require offsetting.

The required offsets for the project have been determined using the FBA methodology in accordance with the biodiversity offsets policy (OEH, 2014c). The offsets have been calculated based on a worst case disturbance footprint and a worst case biodiversity assessment which assumes that all vegetation within the construction footprint would require clearance (refer to **Figure 6-1** to **Figure 6-4** for the construction footprint). The construction footprint may be refined during detailed design. In this instance, biodiversity offset calculations and requirements would be revised to reflect the revised footprint.

Biodiversity offset calculations identified that 261 biodiversity credits would be required for impacts to threatened ecological communities and impacts to the Green and Golden Bell Frog (*Litoria aurea*). As described in **Section 21.2.3**, the FBA credit calculator identified 17 threatened fauna species as ecosystem credit species, ie species which can be reliably predicted as potentially occurring at a location based on the landscape-scale biodiversity features and plant community types present. Although these species are considered unlikely to occur (refer to **Section 21.3.1**), any offsets relating to native vegetation communities present in the biodiversity study area would satisfactorily account for potential impacts to these species.

A summary of the offset credits for the project is provided in **Table 21-13**. The full details of the biodiversity offset methodology and calculations are provided in the Biodiversity Offset Strategy (**Appendix T**).

Table 21-13 Summary of biodiversity offset credits

Threatened ecological communities			
Plant community type	**Mapped vegetation community**	**Area impacted (ha)**	**Number of ecosystem credits required**
Broad-leaved Ironbark Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion (PCT 725)	Cook River Castlereagh Ironbark Forest	1.40	31
Paperbark swamp forest of the coastal lowlands of the NSW North Coast Bioregion and Sydney Basin Bioregion (PCT 1064)	Swamp Sclerophyll Forest on Coastal Floodplains of the NSW North Coast, Sydney Basin and South East Corner bioregions	1.82	27
Total		3.22	58
Threatened fauna			
Species		**Area impacted (ha)**	**Number of species credits required**
Green and Golden Bell Frog (Litoria aurea)		7.82	203
Total			203
Total credits (ecosystem credits and species credits)			**261**

Biodiversity offset investigations

In accordance with the FBA, there are two options, or a combination of the two for fulfilling offset requirements that are relevant to road projects:

- Securing like for like offsets to retire credits
- Contributing to supplementary measures.

The development of the Biodiversity Offset Strategy is ongoing, however works undertaken to date suggest that the Biodiversity Offset Strategy is likely to include both the retirement of relevant ecosystem and species credits through BioBanking agreements, and where credits cannot be obtained, the provision of supplementary measures. Supplementary measures would not be sought beyond ten per cent of the total cost for matters of national environmental significance. Like for like credits and measures would be sought for matters of national environmental significance.

Securing offset credits

Offset credits are generated when a landholder agrees to enter into a BioBanking agreement, which:

- Provides annual in perpetuity payments to landholders to actively manage land for its habitat values in accordance with a management plan
- Is supported by a robust monitoring and compliance framework administered by the Office of Environment and Heritage
- Is attached to property title and obligations to manage the land (and receive annual payments) transfers to new owners if the property is sold.

The process to identify if any credits were available for all the required offsets was followed and is summarised in **Table 21-14**.

Table 21-14 Process to identify biodiversity credits for the project

Step	Activity
Identify available biodiversity credits	Determine if matching credits for biodiversity values to be offset have been issued and are available in the Office of Environment and Heritage biodiversity credits register
Identify potential landholders with suitable credits	Determine if there is a landholder on the Office of Environment and Heritage BioBanking expression of interest register that have matching biodiversity credits that have not been issued.
Place a 'credits wanted' request	A 'credits wanted' request is placed on the Office of Environment and Heritage credits wanted register for the required number and type of credits.
Seek candidate sites	Undertake a desktop assessment of vegetation types, tenure and patch size to shortlist potential sites and landholders
Test landholder interest	Use the shortlist to contact landholders to determine interest in entering into a BioBanking agreement and selling credits to Roads and Maritime
Investigate options for supplementary measures and estimate costs	Where suitable credits cannot be identified, estimate the indicative cost of supplementary measures using similar credits already sold as part of the BioBanking scheme as a surrogate

Efforts to secure credits

The securing of biodiversity offsets for the project has been considered in accordance with the process described in **Table 21-14**. A summary of the steps undertaken to identify and secure offsets for the threatened ecological communities and threatened fauna identified in **Table 21-13** is provided in **Table 21-15** below. As noted earlier, the development of the Biodiversity Offset Strategy is ongoing, and efforts to secure credits will continue throughout the detailed design of the project.

Table 21-15 Steps undertaken to identify and secure offsets for the project

Item requiring offsets	Reasonable steps to secure like-for-like credits	Supplementary measures
Cooks River Castlereagh Ironbark Forest	• A search of the biodiversity credits register was searched and no credits were available for purchase. • No landholders with suitable credits were identified in the Office of Environment and Heritageexpressions of interest register. • A request for credits was registered on the Office of Environment and Heritage BioBanking public registers web page on 16 December 2014. • Six months following the request for credits, there was one approach by a landholder with available ecosystem credits. The landholder was willing to consider a Biobanking agreement on land containing Broad-leaved Ironbark *Melaleuca decora* shrubby open forest. Discussions with this Landholder are ongoing. • A number of additional candidate sites were identified during a desktop assessment.	The likely cost of providing offsets for the residual unavoidable impacts to Cooks River Castlereagh Ironbark Forest would be approximately $465,000 for 31 credits at $15,000 per credit. All efforts will be made to seek 100 per cent of offsets via purchase and retirement of biodiversity credits. If there is a shortfall, ten per cent of the offset obligation amounting to $46,500 would be invested in supplementary measures, in consultation with the Commonwealth and the State regulatory agencies. Supplementary measures may include: • Updates to mapping of Cooks River Castlereagh Ironbark Forest to identify its current extent and condition. • Development and promotion of a landscape-scale response to African Olive invasion on public and private lands within the Cumberland Plain, in consultation with Office of Environment and Heritage and local councils • Provision of funds for research
Paperbark swamp forest	• A search of the biodiversity credits register was searched and no credits were available for purchase. • No landholders with suitable credits were identified in the Office of Environment and Heritage expressions of interest register. • A request for credits was registered on the Office of Environment and Heritage BioBanking public registers web page on 11 August 2015. • When a proponent is unable to locate a 'like for like' offset after taking reasonable steps, there is an option to apply the variation rules. This option is available for the Paperbark swamp forest as it is not listed as a threatened ecological community under the EPBC Act. • A search of the credits issued register was performed to determine if any credits of the alternate PCTs were readily available. While some credits have been issued for two of these PCTs, none were available for purchase and retirement. • Searches for potentially interested landholders are continuing.	The likely cost of providing offsets for the residual unavoidable impacts to Paperbark Swamp Forest would be approximately $405,000 for 27 credits at $15,000 per credit. All efforts will be made to seek 100 per cent of offsets via purchase and retirement of biodiversity credits. If there is a shortfall, ten per cent of the offset obligation amounting to $46,500 would be invested in supplementary measures, in consultation with the Commonwealth and the State regulatory agencies. Supplementary measures may include: • Undertake weed control for Bitou Bush and Boneseed at priority sites in accordance with the approved Threat Abatement Plan. • Determine location, species composition and threats to remaining remnants of Paperbark Swamp Forest to assist with prioritising restoration works. • Collect seed for NSW Seedbank and develop a collection program in collaboration with Botanic Gardens Trust.

Item requiring offsets	Reasonable steps to secure like-for-like credits	Supplementary measures
Green and Golden Bell Frog (*Litoria aurea*)	A credits wanted request for this vegetation community was placed on 16 December 2014 Two expressions of interest were identified on the landowner with two existing expressions of interest on the OEH register seeking to establish a BioBanking agreement with Green and Golden Bell Frog credits. The two expressions were from the same landowner. Of the two expressions of interest, one has not confirmed that Green and Golden Bell Frogs are present. The other expression of interest has 175 available credits. Roads and Maritime is in discussions with all interested parties. In October 2015, a third party with potential Green and Golden Bell Frog credits responded to the renewed credits wanted request. This party is in the process of submitting an application for a Biobank agreement at a site in the Macleay-Hastings IBRA sub-region.	Roads and Maritime owns land at Marsh Street directly adjacent to the existing M5 East Motorway and in proximity to the existing RTA Ponds on the Kogarah Golf course. Opportunities to create new Green and Golden Bell Frog habitat at this location is being pursued as part of the management plan for this species. The Marsh Street land provides a potential opportunity to both expand and secure the Arncliffe Green and Golden Bell Frog population and is the first priority for supplementary measures. In addition, a BioBanking agreement (supported by the annual payments from the BioBanking Trust Fund) could provide the basis for the secure long term funding for the management of any recreated habitat. Active management is essential to the ongoing persistence of this species at Arncliffe due to the ongoing threats of plague minnow, weed infestation and disease.

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22 Greenhouse gas

This chapter outlines the legislative and policy framework for the control of greenhouse gas emissions. It provides an assessment of the contributions of the project to climate change, due to the release of greenhouse gas emissions during the construction and operation stages of the project and provides recommended mitigation measures to reduce greenhouse gas emissions. There are no requirements of the Secretary of the Department of Planning and Environment that are relevant for this environmental assessment.

Greenhouse gases are gases in the atmosphere that absorb and re-radiate heat from the sun, thereby trapping heat in the lower atmosphere and influencing global temperatures. Emissions of greenhouse gases into the atmosphere are caused by both natural processes (eg forest fires) and human activities (eg burning of fossil fuels to generate electricity).

Since the industrial revolution there has been an increase in the amount of greenhouse gases emitted from human activities which increased the global concentration of greenhouse gas' in the atmosphere and has led to an increase in the Earth's average surface temperature (IPCC 2013). Further discussion on climate change, including the identification and assessment of climate change risks to the project, is provided in **Chapter 25** (Climate change risk and adaptation).

22.1 Assessment methodology

The methodology for this greenhouse gas assessment has been based on relevant greenhouse gas reporting legislation and international reporting guidelines, including:

- *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* (World Council for Sustainable Business Development and World Resources Institute 2005)
- *National Greenhouse and Energy Reporting Act 2007* (Commonwealth)
- AS ISO 14064.1:2006 *Greenhouse Gas Part 1: Specification with guidance at the organisational level for quantification and reporting of greenhouse gas emissions and removals*
- The current Australian National Greenhouse Accounts: *National Greenhouse Accounts Factors* (NGA Factors) (Department of the Environment, 2015a)
- *Greenhouse Gas Assessment Workbook for Road Projects* (the TAGG Workbook) (Transport Authorities Greenhouse Group (TAGG) 2013).

The TAGG Workbook provides a consistent methodology for estimating the greenhouse gas emissions from activities that may contribute significantly to the overall emissions associated with the construction, operation and maintenance of road projects. The TAGG workbook has been adopted for the project.

22.1.1 Greenhouse gas assessment methodology

To calculate the potential greenhouse gas emissions associated with the project, the following steps were followed:

- Define the assessment boundary and identify potential sources of greenhouse gas emissions associated with the project
- Determine the quantity of each emission source (fuel and electricity consumed, vegetation cleared, construction materials used and waste produced)
- Quantify the potential greenhouse gas emissions associated with each greenhouse gas source using equations and emission factors specified in the NGA Factors and the TAGG Workbook.

Appendix U provides a detailed description of the greenhouse gas assessment methodology, including the emissions factors used for emission sources, and detailed calculation methods used to estimate the greenhouse gas emissions from fuel combustion, electricity consumption, vegetation clearing, materials use and the decomposition of waste.

Greenhouse gas emissions are reported in this assessment as tonnes of carbon dioxide equivalent (t CO_2-e). While there are numerous greenhouse gases, this standard metric takes into account of the different global warming potentials of different greenhouse gases, and expresses the cumulative effect in a common, universal unit of measurement. This allows for all greenhouse gases associated with project to be combined into one emissions calculation.

22.1.2 Greenhouse gas assessment boundary

The assessment boundary defines the scope of greenhouse gas emissions and the activities to be included in the assessment. The assessment boundary includes all emissions sources that can be influenced by decisions made by designers, constructors, managers and / or operators of the project and accounts for emissions anticipated to be generated during the construction and operation stages of the project. Although approval is not being sought for ongoing motorway maintenance activities likely to be undertaken during operation of the project, major maintenance activities have been included in the greenhouse gas assessment boundary for completeness. The guiding principles for greenhouse gas accounting and reporting, including an assessment of materiality, are provided in **Appendix U**.

Emissions sources are categorised into the following three 'scopes':

- **Scope 1** – direct emissions: greenhouse gas emissions generated by sources owned or controlled by the project. For example emissions generated by the use of diesel fuel by project-owned construction plant, equipment and/ or vehicle.
- **Scope 2** – indirect emissions: greenhouse gas emissions from the consumption of purchased electricity in project-owned or controlled equipment or operations. These greenhouse gas emissions are generated outside of the project's boundaries, for example the use of electricity purchased from the grid
- **Scope 3** – indirect upstream / downstream emissions: greenhouse gas emissions generated in the wider economy due to third party supply chains and road users as a consequence of activity within the boundary of the project, for example greenhouse gas emissions associated with the offsite mining, and production and transport of materials used in construction.

Table 22-1 summarises the emission sources and activities considered within the project's greenhouse gas assessment boundary for construction and operation, according to scope.

Table 22-1 Emission sources and activities included in the assessment

Emission source category	Emission source	Emission scope		
		Scope 1	Scope 2	Scope3
Construction				
Fuel use	Mobile construction equipment	✓		✓
	Site vehicles	✓		✓
	Delivery of plant, equipment and construction materials			✓
	Spoil and waste removal			✓
Electricity consumption	Electricity used to power construction plant and site offices		✓	✓
Vegetation removal	Clearance of vegetation as a result of the project	✓		
Materials	Embodied energy of construction materials			✓
Waste	Decomposition of waste generated during project construction			✓
Operation and maintenance				
Electricity consumption	Electricity used to power tunnel lighting and ventilation, project offices and other electrical systems		✓	✓
Fuel use	Operational road use by light and heavy vehicles			✓
	Mobile construction equipment used for maintenance activities	✓		✓
Materials	Materials used for maintenance activities			✓

Some emissions sources are categorised into two scopes; for example, the use of fuel by mobile construction equipment onsite would generate Scope 1 (direct) emissions from the combustion of fuel as well as Scope 3 (indirect upstream) emissions associated with the extraction, production and transport of the purchased fuel. Consumption of electricity purchased from the grid would generate Scope 2 indirect emissions from the use of electricity to power project equipment and facilities, as well as Scope 3 (indirect upstream) emissions associated with transmission and distribution losses within the electricity network.

The project does not include ongoing motorway maintenance activities during operation as these would be subject to separate assessment and approval. However, in line with the guiding principle of 'completeness' for greenhouse gas reporting and to provide an assessment of the 'whole of life' of the project, an estimate of emissions from major maintenance activities has been included in the greenhouse gas assessment boundary.

The project includes the closure of the Alexandria Landfill, including landform works to facilitate the construction of the St Peters interchange and upgrade of the existing leachate, and landfill gas management systems. At this stage, options for the ongoing management of landfill gas are still being considered and would be investigated as part of detailed design. A qualitative assessment of landfill gas emissions has been undertaken as part of this greenhouse gas assessment to identify the potential sources of emissions associated with the use of the Alexandria Landfill site and the ongoing management of landfill gas post closure.

22.2 Existing environment

The Kyoto Protocol to the *United Nations Framework Convention on Climate Change* (the Kyoto Protocol) (UNFCCC 1998) was signed in 1997 and Australia ratified the protocol in December 2007. The Kyoto Protocol serves to give effect to the UNFCCC's objective of reducing global greenhouse gas emissions by setting reduction targets and reporting requirements for certain ratifying countries. These targets are set using the relevant ratifying countries' 1990 baseline emissions. Australia committed to a target of 108 per cent of its 1990 greenhouse gas emission levels by the end of 2012. In December 2012, Australia signed the Doha Amendment to the Kyoto Protocol (UNFCCC 2012), agreeing to a second commitment period, from 1 January 2013 until 2020.

The Australian Government recently announced it is committed to a target of reducing greenhouse gas emissions by 26 to 28 per cent below 2005 levels by 2030, building on its previous target of five per cent below 2000 emission levels by 2020, irrespective of what other countries do. The Government has submitted this new target to the UNFCCC as its intended nationally determined contribution to the proposed new agreement to be negotiated at United Nations Climate Change Summit held in Paris in December 2015.

22.2.1 Policy Setting

The Emissions Reduction Fund, as part of the Direct Action Plan, aims to reduce Australia's greenhouse gas emissions by creating positive incentives to adopt better technologies and practices to reduce greenhouse gas emissions.

In August 2013, the NSW Office of Environment and Heritage (OEH) released the NSW Energy Efficiency Action Plan (OEH, 2013a), which provides a strategic management approach to improving energy efficiency, with a target for annual energy savings of 16,000 gigawatt-hours by 2020.

The NSW Government Resource Efficiency Policy (OEH, 2014a) 'aims to drive resource efficiency by NSW Government agencies in three main areas – energy, water and waste – and also reduce harmful air emissions from government operations.'

The NSW Long Term Transport Master Plan (Transport for NSW, 2012a) (Transport Master Plan) includes an objective to 'Improve sustainability – by maintaining and optimizing the use of the transport network, easing congestion, growing the proportion of travel by sustainable modes such as public transport, walking and cycling, and becoming more energy efficient.' An action of the Transport Master Plan is also to 'continue to explore opportunities to reduce vehicle emissions, improve air quality and lower greenhouse gas emissions from the NSW transport sector.'

In addition the Environment and Sustainability Policy Framework (Transport for NSW, 2013f) includes an energy management objective 'To use Transport's energy sources more efficiently and reduce its greenhouse gas emissions'.

22.2.2 Greenhouse gas emissions reporting

The Clean Energy Regulator and the Department of the Environment are responsible for administering the Australian Government's greenhouse gas emission policies, regulations and initiatives. The National Greenhouse and Energy Reporting (NGER) Scheme is a national framework for obligated corporations to report on greenhouse gas emissions, energy use and energy production. The NGER Scheme operates under the *National Greenhouse and Energy Reporting Act 2007* (NGER Act).

The most recently published Australian National Greenhouse Accounts estimate annual Australian greenhouse gas emissions for the year to March 2015 to be 533.9 Mt CO_2-e as reported under the Kyoto Protocol (Department of the Environment, 2015b). For 2013, annual NSW greenhouse gas emissions totalled 146.7 Mt CO_2-e (Department of the Environment, 2015c).

The transport sector contributes about 17 per cent of Australia's total greenhouse gas emissions (Department of the Environment, 2015b). Around 90 per cent of these emissions are attributed to the combustion of fuel for road transport (Climate Change Authority 2014; Maddocks et al. 2010). Reducing the contribution of emissions from road transport would have a significant impact on reducing emissions from the transport sector, and for Australia's overall emissions profile.

22.3 Assessment of potential impacts

The data used to estimate the greenhouse gas emissions associated with the project is provided in **Appendix U**. Assumptions have been made, where necessary, to provide a quantitative estimate of emissions.

22.3.1 Construction greenhouse gas emissions

It is estimated that the project would generate about 473,200 t CO_2-e during construction of the project. The breakdown of emissions by scope is shown in **Figure 22-1** and summarised (with numbers rounded to the nearest hundred tonnes) as:

- 83,700 t CO_2-e direct Scope 1 (direct) greenhouse gas emissions
- 109,200 t CO_2-e indirect Scope 2 (indirect) greenhouse gas emissions
- 280,300 t CO_2-e indirect Scope 3 (indirect upstream/downstream) greenhouse gas emissions.

Key emissions sources for construction are shown in **Table 22-2** and **Figure 22-1**. Detailed greenhouse gas emissions results are provided in **Table U-6** of **Appendix U**.

The results demonstrate that the majority of GHG emissions associated with the construction of the project are attributed to indirect Scope 3 emissions (59 per cent). Direct Scope 1 and indirect Scope 2 emissions account for 18 per cent and 23 per cent of total construction emissions respectively.

The embodied energy associated with the offsite mining, production and transport of materials that would be used for the construction of the project contributes the largest proportion of indirect Scope 3 emissions, accounting for 89 per cent (**Figure 22-1**). The use of concrete and, to a lesser extent, asphalt and steel would contribute significantly to the emissions associated with construction materials. The high proportions of emissions associated with these materials are attributed not only to the quantity required for the construction of the project, but also the emissions-intensive processes involved in the extraction and production of these materials.

Figure 22-1 illustrates the breakdown of construction emissions by emission source and scope. The consumption of diesel fuel associated with the operation of mobile construction plant and equipment contributes the largest proportion of Scope 1 emissions (59 per cent), followed by the consumption of fuel associated with heavy vehicle movements for the haulage of construction materials, spoil and waste (28 per cent).

Mitigation and management measures to reduce greenhouse gas emissions for construction of the project are provided in **Section 22.4**.

Table 22-2 Construction greenhouse gas emission results

Emissions source		Greenhouse gas emissions (t CO_2-e)				
		Scope 1	Scope 2	Scope 3	Total	% of total
Fuel use (diesel) – mobile plant and equipment		48,990	-	2,501	**51,492**	10.9%
Fuel use (diesel) – transport of materials and waste to / from site		23,134	-	1,181	**24,315**	5.1%
Fuel use (petrol) – project light vehicles		9,250	-	492	**9,743**	2.0%
Vegetation clearance		2,334	-	-	**2,334**	0.5%
Electricity consumption		-	109,200	15,600	**124,800**	26.4%
Construction materials	Concrete	-	-	174,511	**174,511**	36.9%
	Cement	-	-	3,280	**3,280**	0.7%
	Steel	-	-	51,870	**51,870**	11.0%
	Aggregate	-	-	2,450	**2,450**	0.5%
	Asphalt	-	-	7,830	**7,830**	1.7%
	Copper	-	-	1,030	**1,030**	0.2%
	Plastic	-	-	6,003	**6,003**	1.3%
	Water	-	-	2,100	**2,100**	0.4%
Waste	Construction and demolition waste	-	-	11,400	**11,400**	2.4%
Total		**83,709**	**109,200**	**280,249**	**473,158**	100%
% of total		**18%**	**23%**	**59%**	**100%**	

Note: Results may not add to totals due to rounding of emissions to the nearest whole number.

The results demonstrate that the majority of greenhouse gas emissions associated with the construction of the Operational greenhouse gas emissions

Activities that would generate greenhouse gas emissions during operation and maintenance of the project include:

- Road infrastructure operation: the annual use of electricity for powering tunnel lighting and ventilation, communications systems, control systems, computer and safety systems, the emergency response system, the motorway control centre, electronic signage and other associated electrical systems
- Road infrastructure maintenance: diesel fuel use for the operation of maintenance equipment and the use of materials for maintaining road pavement
- Vehicles using the New M5 during operation: use of the New M5 during operation by future traffic between the St Peters interchange and theM5 East Motorway / King Georges Road interchange, as well as the potential changes to traffic volumes on alternative parallel routes within the study area.

The greenhouse gas assessment results are presented in the following sections. The emission source data, and assumptions used to estimate the greenhouse gas emissions associated with operation and maintenance of the project, are provided in **Appendix U**.

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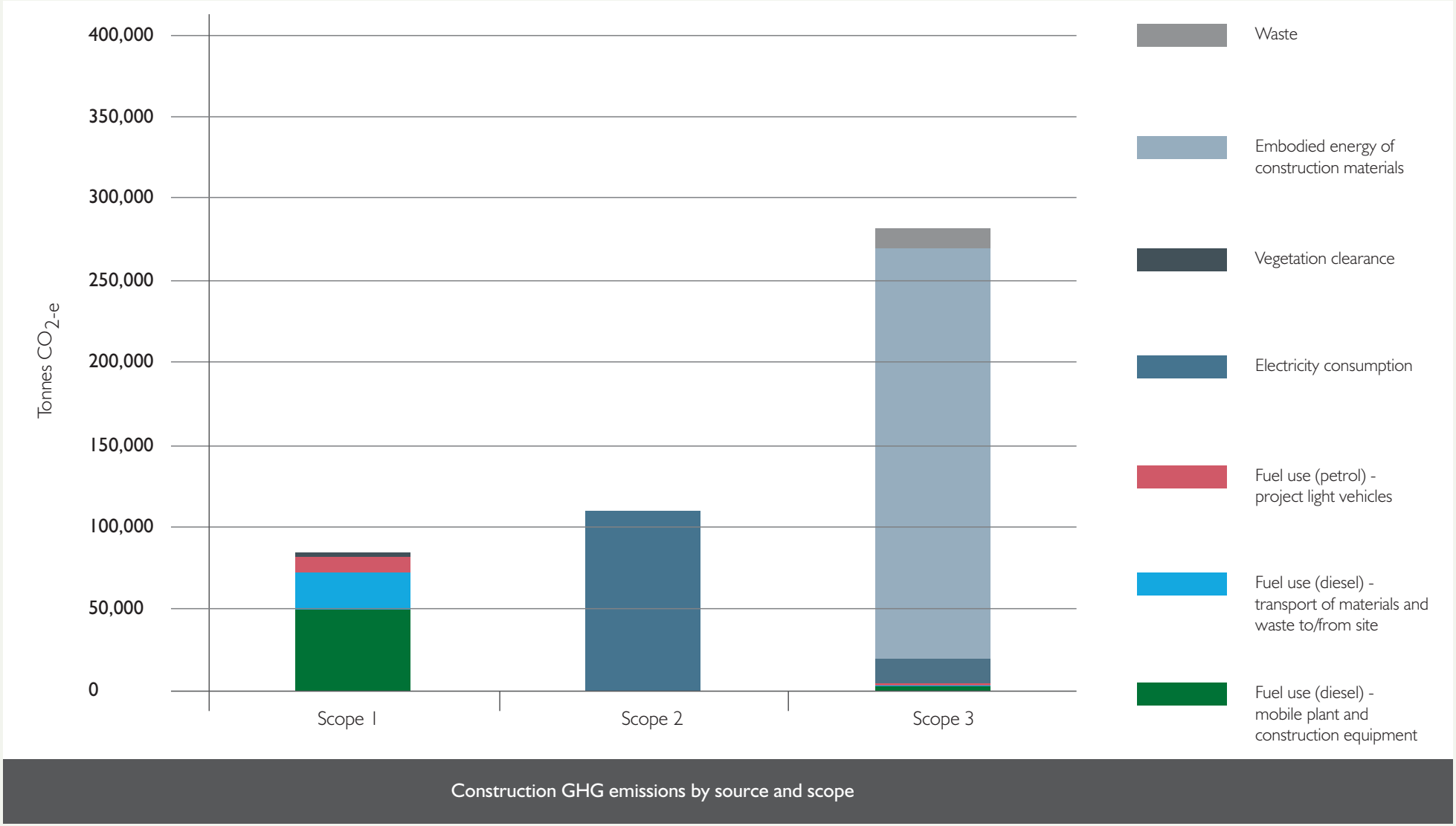


Figure 22-1 Construction GHG Emissions by scope and emission source

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Emissions from road infrastructure operation and maintenance

The estimated greenhouse gas emissions that would be generated by road infrastructure operation and maintenance activities are presented in **Table 22-3**. Annual operational emissions and emissions from major maintenance have been calculated according to the greenhouse gas assessment methodology summarised in **Section 22.1** and the assumptions and inputs provided in **Appendix U**.

Table 22-3 Road infrastructure operation and maintenance greenhouse gas emissions results

Emission source		Greenhouse Gas Emissions			
		Scope 1	Scope 2	Scope 3	Total
Annual operation emissions (t CO_2-e per year)					
Annual electricity consumption of road infrastructure and associated management systems	Lights	-	1914	273	2188
	Jet Fans	-	2995	428	3422
	Vent Fans Kingsgrove	-	3898	557	4454
	Vent Fans Bexley	-	759	108	867
	Local control centre	-	1104	158	1261
	Water treatment plant	-	552	79	631
	Pumps	-	2872	410	3282
	Vent fans Golf Course	-	920	131	1051
	Vent fans St Peters	-	6762	966	7728
	Sub stations & control points	-	1546	221	1766
Total annual emissions from operational electricity consumption		-	23321	3332	26,652
Total maintenance emissions (50 year major maintenance) (t CO_2-e)					
Fuel use (diesel) – mobile plant and equipment		5211	-	396	5606
Maintenance materials	Cement	-	-	944	944
	Steel	-	-	7991	7991
	Aggregate	-	-	106	106
Total maintenance emissions		5211	0	9436	14,647

Note: Results may not add to totals due to rounding of emissions to the nearest whole number.

Annual electricity use of for powering tunnel lighting and ventilation, communications systems, control systems, computer and safety systems, the emergency response system, the motorway control centre, electronic signage and other associated electrical systems would generate around 23,300 t CO_2-e indirect Scope 2 emissions and around 3,300 t CO_2-e indirect Scope 3 emissions per year.

Emission estimates for the use of fuel and materials for the maintenance of the road pavement are based on the replacement of five per cent of the concrete pavement every 50 years, with only the top concrete layer requiring replacement (in accordance with 'typical' maintenance activities given in the TAGG Workbook).

The use of fuel and materials to undertake maintenance activities would result in around 5,200t CO_2-e direct Scope 1 emissions and around 9,400 t CO_2-e indirect Scope 3 emissions. The total quantity of greenhouse gas emissions associated with the above road maintenance activities would be about 14,600 t CO_2-e. Averaged over the 50 year period from the commencement of operation, this would generate around 300 t CO_2-e of maintenance emissions per year.

Emissions from vehicles during operation

Greenhouse gas emissions generated from the operation and maintenance of road infrastructure are relatively small compared to indirect emissions associated with the fuel consumed by vehicles using the road network.

To assess the Scope 3 (indirect downstream) emissions associated with fuel consumed by vehicles using the project, and to evaluate any potential greenhouse gas emissions savings as a result of the project, the following road use scenarios were considered:

- Base case (2021) without the project:
  - The primary 'do minimum' case assumes that the King Georges Road Interchange Upgrade and the M4 Widening projects are complete, but the remainder of the WestConnex program of works and the future Southern extension are not built. It is called 'do minimum' rather than 'do nothing' as it assumes that infrastructure schemes currently incomplete but scheduled for opening prior to the assessment year are operational
- Base case (2021) with the project:
  - As per the primary 'do minimum' scenario with the project, King Georges Road Interchange Upgrade and the M4 Widening complete and open to traffic, but without any other subsequent components of the WestConnex program of works or the future Southern extension (note: the NSW Government has committed to achieving completion of the project by 2019)
- Future case (2031) without the project:
  - A future network including the WestConnex King Georges Road Interchange Upgrade and the M4 Widening and some upgrades to the broader transport network over time to improve capacity and cater for traffic growth but does not include the remainder of the WestConnex program of works or the future Southern extension
- Future case (2031) with the project:
  - As per the 'do minimum' scenario for 2031 with the project, King Georges Road Interchange Upgrade and the M4 Widening complete and open to traffic, but without any other subsequent components of the WestConnex program of works or the future Southern extension (note: the NSW Government has committed to achieving completion of the project by 2019)
- Future (2031) cumulative case:
  - All WestConnex projects complete and the Sydney Gateway and the Southern extension projects also complete and operational (note: the NSW Government has committed to achieving completion of the M4 East project by 2019 and the future M4–M5 Link project by 2023).

Traffic volumes were modelled in line with the traffic and transport assessment provided in **Chapter 9** (Traffic and transport).

Results of the operational road use assessment are provided in **Table 22-4** and **Appendix U**. **Table 22-4** shows the difference between the total greenhouse gas emissions generated in the 'do minimum' (without project) and 'do something' (with project) scenarios for both 2021 and 2031. The final column in **Table 22-4** shows the difference between the total greenhouse gas emissions generated in the 'do minimum' (without project) and the 'cumulative' scenarios for 2031.

Table 22-4 Scope 3 operational road use greenhouse gas emissions results

Route	Greenhouse gas emissions (t CO_2-e)					Difference between scenarios (t CO_2-e)		
	'Do minimum' (without project)		'Do something' (with project)		'Cumulative'	'Do something' – 'Do minimum'		'Cumulative' – 'Do minimum'
	2021	2031	2021	2031	2031	2021	2031	2031
Existing road network (within the study area)	5,924,115	7,885,465	5,938,768	7,532,411	5,812,520	14,653	-353,054	-2,072,945
New M5	NA	NA	94,946	123,867	198,909	94,946	123,867	198,909
Totals	**5,924,115**	**7,885,465**	**6,033,714**	**7,656,278**	**6,011,429**	**109,599**	**-229,187**	**-1,874,036**

Note: negative values indicate a savings in greenhouse gas emissions for the 'do something' (with project) and 'cumulative' scenarios compared with the 'do minimum' (without project) scenario. NA = not applicable (the 'do minimum' scenario does not include the project).

The results for 2021 indicate that the project would generate an additional 109,600 t CO_2-e of Scope 3 emissions from fuel use of light and heavy vehicles using roads within the study area, compared with the '2021 without project' scenario.

Over time, it is anticipated that the road network performance would improve, as traffic patterns become accustomed to changes brought about by the project. The results for 2031 demonstrate the benefits of road tunnel usage in urban areas, where travel along a more direct route at higher average speeds results in fewer greenhouse gas greenhouse gas emissions being generated by road users, as reduced congestion and stop-start driving reduces the fuel used by vehicles.

The assessment results indicate that the project would reduce annual greenhouse gas emissions by around 229,200 t CO_2-e the future case (2031) with the project scenario and around 1,874,000 t CO_2-e in 2031 for the 'cumulative' scenario, within the study area assessed. The predicted reduction in greenhouse gas emissions as a result of the project would be due to an improvement in vehicle fuel efficiency for most links within the study area as well as the operational efficiency of the project tunnels.

The magnitude of greenhouse gas emissions savings for the future 'cumulative' scenario is likely to be attributed, not only to an increase in average speeds, but to a reduction in the number of vehicles utilising roads within the study area as alternate routes become available through the completion of subsequent WestConnex projects and projects and the future Southern extension. This conclusion is consistent with the future forecast traffic performance of the study area as identified in Technical Working Paper: Traffic and transport (**Appendix G**).

Forecast changes in daily road-based freight, heavy vehicle movements and general traffic movements, show large daily volumes forecast for the M4 East, the future M4-M5 Link and the future Sydney Gateway to Sydney Airport. Reductions are forecast for the existing M5 East Motorway, King Georges Road between the M4 East and the M5 East Motorway, Southern Cross Drive, Princes Highway, Parramatta Road and the City West Link, as well as other regional roads, compared to the 2031 'with project' scenario, i.e. just the New M5. The shift of vehicles to the surrounding road network is less under the 'full WestConnex and southern extension' scenario than in the 'with project' scenario, i.e. just the New M5, as drivers realise the benefits of the full WestConnex network.

Vehicle fuel efficiency is anticipated to improve as part of the project based on:

- Increased average speeds on key parallel routes within the study area due to reduced congestion
- Increased average speeds as a result of the operational efficiency of the New M5 tunnels, which would minimise the number of intersections and the frequency of stopping
- Reduced length of travel between the St Peters interchange and the M5 East Motorway / King Georges Road interchange.

Mitigation and management measures, including efficiencies incorporated into the project design to reduce energy and resource requirements, and therefore greenhouse gas emissions, are provided in **Section 22.4**.

Combined greenhouse gas emissions

The additional greenhouse gas emissions of around 109,600 t CO_2-e generated by the project in the 'base case (2021) with project' scenario for 2021 would represent around 0.02 per cent of the Australian national inventory for the year ending March 2015, and 0.07 per cent of the NSW inventory for 2013, as discussed in **Section 22.2**.

The greenhouse gas emissions saving of 229,200 t CO_2-e in the year 2031 under the future case (2031) with project scenario would represent around 0.04 per cent of the Australian National inventory for 2015, and 0.16 per cent of the NSW inventory for 2013.

Figure 22-2 shows the combined emissions profile for the project, from the completion of construction in 2019 to the operational road use in 2031. **Figure 22-2** demonstrates that emissions estimated to be generated during construction and the annual emissions from the operation and maintenance of road infrastructure would be offset against emissions savings as a result of improved road performance. Emissions were not able to be extrapolated beyond the operational traffic impact footprint for the project, which was assessed up to 2031. However, it is expected that the savings in emissions from improved road performance would reduce over time as traffic volumes increase.

As discussed, the magnitude of greenhouse gas emissions savings for the 'cumulative' scenario is likely to be attributed to the reduction of traffic using the existing road network within the study area as alternate routes become available through the completion of subsequent future WestConnex projects and such as the future Southern extension.

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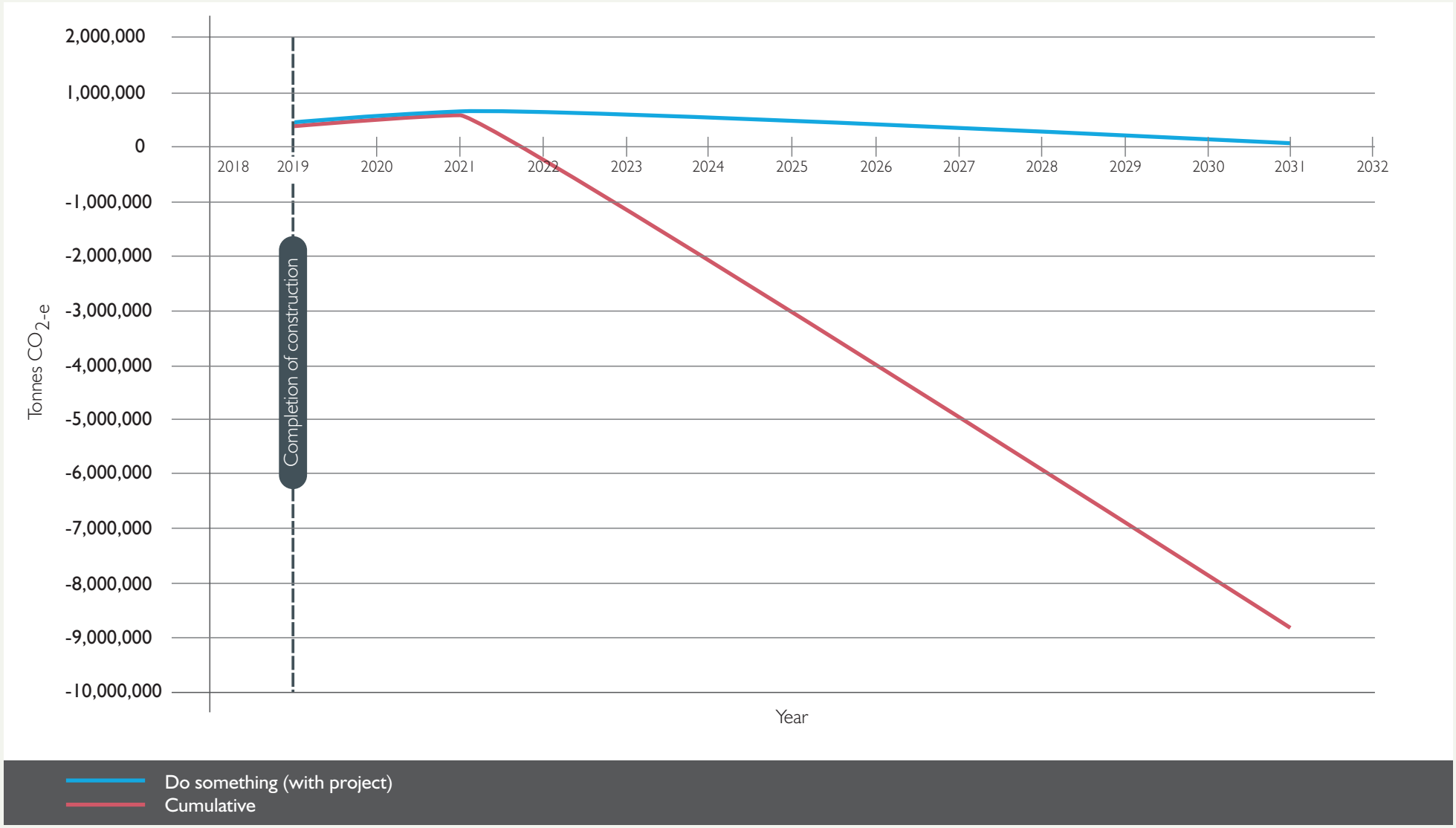


Figure 22-2 Combined greenhouse gas emissions profile: construction, operation and maintenance emissions offset against emissions savings

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22.3.2 Emissions associated with the Alexandria Landfill

Landfill gas is generated when organic waste within a landfill decomposes. The volumetric composition of the gas produced is approximately 50 per cent methane, 38 per cent carbon dioxide, and 12 per cent other gases (Warnken ISE, 2007).

Landfill gas emissions are considered anthropogenic as human activities create the anaerobic conditions which cause the decomposition of organic waste, when waste is buried and contained in an unnaturally low oxygen environment. Methane generation from waste in landfill is therefore required to be assessed as part of a greenhouse gas assessment under the *National Greenhouse and Energy Reporting Act 2007* (Commonwealth). Carbon dioxide emitted as landfill gas is not considered in the assessment of greenhouse gas as it is considered to be part of the natural carbon cycle, and would be emitted from the decomposition of organic materials regardless of human intervention.

The anaerobic decomposition of waste varies depending on the composition of waste within the landfill and is influenced by local climate conditions. Landfill gas is not generated immediately at the time of disposal of the waste. Legacy landfill gas emissions can therefore continue to be generated post-closure of the landfill, requiring the ongoing management of landfill gas (Warnken ISE, 2007).

Qualitative assessment of greenhouse gas emissions for the Alexandria landfill

A qualitative assessment of landfill gas emissions has been considered within the greenhouse gas assessment boundary as the closure and remediation of the Alexandria landfill forms part of the project.

The Alexandria Landfill site was acquired by the NSW Government in December 2014 and the operations of the previous landowner ceased at that time. Activities consistent with the existing planning approvals are continuing on site. The Alexandria landfill was historically operated as a non-putrescible landfill, waste recycling and storage facility, accepting the following waste streams:

- Non-putrescible household waste
- Demolition and construction waste
- Solid industrial and commercial waste
- Incinerated and unincinerated green waste
- Incinerator ash from the former Waverly Woollahra Process Plant
- Shredded tires
- Asbestos.

An overview of Alexandria landfill gases is provided in **Chapter 17** (Contamination), with further detail provided in Technical working paper: Contamination (**Appendix O**).

Works to facilitate the closure and remediation of the Alexandria landfill facility would include:

- Bulk earthworks to prepare the site for construction of the St Peters.
- Installation of a capping layer
- Installation of a cut off wall to minimise inflow from the Botany Sands aquifer
- Augmentation of the existing leachate management system
- Installation of a landfill gas collection and management system

As part of the landfill closure works, a gas collection and management system would be installed, comprising both active and passive components. It is anticipated that the collected gas will be treated through flaring, but other control measures, such as the use of biological treatment to convert methane to carbon dioxide, would be considered as part of detailed design. Not all landfill gas would be able to be captured by the gas collection system, and some fugitive emissions of landfill gas are anticipated to continue to be emitted. The management of landfill gases throughout construction and operation of the project is described in more detail in the Alexandria Landfill Closure Management Plan provided in **Appendix F**.

Table 22-5 summarises the emission sources and activities considered likely to be generated during the closure, remediation and ongoing management of the Alexandria landfill, according to scope.

Table 22-5 Greenhouse gas emission sources and activities associated with Alexandria landfill

Emission source category	Emission source	Emission scope		
		Scope 1	Scope 2	Scope3
Construction				
Landfill gas	Fugitive emissions of legacy landfill gas (methane)	✓		
Fuel use	Mobile construction equipment	✓		✓
	Site vehicles	✓		✓
	Delivery of plant, equipment and materials			✓
Materials	Embodied energy of materials required for landform reshaping works, capping of landfill and installation of new leachate, groundwater and gas management systems			✓
Operation and maintenance				
Landfill gas	Fugitive emissions of legacy landfill gas (methane)	✓		
	Emissions from treatment of landfill gas through flaring, biological treatment or other gas management system(s)	✓		
Electricity consumption	Electricity used to power the upgraded leachate treatment plant, gas collection and management system and other associated environmental control systems		✓	✓

Given that the Alexandria landfill was operated as a non-putrescible landfill, the quantity of methane produced under the anaerobic conditions of the landfill and the subsequent fugitive emissions of landfill gas are anticipated to be lower than that of a general solid waste (putrescible) facility (Warnken ISE, 2007). The proportion of inert materials such as glass, steel, concrete and plastic is likely to be higher, with no putrescible material such as organic food waste within the landfill. The composition of the waste and the lower amount of degradable organic carbon in the landfill is therefore anticipated to result in a lower quantity of methane produced. Further assessment of the potential methane generation from the Alexandria Landfill would be undertaken during detailed design.

Ongoing monitoring of the Alexandria Landfill would be undertaken in accordance with the relevant requirements outlined in the existing consents and trade waste agreement.

A Landfill Closure Management Plan has been developed in accordance with the requirements of the *Protection of the Environment Operations Act 1997* and is provided in **Appendix F**. The Landfill Closure Management Plan outlines the key landfill closure activities and document the proposed landform, capping detail, leachate and gas management and monitoring protocols to be adopted for the landfill closure process. The Landfill Closure Management Plan has been prepared in consultation with the NSW Environment Protection Authority and the Site Auditor, accredited under the *Contaminated Land Management Act 1997* and all landfill closure works would be carried out in accordance with the final approved Landfill Closure Management Plan.

Further detail regarding the closure of the Alexandria Landfill is provided in **Section 5.9** (Landfill closure infrastructure).

22.4 Environmental management measures

The design of the project has been optimised such that measures to reduce energy and resource requirements, and therefore greenhouse gas emissions, are inherent in the design. The project design has been optimised to:

- Reduce energy and resource consumption, and spoil generation during tunnel excavation, by selecting to excavate the main alignment tunnels using roadheader and drill and blast methods, instead of use of a tunnel boring machine which would consumes more electricity, potable water and concrete, and generate more spoil
- Reduce energy and resource consumption through an LED lighting design. The design significantly reduces the number of fittings required in comparison to similar existing NSW tunnels which use end-to-end fluorescent fittings or high-pressure sodium lights. When compared to interior zone tunnel high-pressure sodium lights, as used on the (EastLink) motorway in Melbourne and the Airport Link, the number of fittings can be reduced by using LED lights as they can be oriented to spread the light evenly while meeting lighting standards. LED light banks also have a longer life expectancy and decrease the operational power demand.
- Reduce power consumption through the design of the ventilation system, which incorporates low pressure fans that consume around 50 per cent less energy compared with a high pressure fan solution. These low pressure fans are oriented vertically which also reduces the total ventilation structural footprint by 20-30 per cent, reducing the amount of embodied energy.
- Reduce power consumption associated with tunnel ventilation by locating the ventilation facilities close to the main alignment tunnel portals thereby optimising the piston effect generated by vehicles moving through the main alignment tunnels.

Table 22-6 provides a list of mitigation measures to further reduce the greenhouse gas emissions generated by the project.

Table 22-6 Environmental management measures

Impact	No.	Environmental management measures	Timing
Construction			
Emission of greenhouse gases during construction	GHG1	Prepare a Greenhouse Gas Emissions Strategy and Management Plan for the project.	Detailed design
	GHG2	Undertake an updated greenhouse gas assessment based on detailed design.	Detailed design
	GHG3	The emissions intensity of significant construction materials specified in the design of the project would be assessed and, where feasible and in compliance with technical specifications, low emission construction materials would be used.	Detailed design
	GHG4	Where feasible, recycled content road construction materials such as recycled aggregates in road pavement and surfacing, or similar, would be used.	Detailed design

Impact	No.	Environmental management measures	Timing
	GHG5	The fuel efficiency of construction plant and equipment would be assessed before selection and, where feasible and reasonable, equipment with the highest fuel efficiency or equipment that uses lower greenhouse gas intensive fuel such as biofuels (eg biodiesel, ethanol) would be used.	Pre-construction and construction
	GHG6	Project planning would be undertaken to ensure that the site vehicle movements and construction activities are efficient, to avoid double handling of materials and unnecessary fuel use where possible.	Detailed design
	GHG7	Locally produced goods and services would be procured where feasible and cost effective to reduce transport fuel emissions.	Detailed design and construction
	GHG8	At least six per cent of construction energy required for the project would be sourced where possible from an accredited GreenPower energy supplier	Pre-construction and construction
	GHG9	Where possible, and fit for purpose, spoil would be beneficially re-used within the project before off-site re-use or disposal options are investigated. A spoil management strategy would be developed for the project prior to the commencement of construction and would identify spoil disposal sites and the management of excess spoil.	Pre-construction and construction
	GHG10	Waste would be diverted from landfill, including diversion of spoil, construction and demolition waste, and commercial and industrial waste, where reasonable and feasible. The management of waste would be considered as part of the preparation of the Construction Environmental Management Plan for the project, detailing the appropriate procedures for waste management.	Detailed design and construction
Operation			
Emission of greenhouse gases during operation	OpGHG 1	The main alignment tunnels would be designed to minimise fuel consumed by vehicles using the road, for example through the provision of a vertical alignment that allows consistent vehicle speeds to be maintained.	Detailed design
	OpGHG 2	A life cycle assessment would be undertaken as part of the detailed design in order to select mechanical and electrical systems with increased energy efficiencies, where reasonable and feasible, such as the tunnel ventilation system, tunnel lighting, water treatment systems and electronic toll and surveillance systems.	Detailed design

Impact	No.	Environmental management measures	Timing
	OpGHG 3	Low carbon energy generation options would be investigated as part of the detailed design process in order to reduce the demand on mains electricity and generate renewable energy onsite, where feasible. At least six per cent of energy required for the project would be sourced from an accredited GreenPower energy supplier, where possible.	Detailed design

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23 Aboriginal heritage

This chapter assesses the potential impacts of the project on Aboriginal heritage, including cultural and archaeological impacts. Full details of the assessment are presented in the Technical working paper: Aboriginal heritage (**Appendix V**) with a summary provided below. The assessment has been prepared to address relevant Secretary's Environmental Assessment Requirements (SEARs) as documented in **Table 23-1**.

Table 23-1 SEARs – Aboriginal heritage

SEARs	Where addressed in the EIS
Impacts to Aboriginal heritage (including cultural and archaeological significance), in particular impacts to Aboriginal objects and potential archaeological deposits (PAD), should be assessed. Where impacts are identified, the assessment shall:	This chapter and Technical working paper: Aboriginal heritage (**Appendix V**).
• outline the proposed mitigation and management measures (including measures to avoid significant impacts and an evaluation of the effectiveness of the measures) generally consistent with the Draft Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation (Department of Environment and Conservation, 2005a) and other relevant guidelines and requirements,	Proposed mitigation and management measures are described in **Section 23.4.**
• be undertaken by a suitably qualified heritage consultant(s),	Technical working paper: Aboriginal heritage (**Appendix V**).
• demonstrate effective consultation with Aboriginal stakeholders in determining and assessing impacts and developing and selecting options and mitigation measures (including the final proposed measures),	Consultation with Metropolitan Local Aboriginal Land Council (MLALC) is outlined in **Section 23.1.3.**
• assess and document the archaeological and cultural heritage significance of affected sites, and	The archaeological and cultural significance of sites potentially impacted by the project are detailed in **Section 23.3.**
• Undertake appropriate archaeological investigations generally in accordance with the Code of Practice for Archaeological Investigation of Aboriginal Objects in NSW (Department of Environment, Climate Change and Water, 2010b), to establish the full spatial extent and significance of any archaeological evidence across each site/area of PAD, and include the results of these excavations. If an alternative excavation method is proposed, it shall be developed in consultation with OEH.	Impacts to known Aboriginal objects and PADs are not considered likely as a result of the project. Therefore, further investigation, including archaeological investigations, are not required. The assessment of potential impacts to archaeological and cultural heritage sites is outlined in **Section 23.3.**

SEARs	Where addressed in the EIS
During the preparation of the EIS, you must consult with the relevant local, State or Commonwealth Government authorities, service providers, community groups and affected landowners. • local, State and Commonwealth government authorities, including the: • Environment Protection Authority, • Office of Environment and Heritage (including Heritage Division), • The Heritage Council of NSW, • Department of Primary Industries, • NSW Office of Water, • NSW Health (including Local Health Districts), • Roads and Maritime Services, • Transport for NSW, • UrbanGrowth NSW; • Sydney Water, • Canterbury City Council, • Hurstville City Council, • Rockdale City Council, • Marrickville Council, • City of Botany Bay Council, • City of Sydney, • Civil Aviation Safety Authority, and • Air Services Australia; • specialist interest groups, including Local Aboriginal Land Councils, Aboriginal stakeholders, and pedestrian and bicycle user groups; • utilities and service providers; and • the public, including community groups and adjoining and affected landowners.	Consultation with Aboriginal heritage participants / stakeholders is outlined in **Section 23.1.3**.

23.1 Assessment methodology

The Aboriginal cultural heritage assessment (including cultural and archaeological significance) was conducted in accordance with the:

- *Draft Guidelines for Aboriginal Cultural Heritage Impact Assessment and Community Consultation* (DEC, 2005a)
- *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales* (DECCW, 2010b)
- *Procedure for Aboriginal Cultural Heritage Consultation and Investigation* (PACHCI) (Roads and Maritime, 2011a) by a team of suitably qualified heritage consultants.

The PACHCI procedure involves four stages; however projects that can avoid impacts to Aboriginal cultural heritage may only be required to complete some stages of the procedure. The four stages include:

- Stage 1. An initial assessment (desktop) to determine whether the project is likely to harm Aboriginal cultural heritage
- Stage 2. Further assessment and site survey with Aboriginal stakeholders and an archaeologist to assess the project's potential harm to Aboriginal cultural heritage
- Stage 3. Formal consultation and preparation of a cultural heritage assessment report when Stage 1 and Stage 2 have led to the preliminary view that harm to Aboriginal cultural heritage is likely to occur
- Stage 4. Implementation of project mitigation measures based on recommendations in Stage 3 and to obtain an Aboriginal heritage impact permit if required.

The methodology adopted for this assessment was developed in accordance with the requirements of Stage 2 of the PACHCI based on the assessment conclusion that direct or indirect impacts to Aboriginal cultural values are unlikely to occur as a result of the project.

As a result, further archaeological investigations (in accordance with Stage 3 of the PACHCI process) were not warranted. An overview of the stages of this procedure can be found in the Technical working paper: Aboriginal heritage (**Appendix V**).

Aboriginal heritage legislation relevant to the project is described in **Table 23-2**.

Table 23-2 Legislation relevant to the project – Aboriginal heritage

Legislation	Relevance to project
National Parks and Wildlife Act 1974 (NSW) (NPW Act)	The NPW Act is the primary legislation for the protection of Aboriginal cultural heritage in NSW and provides for the proper care, preservation and protection of 'Aboriginal objects' and 'Aboriginal places', defined under the Act. Under Part 6 of the NPW Act it is an offence to harm or desecrate Aboriginal objects or places. It is a defence to prosecution for such an offence if the harm was authorised by an Aboriginal Heritage Impact Permit issued under section 90 of the NPW Act. As discussed in this chapter, the project would not impact on any known Aboriginal objects or places, and an Aboriginal Heritage Impact Permit would not be required.
Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (Commonwealth) (ATSIHP)	The ATSIHP Act provides for the preservation and protection of places, areas and objects of particular significance to Indigenous Australians. Under the ATSIHP Act, the Australian Government Minister for the Environment, in consultation with the State/Territory minister, may make a declaration to protect an Aboriginal area or object.

Broadly, the Aboriginal cultural heritage assessment included:

- A desktop review of background literature, previous investigations and database including the Aboriginal Heritage Information Management System (AHIMS)
- Consultation with relevant Aboriginal representatives to assist with the archaeological field survey
- An archaeological field survey, which was conducted over four days between 24 and 27 November 2014
- Identification of mitigation measures to reduce impacts to Aboriginal heritage based on the results of the investigation and the anticipated impacts of the project on Aboriginal archaeological and culturally sensitive sites.

23.1.1 Desktop review

The desktop review and Aboriginal stakeholder consultation were used to determine if known Aboriginal archaeological and culturally sensitive sites are located in or near potential project surface disturbance areas. The desktop assessment comprised:

- A search of the AHIMS database
- A review of the landscape context of the project alignment and construction footprint
- A review of relevant archaeological and ethno-historic information for the project alignment and construction footprint
- Development of a predictive model for Aboriginal site types and distribution within and in proximity to the project alignment and construction footprint, based on the landscape context review
- Identification of areas of Aboriginal archaeological sensitivity within and adjacent to the project alignment and construction footprint.

Four areas of potential archaeological sensitivity were identified:

- Wolli Creek Valley, a 50 hectare area of bushland and sandstone escarpments bordering Wolli Creek, located between Bexley North and Tempe
- Stotts Reserve, a four hectare area of bushland containing a tributary of Bardwell Creek and sandstone outcrops, located a short distance from Bexley North railway station
- Bardwell Creek Reserve, a six hectare area of remnant bushland featuring sandstone outcrops and Turpentine Forest and Eucalypt woodland, located south of Bardwell Valley Golf Course
- Foreshore zones of estuarine environments such as the Alexandra Canal, Cooks River, Wolli Creek and Botany Bay. Past archaeological assessments demonstrated the potential for Aboriginal midden sites to occur in these environments.

23.1.2 Study Area

Based on the desktop review, a study area (**Figure 23.1**) for the heritage assessment, including the archaeological survey, was developed. A conservative area extending beyond the project alignment and construction footprint for the project was chosen. The study area included the locations of potential ancillary facilities such as construction ancillary facilities and ventilation facilities.

23.1.3 Consultation

In accordance with the project SEARs and Stage 2 of Roads and Maritime's PACHCI process, the following Aboriginal community consultation process has been carried out:

- Identification of key Aboriginal stakeholders through searches of the National Native Title Register and Register of Aboriginal Owners
- Identification of the relevant Local Aboriginal Land Council and engagement of an identified Aboriginal representative to carry out the archaeological survey
- Invitation for the Aboriginal representative(s) to prepare a cultural heritage survey report.

No Aboriginal stakeholders were identified from searches of the National Native Title Register and Register of Aboriginal Owners.

The Metropolitan Local Aboriginal Land Council (MLALC) was identified as the relevant Local Aboriginal Land Council to consult regarding the project. A representative from the MLALC participated in the archaeological survey. The MLALC representative also prepared a cultural heritage survey report for the project (Appendix B of Technical working paper: Aboriginal heritage (**Appendix V**)). Findings from the report were incorporated into the design development as part of an environmental constraints analysis.

A draft copy of the Technical working paper: Aboriginal heritage (**Appendix V**) was provided to the MLALC on 1 November 2015 with an invitation to provide comment. The MLALC representative responded on 6 November 2015, stating that MLALC agreed with the findings and recommended management measures relating to vibration, unanticipated finds, human skeletal remains and the effectiveness of proposed management measures in relation to the potential AHIMS site SR-OVRH-1, as described within the Technical working paper. MLALC also requested that they be contacted immediately, should Aboriginal features be uncovered during future works. A copy of the correspondence from MLALC is provided in Appendix C of **Appendix V**.

The outcomes of the Stage 2 PACHCI process confirmed that a more detailed Stage 3 PACHCI assessment is not required for the project (refer to Technical working paper: Aboriginal heritage (**Appendix V**)). Consequently, identification of, and formal statutory consultation with, registered Aboriginal parties has not been conducted.

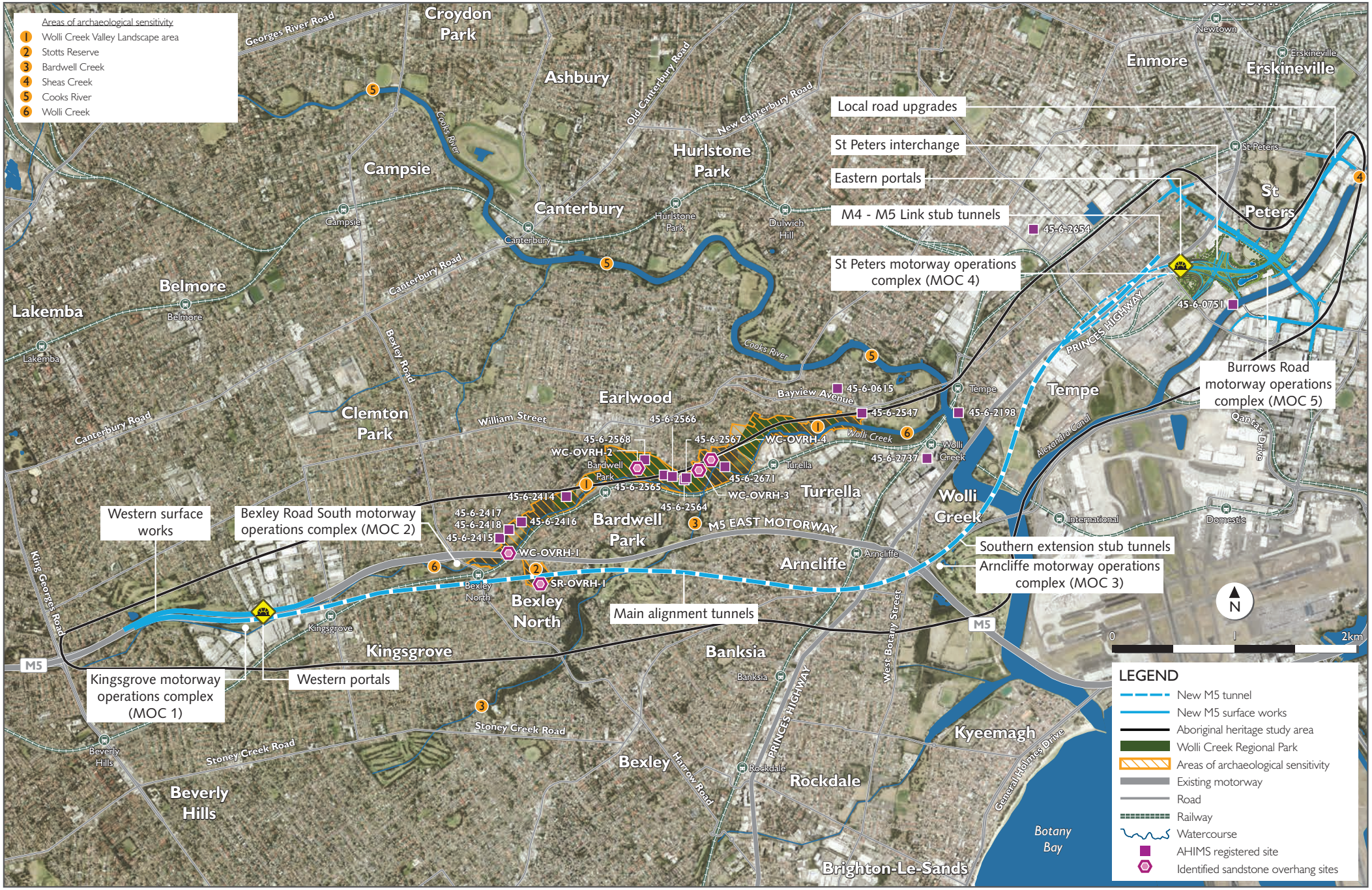


Figure 23-1 Aboriginal heritage study area

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23.1.4 Archaeological field survey

The archaeological field survey:

- Identified and recorded existing surface evidence of past Aboriginal activity
- Identified areas with potential for subsurface archaeology
- Informed the development of strategies for avoiding and / or mitigating potential impacts to Aboriginal heritage.

The archaeological survey was carried out between 24 and 27 November 2014, in the presence of a MLALC representative.

During the archaeological survey, AHIMS sites that had been previously recorded within the study area were visited. The survey was conducted on foot and by vehicle, during which details of the ground surface visibility, integrity (land condition) and archaeological sensitivity were noted. Data was recorded on a hand-held GPS and photographs were taken.

Aboriginal archaeological sites/ objects identified during the survey were recorded in accordance with the *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales* (DECCW, 2010b). Individual site boundaries were captured by differential GPS. The survey findings are provided in the following sections.

Further details of the methodology, timing and extent of the archaeological survey are provided in Technical working paper: Aboriginal heritage (**Appendix V**).

23.2 Existing environment

The existing environment for Aboriginal cultural heritage is presented in terms of the:

- Pre-European occupation of the land
- The landscape context and the way in which it influenced Aboriginal occupation
- Records of Aboriginal objects recorded in AHIMS
- Previous Aboriginal heritage investigations
- Findings and recommendations of the field survey/ Stage 2 PACHI.

23.2.1 Pre-European occupation of land

The project would be located within the boundaries of the Darug (also spelt Dhaŕ-rook, Dharrook, Dhaŕook, Dharruk and Dharug) linguistic group. The boundaries of the Darug linguistic group stretched from the Hawkesbury River in the north, to Appin in the south, and from the coast west across the Cumberland Plain into the Blue Mountains. Two dialects of Darug; a coastal and a hinterland dialect; were spoken at the time of European contact.

The primary unit of social organisation amongst the Darug was the clan consisting of around 50 to 60 people and taking its name from the place where its members resided. Records indicate that a wide range of marine, freshwater, terrestrial and avian fauna were exploited by Darug-speaking peoples for food (Attenbrow, 2010). Fish and shellfish were principally exploited in coastal areas and land mammals such as kangaroos, wallabies, possums and koalas among others were hunted further inland.

Hunting and gathering tools were employed by men and women (McDonald, 2008). Men used spears (including barbed spears), clubs, spear throwers, ‘swords’, boomerangs, shields and hafted stone hatchets (known as mogo). Women used fishing hooks, lines and sinkers, digging sticks and various containers (shell and wood). Net bags made from plaited wood fibre and bark canoes were also widely used (Attenbrow, 2010).

Two major forms of shelter appear to have been utilised by Darug speaking peoples at the time of European contact: rockshelters and small huts built from sheets of bark, branches and bushes (Barrington, 1802; Collins, 1798, 1802; Tench, 1793). Evidence for ceremonial or ritual behaviour amongst Darug-speaking peoples can be found in the writings of a number of early observers (for example, Collins, 1798; Phillip, 1788 in Hunter 1793 [1968]; Tench, 1793), with documented activities including corroborees, male initiation ceremonies, ritual combats and various burial, body adornment and personal decoration practices.

23.2.2 Landscape context

The study area is located across the physiographic regions of the Botany Lowlands and Cumberland Lowlands. The topography of Botany Lowlands region, in the east is characterised by deep sand dunes and patches of swampland found to the north and west of Botany Bay broadly encircling it. In the western portion of the study area, the topography of the Cumberland Lowlands varies, including ranges from undulating low hills to very steep hills associated with Hawkesbury Sandstone outcrops bordering the Wolli Creek Valley.

The surface geology within the study area comprises a mixture of Quaternary alluvium and sands associated with watercourses, and Wianamatta Group shales and Hawkesbury Sandstone away from watercourses. The geological context of the project is described in **Chapter 17** (Geology and groundwater).

Vegetation within the study area has been extensively cleared with the exception of some isolated pockets in reserves and parklands. Large areas of reclaimed land are found around the lower reaches of the Cooks River and Botany Bay. Relatively undisturbed remnant landscapes are found in three locations within the study area: Wolli Creek Valley (referred to as Wolli Creek Valley Landscape Area), Stotts Reserve and Bardwell Creek Reserve.

The Wolli Creek Valley is one of the few remnant landscapes within the study area that has been not subjected to significant landscape modification due to urban development. From an Aboriginal heritage perspective, it is unique in the inner city area, containing an archaeological resource comprising of rockshelters and artefact scatters linked to relatively undisturbed key landscape features of Wolli Creek and the escarpments of Hawkesbury Sandstone. There is potential for additional sites to be present within this landscape area, both in surface and subsurface contexts. Taken as a whole, this area is considered highly significant, both archaeologically and culturally (refer to **Appendix V** for a cultural assessment from the MLALC representative).

Stotts Reserve comprises of about four hectares of bushland and is located about 370 metres east of Bexley North railway station. The reserve contains a tributary of Bardwell Creek and sandstone outcrops. Reference to 1943 historic aerials suggests this bushland area has remained relatively undisturbed over the past 70 years (refer to **Appendix V** for aerial photo). Bardwell Creek Reserve, located south of Bardwell Valley Golf Course, covers around six hectares and includes remnant bushland featuring sandstone outcrops, Turpentine forest and Eucalypt woodland.

The remainder of land within the study area has been subjected to varying degrees of landscape disturbance and is unlikely to contain in-situ evidence of past Aboriginal activity.

23.2.3 New South Wales Aboriginal Heritage Information Management System (AHIMS)

The AHIMS database contains records of Aboriginal objects reported in accordance with section 89A of the NPW Act. It also contains information about Aboriginal places which have been declared by the Minister for the Environment to have special significance with respect to Aboriginal culture. Previously recorded Aboriginal objects and declared Aboriginal places are referred to by AHIMS as ‘Aboriginal sites’.

A search of the AHIMS database for previously recorded Aboriginal sites within and surrounding the study area (being areas within one kilometre of the study area) was lodged with the NSW Office of Environment and Heritage (OEH) on 7 November 2014. A total of 17 sites were initially identified within the search area comprising:

- Eleven rockshelters
- Three open artefact sites (artefact scatters and isolated artefacts)
- One shell midden
- One Potential Archaeological Deposit (PAD)
- A site containing an artefact scatter, edge ground axe head and dugong bones (referred to as the Sheas Creek site)

The AHIMS database identified the Sheas Creek (#45-6-0751) site as being located within the study area near the Alexandra Canal. The site was identified during construction of the canal in 1896 and comprised dugong bones and axe heads located within a layer of unctuous plastic dark bluish grey sandy clay with marine shells, five metres below the current ground surface. The excavated material was collected and retained by the Australian Museum. AHIMS currently lists the site as valid however the site card identifies that the site was actually excavated and destroyed.

23.2.4 Previous Aboriginal heritage investigations

Previous archaeological assessments involving survey, excavation and / or salvaging have been carried out in the region by others over the past three decades, relating to known sites and past development projects. Eight of these assessments are relevant to the Aboriginal heritage study area and have been used to inform the development of Aboriginal site predictions and the scope of field surveys.

A summary of the relevant past archaeological assessments is provided in the Technical working paper: Aboriginal heritage (**Appendix V**).

23.2.5 Field survey / Stage 2 PACHCI findings and recommendations

Combined, the archaeological field survey conducted for the project and the desktop review identified the following within one kilometre of the study area:

- Five newly identified potential Aboriginal sites
- Seventeen previously recorded Aboriginal site
- Twenty-one verified Aboriginal sites
- One landscape area, being the Wolli Creek Valley Area.

A summary of verified AHIMS sites and additional newly recorded Aboriginal sites within the study area is provided in **Table 23-3**. A map showing their respective locations is provided in **Figure 23-1**.

The archaeological survey identified five sandstone overhangs that are considered to be PAD based on habitation area size and presence of potential deposits. Aboriginal rockshelter sites and sandstone overhangs have the potential to be impacted by vibration and settlement, both as a result of tunnelling or carrying out construction activities below or nearby the sites.

No Aboriginal sites have been identified within areas that would be disturbed by the surface works as part of the project.

Table 23-3 AHIMS sites identified within the Aboriginal heritage study area

Site name	AHIMS reference	Site type	Site features	Location / description
Previously recorded AHIMS sites^				
Undercliffe Road	45-6-0615	Rockshelter	Art; Midden	Site location confirmed.
Sheas Creek*	45-6-0751	Includes artefact scatter, edge ground axes and dugong bones	Artefacts, shell and bones	Site salvaged and is likely to have been destroyed during construction of the Alexandra Canal.
View Street	45-6-2198	Midden	Shell; artefacts	Site inspected and partially destroyed. The AHIMS coordinates are incorrect and require updating.
4 Wolli_Creek 1.6	45-6-2414	Rockshelter	Deposit; artefacts	Site inspected and in good condition. The AHIMS coordinates are incorrect and require updating. No artefacts were observed.
Wolli_Creek 1.4	45-6-2415	Rockshelter	Deposit; artefacts	Site not located.
Wolli_Creek 1.3	45-6-2416	Rockshelter	Deposit; shell	Site inspected and in good condition. The AHIMS coordinate are incorrect and require updating. No shell deposits were observed.
Wolli_Creek 1.2	45-6-2417	Rockshelter	Shell; artefacts	Site not located. Possibly built over by houses along Sutton Avenue.
Wolli_Creek 1.1	45-6-2418	Rockshelter	Deposit; artefacts	Site not located. Possibly built over by houses along Sutton Avenue.
Nanny Goat Hill 1;NGH 1	45-6-2547	Open artefact site	Artefacts	Site inspected and no artefacts were observed.
Wolli Creek 2.5	45-6-2564	Rockshelter	Shell; artefacts	Site inspected and in good condition. The AHIMS coordinates are incorrect and require updating. No shell or artefacts were observed.
Wolli Creek 2.4	45-6-2565	Rockshelter	Deposit; artefacts	Site inspected and in good condition. The AHIMS coordinates are incorrect and require updating. No artefacts were observed.
Wolli Creek 2.1	45-6-2566	Rockshelter	Deposit; artefacts	Site inspected and in good condition. The AHIMS coordinates are incorrect and require updating. No artefacts were observed.
Wolli Creek	45-6-2567	Rockshelter	Shell; artefacts	Site inspected and in poor condition due to contemporary use as a rock-climbing wall. No artefacts were observed, however small bone animal fragments were identified.

Site name	AHIMS reference	Site type	Site features	Location / description
Wolli Creek	45-6-2568	Rockshelter	Deposit; artefacts	Site inspected and in good condition. The AHIMS coordinates are incorrect and require updating. No artefacts were observed.
Fraser Park PAD	45-6-2654	PAD	PAD	Site not located.
Wolli Creek 3	45-6-2671	Open artefact site	Artefacts	Site inspected. No artefacts were observed, possibly removed or washed away during rain / flooding.
Tempe House 1	45-6-2737	Open artefact site	Artefacts; PAD	Site partially destroyed and comprises of a subsurface deposit. No surface artefacts identifiable.
Newly recorded potential Aboriginal sites				
Pending	SR-OVRH-1	Sandstone overhang	PAD	Site located on an upper slope overlooking an unnamed tributary of Wolli Creek in Stotts Reserve
Pending	WC-OVRH-1	Sandstone overhang	PAD	Site located on a lower slope 20 metres from Wolli Creek.
Pending	WC-OVRH-2	Sandstone overhang	PAD	Site located on a middle slope PAD in the Wolli Creek area.
Pending	WC-OVRH-3	Sandstone overhang	PAD	Site located on a middle slope 100 metres from Wolli Creek.
Pending	WC-OVRH-4	Sandstone overhang	PAD	Site located on a middle slope 60 metres from Wolli Creek.

^The field survey identified site # 45-6-1496 in the AHIMS database was determined not to be a site.
* This site was documented in the late 19th century during construction of the Alexandra Canal at a time when archaeological reporting requirements were poor. Stone artefacts and a dugong skeleton were recovered from the site, and while suspected based on known impacts, it is unclear from available documentation whether the site was subsequently completely destroyed during construction.

23.3 Assessment of potential impacts

The Technical working paper: Aboriginal heritage (**Appendix V**) identifies three broad areas of Aboriginal archaeological and / or cultural heritage significance relevant to the project:

- The Wolli Creek Valley Landscape Area, an area of archaeological sensitivity and registered AHIMS sites
- Alexandra Canal / Sheas Creek, an area that may contain artefact bearing deposits
- Newly identified potential Aboriginal sites.

23.3.1 Construction

Construction works have the potential to directly and indirectly impact on Aboriginal cultural heritage as a result of surface and tunnel works:

- Direct impacts - direct impacts are those with the potential to damage or destroy Aboriginal sites within the proposed disturbance footprint of the project. No direct impacts have been identified for this project
- Indirect impacts - the potential for the project to indirectly damage Aboriginal sites is low. Indirect impacts include those resulting from vibration during construction, as well as blasting activities, and settlement from tunnelling.

The potential for impacts to occur at the areas of Aboriginal archaeological and / or cultural heritage significance identified is discussed below.

Wolli Creek Valley Landscape Area

The Wolli Creek Valley Landscape Area is located immediately east of the Bexley Road East construction compound (C6). The project would not directly impact the Wolli Creek Landscape Area.

Indirect impacts the Wolli Creek Valley Landscape Area from noise, vibration, visual and dust are unlikely to cause significant landscape modifications or impact on undisturbed key landscape features. As such, the likelihood that the project would create indirect impacts to the Wolli Creek Valley Landscape Area is low.

Nonetheless and to further reduce the likelihood of indirect impacts, appropriate mitigation measures have been identified in **Table 23-6**.

Rockshelters

The closest valid site to areas of surface distance is Aboriginal rockshelter Wolli Creek 4.1 (#45-6-2415), located about 250 metres north-west of the Bexley Road East construction compound (C6). This site would not be directly impacted by the project. Given the distance between the valid site and construction activities, the potential for indirect impacts is low.

Alexandra Canal

The AHIMS registered artefact scatter site Sheas Creek (#45-6-0751) was destroyed during construction of Alexandra Canal (refer to **Section 23.2.3**). Archaeological data indicates that should other objects of Aboriginal heritage be present within Alexandra Canal these would be located around five metres below the current ground surface.

Most of the construction works for the local road upgrades adjacent to the canal are unlikely to extend to five metres below the ground surface. However, the proposed bridges over Alexandra Canal would be supported by two piers either side of the canal each supported by eight piles each measuring 900 millimetres in diameter, bored about 18 metres below the ground surface. Given the restricted subsurface footprint of the project, the likelihood of disturbing any artefact bearing deposits associated with site #45-6-0751 is considered low.

A procedure for the management of any unanticipated Aboriginal objects identified during the construction of the Campbell Road bridge, pedestrian and cycle bridge and Gardeners Road bridge is provided in **Table 23-6**.

Sandstone overhang sites

Several archaeologically sensitive sandstone overhang sites are located in the study area. The closest archaeologically sensitive site to the project alignment that may have had past Aboriginal use is a sandstone overhang (SR-OVRH-1). However, no direct evidence of use has been identified. This sandstone overhang is located within Stotts Reserve.

Direct impacts to sandstone overhang sites would not occur as the project would be underground at this location. However, indirect impacts to the sandstone overhang could occur due to tunnelling activities.

Tunnelling has the potential to cause indirect impacts to Aboriginal heritage sites through subsidence as a result of settlement and vibration. Subsidence, in the context of the current project refers to the vertical and horizontal displacement of the ground surface as a result of tunnelling or groundwater drawdown.

Table 23-4 identifies the criteria used for assessing settlement damage to standing structures and is found in existing studies (Burland et al., 1977 and Boscardin and Cording, 1989).

Settlement beneath and around the sandstone overhang site (# SR-OVRH-1) would be less than five millimetres (refer to **Chapter 13** (Land use and property)). This low settlement value, and the relatively small size of the site (21 cubic metres), indicates that settlement-related impacts are unlikely. Settlement-related impacts to other known Aboriginal sites and areas of archaeological sensitivity found within the study area are unlikely given the distance to the project alignment.

Table 23-4 Criteria for assessing settlement damage

Maximum settlement (mm)	Degree of damage	Description of potential damage	Approximate crack width (mm)
<5	Negligible	Hairline cracks	<0.1
<10	Very slight	Fine cracks	<0.1 to 1.0
10-50	Slight	Potential fractures	5 – 15

In order to assess potential impacts to Aboriginal rockshelters from vibration caused from construction (including blasting) and during operation of the project, the German Standard (DIN 4150 Group 3) guidelines have been applied (see **Table 23-5**). These standards are commonly used in Aboriginal heritage assessments to assess impacts to Aboriginal rockshelter sites. Group 3 represents the most sensitive safe limit for vibration impacts on structures and has been adopted here as it represents a conservative approach.

Table 23-5 Criteria for assessing vibration: DIN 4150: Structural damage safe limits for building vibration

Group	Type of Structure	Vibration Velocity in mm/s At Foundation at a Frequency of			Vibration at the Horizontal Plane of the Highest Floor
		Less than 10 Hz	10 Hz to 50 Hz	50 Hz to 100 Hz	All Frequencies
1	Buildings used for commercial purposes, industrial buildings and buildings of similar design.	20	20 to 40	40 to 50	40
2	Dwellings and buildings of similar design and/or use.	5	5 to 15	15 to 20	15
3	Structures that because of their particular sensitivity to vibration do not correspond to those listed in Lines 1 or 2 and have intrinsic value (eg buildings that are under a preservation order).	3	3 to 8	8 to 10	8

Maximum predicted surface, tunnelling and blasting vibration intensities at the sandstone overhang (SR-OVRH-1) is below the Group 3 safety limit of three millimetres per second for all identified Aboriginal sites (**Chapter 12** (Noise and vibration)).

Based on this, vibration related impacts on SR-OVRH-1 would be unlikely. Other known Aboriginal sites and areas of archaeological sensitivity found within the study area are unlikely given the distance to the project alignment.

Nevertheless as a precaution, management of SR-OVRH-1 would include:

- Vibration monitoring for vibration intensive works within 50 metres of SR-OVRH-1. The need for vibration monitoring would be informed by a preliminary screening of activities that have the potential for vibration. Details would be contained within the construction environmental management plan
- A condition assessment prior to the commencement of construction, following vibration intensive works within 50 metres of SR-OVRH-1 and at the completion of construction.

23.3.2 Operation

Potential indirect and direct impacts to Aboriginal heritage during operation of the project relate to impacts associated with urban design, landscape character and visual amenity impacts. The project has been designed to integrate with the visual appearance of existing infrastructure and to be sympathetic to the surrounding landscape context.

A summary of changes to the landscape or scenic context in relation to the urban design of the project is provided in **Chapter 14** (Visual impacts and urban design).

23.4 Environmental management measures

Direct impacts to sites and items of known Aboriginal heritage items and areas of archaeological and cultural heritage significance have been avoided through the design of the project. The archaeologically sensitive Wolli Creek Valley Landscape Area is located adjacent to the Bexley Road East construction compound. No indirect impacts (including vibration) on areas of Aboriginal cultural significance are anticipated as a result of the project.

Despite this and to further reduce the potential for impacts to Aboriginal heritage, environmental management measures relating to Aboriginal heritage during construction are provided in **Table 23-6**.

The recommended management and mitigation measures draw on best management practice, government standards and guidelines, and specialist knowledge. All measures are expected to be effective avoid in Aboriginal heritage impacts. No operational mitigation measures relating to Aboriginal heritage are necessary.

Table 23-6 Environmental management measures – Aboriginal heritage

Impact	No.	Environmental management measure	Timing
Construction			
Impacts on culturally sensitive Aboriginal sites	AH 1	Vibration generating activities, including blasting would be conducted in a manner to ensure vibration levels do not exceed three millimetres per second at potential Aboriginal heritage site SR-OVRH-1.	Construction
Indirect impacts on sandstone rock overhang site	AH 2	Vibration monitoring would be carried out during vibration intensive works within 50 metres of SR-OVRH-1. The need for vibration monitoring would be informed by a preliminary screening of activities at this location to identify what activities have the potential for vibration at this location. The preliminary screening and works requiring monitoring would be contained within the construction environmental management plan.	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
	AH 3	A baseline condition assessment would be completed by a qualified structural engineer for Aboriginal site SR-OVR-1 before construction commences, followed by a condition assessment immediately following significant vibration and with recommendations for remediation measures if required.	Pre-construction and construction
Unexpected discovery of Aboriginal objects (Project wide)	AH 4	If an Aboriginal object(s) is discovered during construction it would be managed in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime Services, 2015), including: • Ceasing works in the vicinity of the object(s), where there is the potential to directly or indirectly impact on the object(s) • Notifying the construction Environmental Representative and OEH of the discovery • Engaging a qualified archaeologist to determine the nature, extent and scientific significance of the object(s) • Developing management recommendations in consultation with the qualified archaeologist, OEH and RAPs.	Construction
Unexpected discovery of Aboriginal objects (Alexandra Canal)	AH 5	In order to manage the potential discovery of an Aboriginal object(s) during pile installation adjacent to Alexandra Canal the following strategy would be implemented: • Geotechnical coring at each pile location by a geotechnical engineer to obtain intact sediment samples to a depth of around seven metres • Inspection of obtained sediment samples by a qualified archaeologist in consultation with the geotechnical engineer in order to characterise the soil profile and identify any Aboriginal archaeological materials Should Aboriginal archaeological material be present within one or more core samples, management would occur in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime, 2015).	
Unexpected discovery of human remains	AH 6	If human remains are discovered during construction would be managed in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime Services, 2015), including: • Ceasing works in the vicinity of the remains, with the potential to directly or indirectly impact on the remains • Notifying the construction Environmental Representative, OEH and NSW Police of the discovery • Following directions from the NSW Police and / or OEH, as relevant, depending on the nature of the remains and the outcomes of forensic investigations.	Construction

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24 Resource use and waste minimisation

This chapter describes the construction resources and materials, including potential sources and expected quantities that would be used for the project.

In addition, construction and operation of the project would generate waste streams that would require management and disposal in accordance with relevant NSW policies and guidelines. This chapter also provides a description of each waste stream, expected quantities of waste materials where known, and applicable waste management strategies.

Resource consumption and waste generated by the project would also contribute to the emission of greenhouse gases during construction and operation. The consideration of this impact and potential emission reduction opportunities are discussed in **Chapter 22** (Greenhouse gas).

Table 24-1 sets out the Secretary's Environmental Assessment Requirements (SEARs) as they relate to resource management and waste minimisation, and notes where in the environmental impact statement (EIS) they have been addressed.

Table 24-1 SEARs – resource and waste

SEARs	Where addressed
A Spoil Management Strategy detailing how spoil will be managed during construction, including likely volumes, likely nature and classification of excavated material, opportunities for recycling, potential disposal sites (including description of sites), stockpile management, and method(s) and route of transportation.	Spoil management during construction is detailed in **Section 24.1**. Spoil transportation method and routes are detailed in **Chapter 9** (Traffic and transport).

24.1 Assessment of potential impacts

The *Waste Avoidance and Resource Recovery Act 2001* is the primary legislation for managing waste. The key objectives of the Act in respect to this project are:

- To encourage the most efficient use of resources and to reduce environmental harm
- To ensure that resource management options are considered against a hierarchy of the following order: avoidance, resource recovery and disposal
- To assist in the achievement of the objectives of the *Protection of the Environment Operations Act 1997* (POEO Act). The POEO Act establishes management and licensing requirements for the transport, storage, disposal and re-use of waste.

This section outlines the impacts that the project would have on resource consumption and waste generation during construction and operation, in the context of the objectives of the *Waste Avoidance and Resource Recovery Act 2001* and the SEARs.

24.1.1 Construction

Construction resource consumption

Indicative quantities of materials required for construction of the project are detailed in **Table 24-2**. Where feasible and reasonable, construction material would be sourced from within the Sydney region. Select materials such as steel, copper and polypropylene are likely to be required from quarries, manufacturers and suppliers outside the Sydney region. Construction resource requirements for the project are typical for a tunnelling project of this scale. Resource requirements may have a temporary impact on resource availability within the local area during construction.

Additional specific details for subcontractor management would be included in the Construction Environmental Management Plan, and the Workplace Health and Safety Plan for the project. Further procurement strategies would be identified during detailed design to manage the competition for the selection of suitably qualified and capable subcontractors, suppliers and providers of other resources.

The earthworks required as part of the closure of the Alexandria Landfill is anticipated to require about 620,000 cubic metres of cut and around 556,000 cubic metres of fill material. Due to compaction and importation of materials from tunnel spoil, this is expected to result in a cut / fill balance. Any excess cut material is expected to minimal, and would be classified as waste and therefore managed, treated and transported accordingly.

Table 24-2 outlines the materials required for construction of the project.

Table 24-2 Materials required for construction

Material	Estimated quantity required
Concrete – plain shotcrete (cast *in situ*)	2000 cubic metres
Concrete – reinforced shotcrete (cast *in situ*)	130,000 cubic metres
Concrete – no-fines (cast *in situ*)	80,000 cubic metres
Concrete – piles (cast *in situ*)	12,000 cubic metres
Concrete – New Jersey kerbs slipformed	13,000 cubic metres
Concrete – retaining walls (precast)	1000 cubic metres
Concrete – base paving	80,000 cubic metres
Concrete – drainage pipes (precast)	40,000 metres
Concrete – Other	200,000 cubic metres
Steel – steel fibre reinforcement for shotcrete	4,300 tonnes
Steel – rock bolts	5100 tonnes
Steel – rebar	40,000 tonnes
Asphalt	135,000 tonnes
Aggregate	350,000 tonnes
Copper wire cable	200 tonnes
Plastic – PVC (conduit)	402 tonnes
Plastic – polypropylene	180 tonnes
Pre-fabricated noise walls	13,446 metres squared
Noise wall – plexiglass	128 cubic metres
Noise wall – polyethylene	900 cubic metres

A procedure for the procurement and management of subconractors would be implemented to ensure that only those subcontractors which are capable of fulfilling the project's requirements would be given the opportunity to tender for the appropriate trade and supply packages. Procurement procedures would detail:

- How the procurement of subcontractors / products and services would be sourced and managed. This would include provisions for local content in accordance with the requirements of the Australian Industry Participation Plan, along with local training and development opportunities
- Prior to engagement, suppliers and subcontractors would be required to demonstrate acceptable health, safety and environmental practices which comply with design and construction best practices, along with capability of key personnel. Compliance with the project health and safety and environmental requirements would be mandatory
- Performance of subcontractors / suppliers would be monitored against requirements and poor workmanship and / or poor site behaviour would not be tolerated.

Water resources

The use of water during construction would be required for:

- Tunnelling activities such as cooling water and dust suppression
- Surface works, including compaction of pavement materials and dust suppression
- Site office and ablutions
- Commissioning of the fire and life safety deluge systems within the tunnels.

The total volume of water required for construction of the project would be around 2,500 mega litres. Water would primarily be sourced from the Sydney water mains (potable water). Non potable water sources include collected rainwater and treated groundwater would also be used. Estimated volumes and potential supplies of water for each site, based on the construction program and the anticipated demand and supply sources at varying times throughout construction are shown in **Table 24-3.**

Table 24-3 Water requirements (total construction period)

Compound	Potable water supply from Sydney Water mains (mega litres)	Non-potable water supply (mega litres)		Total (mega litres)
		Collected rainwater	Treated groundwater	
Kingsgrove North construction compound (C1)	440	2	58	500
Kingsgrove South construction compound (C2) and Commercial Road construction compound (C3).	25	0	55	80
Bexley Road North construction compound (C4)	150	2	33	185
Bexley Road South construction compound (C5)	150	4	31	185
Bexley Road East construction compound (C6)	1	1	0	2
Arncliffe construction compound (C7)	480	5	100	585
Canal Road construction compound (C8)	340	3	67	410
Campbell Road construction compound (C9)	419	1	0	420
Landfill compound (C10)	2	0	0	2
Burrows Road construction compound (C11)	30	<1	0	30
Campbell Road bridge construction compound (C12)	30	<1	0	30
Gardeners bridge construction compound (C13)	30	0	0	30
Sydney Park construction compound (C14)	<1	0	0	<1

Power

A temporary bulk power supply for the use of roadheaders, tunnel support sites and construction compounds would be required during construction. The power supply would be sourced, through connections to the existing power supply network.

Construction power supply details for major construction compounds are summarised in **Table 24-4** including supply source and power demand. The potential routes for the power supplies are shown in **Figure 24-1**, **Figure 24-2** and **Figure 24-3**. Environmental impact assessment and approval of these power supplies are being progressed separately from the project and they do not form part of this EIS.

Table 24-4 Construction power supply for major construction compounds

Compound	Supply source substation	Likely supply route length (kilometres)	Connected load (megavolt-ampere)
Kingsgrove North (C1), Kingsgrove South (C2) and Commercial Road (C3) construction compounds	Punchbowl Substation	4	3
Bexley Road North (C4), Bexley Road South (C5) and Bexley Road East (C6) construction compounds	Canterbury Zone Substation	2	6
Arncliffe construction compound (C7)	Canterbury Zone Substation	4	2 x 36 (33kV)
Canal Road construction compound (C8)	Green Square Substation	2	6
Campbell Road construction compound (C9)	St Peters Substation	2	10

Ancillary facilities that are not supporting tunnelling works, such as the Landfill compound (C10), Burrows Road construction compound (C11), Campbell Road bridge construction compound (C12), Gardeners bridge construction compound (C13) and Sydney Park construction compound (C14), would not require access to high voltage power. These sites would be powered via diesel powered generators or a local connection to the existing power supply network.

Around 130,000 Megawatt hours of electricity and up to around 30,500 kilolitres of fuel (diesel and petrol) would be required to construct the project. As per the sustainability targets for the project (refer to **Chapter 28** (Sustainability), at least six per cent of construction energy would be sourced where possible from an accredited GreenPower energy supplier. It is expected that around two per cent of construction phase power requirements would be offset in accordance with the Commonwealth Government's National Carbon Offset Standard. This would be reviewed during detailed design to refine the approach to offsetting energy requirements, and to identify whether additional power consumption can be offset.



Figure 24-1 Indicative construction power supply routes - Kingsgrove North (C1), Kingsgrove South (C2) and Commercial Road (C3) construction compounds

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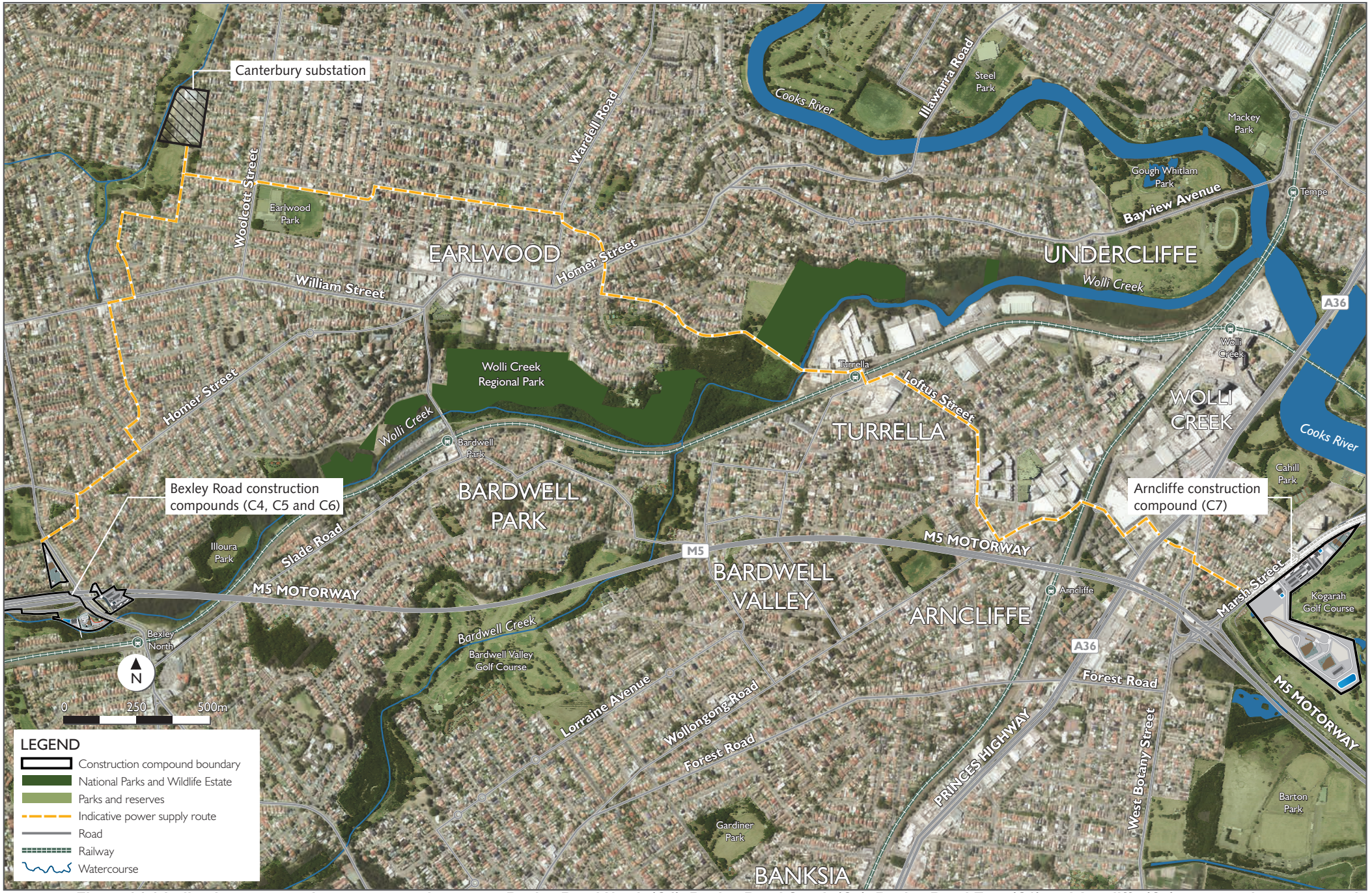


Figure 24-2 Indicative construction power supply routes - Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6) and Arncliffe (C7) construction compounds

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Figure 24-3 Indicative construction power supply routes - Canal Road (C8) and Campbell Road (C9) construction compounds

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Construction waste

Waste streams expected to be generated during construction of the project, would include:

- Spoil from tunnelling activities including soil and rock
- Contaminated soil (if present)
- Wastewater from tunnel construction, dust suppression, the use of wash down areas and construction compounds (grey water)
- General construction waste.

These waste streams are discussed in more detail below.

Tunnelling spoil

The project would generate around 3,200,000 cubic metres of spoil. The majority of spoil would be generated from the excavation of the main alignment tunnels. Site preparation activities, excavation of dive structures, excavation of ventilation shafts, and cut and fill activities for the aboveground components of the project would also generate spoil. The indicative breakdown of spoil volumes generated at each construction compound from surface works and tunnelling is summarised in **Table 24-5**.

Table 24-5 Anticipated spoil generation

Construction compound	Spoil volume- surface works (cubic metres)	Spoil volume- tunnelling (cubic metres)	Spoil volume- total (cubic metres)
Kingsgrove North (C1)	237,130	100,540	337,670
Kingsgrove South (C2)	117,830	0	117,830
Commercial Road (C3)	0	43,088	43,088
Bexley Road North (C4),	0	450,937	450,937
Bexley Road South (C5)	0	300,624	300,624
Bexley Road East (C6)	0	0	0
Arncliffe (C7)	50,000	975,635	1,025,635
Canal Road (C8)	90,000	787,660	877,660
Campbell Road (C9)	90,000	0	90,000
Landfill Closure (C10)	0	0	0
Burrows Road (C11)	6,000	0	6,000
Campbell Road bridge (C12)	6,000	0	6,000
Gardeners Road bridge (C13)	0	0	0
Sydney Park (C14)	1,000	0	1,000
Total spoil	**597,960**	**2,658,484**	**3,256,444**

The tunnel support sites would act as the primary facilities for receipt and dispatch of spoil.

Based on the depth of the tunnel and the local geology, the majority of excavated spoil material would be uncontaminated crushed sandstone and shale, classified as virgin excavated natural material (VENM). This spoil would consist of mixed size crushed rock, ranging from shale and sand to lumps of rock.

Potential opportunities for onsite reuse of spoil include use for the formation of embankments and earth mound noise barriers, site rehabilitation, and the infill of temporary tunnel access shafts and declines. About 80 per cent of usable (eg uncontaminated) construction and demolition waste is anticipated to be reused and / or recycled as part of the project. A Waste Management Plan would be prepared as part of the Construction Environmental Management Plan for the project, detailing the appropriate procedures for waste management. Residual waste which cannot be re-used or recycled would be disposed of to a suitably licenced landfill or waste management facility. Sites which have been identified as being appropriately licenced and potentially having capacity for spoil disposal are outlined in **Table 24-6**.

These potential offsite spoil application sites have been identified as preferred based on an analysis of commercial viability, traffic considerations and community impacts through the various construction phases of the project. Further consultation would take place with those facilities to confirm they are able to accept the required materials within the necessary timeframe, with consideration also given to other projects taking place in the area at the same time.

Excavated spoil would be tested and classified in accordance with the *Waste Classification Guidelines: Part 1 Classifying Waste* (EPA, 2014a) prior to being separated, stored and then transported away (if required) from each construction site. Spoil would be transported to disposal sites along nominated haulage routes. The identification of these haulage routes, potential impacts arising from their use and appropriate management measures are described in **Chapter 9** (Traffic and transport) and **Chapter 12** (Noise and vibration).

Stockpile management

Stockpiles would be located at the following construction compounds:

- Kingsgrove North (C1)
- Kingsgrove South (C2)
- Commercial Road (C3)
- Bexley Road North (C4)
- Bexley Road South (C5)
- Arncliffe (C7)
- Canal Road (C8)
- Campbell Road (C9)
- Campbell Road bridge (C12)
- Gardeners Road bridge (C13).

Construction stockpiles would also be located at the Alexandria Landfill. Suitable areas would be identified to allow for contingency management of unexpected waste materials, including contaminated materials, and to segregate materials for storage and recycling.

Measures would be implemented to manage stockpiles such as potentially locating stockpiles outside of overland flowpaths, riparian corridors and finished and contoured so as to minimise loss of material in flood or rainfall events. Stockpiles left exposed and undisturbed for longer than 28 days would be stabilised by compaction then either sprayed with suitable stabiliser, covered with anchored fabrics, or seeded with sterile grass.

Contaminated spoil

There is potential to encounter contaminated soil during construction of the project during surface works and / or from tunnelling activities. This potential and associated risk is assessed in **Chapter 17** (Contamination) through a preliminary risk evaluation.

In situ testing of soils in areas of potential contamination concern would be conducted to determine the appropriate waste classification. Contaminated spoil would need to be sampled and immobilised, before being transported and disposed of at a suitably licensed offsite location.

An Unexpected Finds Protocol would be implemented in the event of encountering previously unidentified area(s) or types of contaminated material. Where this happens, all relevant work would cease in the vicinity of the discovery in accordance with a unsuitable spoil management contingency procedure which would be included as part of the Spoil Management Strategy for the project. Relevant works would not recommence until the need for and scope of remedial action(s), if required, is identified in accordance with the requirements of the *Contaminated Land Management Act 1997*.

Special wastes

Acid sulfate soils

The potential for acid sulfate soils to be present within the construction footprint (**Chapter 16** (Soil and water quality)).

An acid sulfate soil management plan would be prepared as a sub-plan to the Construction Environment Management Plan to outline the requirements for the management of potential acid sulfate soils. Identified acid sulfate soil material would be stored temporarily in a bunded area, transported and treated and disposed of off-site at a licensed facility. Management of acid sulfate soils would be in accordance with the Guideline for the Management of *Acid Sulfate Materials* (RTA, 2005c).

Unexploded ordnance

Chapter 17 (Contamination) identified a former ammunition storage site as a potential area of contamination concern at the Bexley surface works. The site is located between Flatrock Road, Bexley Road and Wolli Creek and has the potential to contain unexploded ordnance and heavy metals. Prior to construction a due diligence assessment would be completed for explosive ordnance to further investigate the risk and identify appropriate management measures. The potential for heavy metals is discussed below.

Asbestos

There is the potential for asbestos containing materials to be present within noise mounds within Beverly Grove Park and within light industrial / commercial properties at Garema Circuit in Kingsgrove. Asbestos containing materials are known to occur at the Alexandria Landfill. The excavation, movement and disposal of asbestos containing materials would be undertaken in strict accordance with procedures detailed in the Asbestos Management Plan and Asbestos Removal Control Plans for the project, and the *Work Health and Safety Regulation 2011*. For further details on known and potentially contaminated sites within the project area, refer to **Chapter 17** (Contamination).

Heavy metals

There is the potential for heavy metals such as cadmium, arsenic, copper, lead, mercury, at magnesium, aluminium and iron to occur near the Commercial Road (C3) construction compound, Kingsgrove, due to the various historical and current commercial and industrial land uses that have occurred at this location. The excavation, movement and disposal of waste material that is identified as contaminated with heavy metals would be undertaken in strict accordance with the procedures detailed in the *Work Health and Safety Regulation 2011*. For further details on known and potentially contaminated sites within the project area, refer to **Chapter 17** (Contamination).

Materials excavated from within the Alexandria Landfill

The project would involve some excavation of Stockpile 21 within the Alexandria Landfill. Stockpile 21 is subject to a NSW EPA issued clean-up notice due to the presence of asbestos containing materials. Around 70,000 cubic metres of material to be excavated from Stockpile 21 would be reused onsite to maintain batter stability and for the construction of the stockpile mound in the south-east corner of the site (refer to **Figure 5-28** of **Chapter 5** (Project description) for the operational layout of the St Peters interchange). Excavated material that is identified as contaminated would be segregated from uncontaminated material on-site to prevent cross-contamination during landfill closure works, in accordance with a Construction Environmental Management Plan for the site. Additional detail regarding the management of contaminated material within the former Alexandria Landfill site is provided in **Chapter 16** (Soil and water quality), **Chapter 17** (Contamination), **Chapter 26** (Hazard and Risk), and **Chapter 10** (Air quality).

The Landfill Closure Management Plan would be implemented for works associated with the closure of the Alexandria Landfill. The Alexandria Landfill Closure Management Plan includes measures to manage excavated materials and wastes generated from works within the Alexandria Landfill and is provided at **Appendix F**.

In the instance that hazardous materials are encountered during construction works within the Alexandria Landfill site, it may be necessary to dispose of them off-site at a suitably licensed facility. Where materials excavated from within the Alexandria Landfill are identified as being potentially hazardous, they would be sampled at an appropriately licenced laboratory and sent offsite for as appropriate for treatment / disposal at a suitably licenced facility.

Spoil management strategy

A Spoil Management Strategy would be prepared and implemented for the project prior to the commencement of construction. The Strategy would take into account the construction staging and specific conditions of approval that may be applied to the project. The broad parameters within which the Strategy would be developed are summarised in **Table 24-6**.

Table 24-6 Spoil Management Strategy broad parameters

Parameter	Strategy response*
Spoil generation	About 3.2 million cubic metres of spoil
Spoil generation locations	Indicative volumes of spoil that would be generated at the construction compounds would include: • Kingsgrove North (C1), Kingsgrove South (C2) and Commercial Road (C3) construction compounds - about 500,000 cubic metres • Bexley Road North (C4) and South (C5) construction compounds - about 750,000 cubic metres • Arncliffe construction compound (C7) - about 1,025,000 cubic metres • Canal Road compound (C8) - about 880,000 cubic metres • Campbell Road compound (C9) - about 90,000 cubic metres • Burrows Road (C11) and Campbell Road bridge construction compounds (C12) - about 12,000 cubic metres • Sydney Park construction compound (C14) - about 1,000 cubic metres.
Spoil management hierarchy	Spoil would be managed following the hierarchy of avoidance, minimisation, reuse, recycling and finally disposal.
On-site management	Spoil would be transported from the tunnel face to the surface by truck or conveyer belt. Spoil would be stored and processed at construction site compounds. Environmental and workplace health and safety mitigation and management measures would be applied.
Spoil testing and classification	Spoil testing would be limited to initial testing to confirm the excavated material is VENM. VENM would be reused where possible.
Spoil category	Spoil would generally fall into one of the following categories, according to which it would be classified, stored and transported separately: • VENM, including materials such as clay, gravel, sand, soil or rock fines excavated from non-contaminated areas, and which do not contain sulfidic ores or soils, or any other wastes • Excavated natural material (ENM) (naturally occurring rick and soil such as sandstone clay and soil containing at least 98 per cent by weight natural material, and which does not meet the definition of VENM, and which does not contain processed materials, asbestos, acid sulphate soils or sulfidic ores, and which is therefore kept separate from VENM) • General solid waste • Potentially some contaminated materials. In order to determine which category spoil falls into, it may be necessary to conduct a soil analysis.

Parameter	Strategy response*
Potential spoil reuse locations	Potential spoil reuse locations would be consulted with during detailed design. Identified potential spoil reuse locations include: • Boral CSR Brick Pit, Townson Road, Schofields – capacity of around 550,000 cubic metres. Licensed to receive wastes onsite (types of waste not restricted in Environment Protection Licence 2014) • Defence Housing Australia Schofields Aerodome, Quakers Road, Quakers Hill – capacity of around 500,000 cubic metres. Further consultation would be required with Defence Housing Australia to confirm whether this site can receive such wastes • Austral Bricks, 738-780 Wallgrove Road, Horsley Park - capacity of around 3,000,000 cubic metres. Environment Protection Licence 546 allows the receipt of wastes onsite if those wastes are covered by a current resource recovery exemption under clause 51A of the *Protection of the Environment Operations (Waste) Regulation 2005*, and is also licensed to receive and apply wastes to land where this does not require licensing under the Act. Resource recovery exemptions relevant to the types of spoil generated by the project include those for excavated natural materials and excavated public road materials • Sakkara Riverstone West (North West Growth Centre development), Brandon Road, Riverstone - capacity of around 3,500,000 cubic metres. Further consultation would be required with this developer to confirm whether this site can receive such wastes • Kurnell Landfill Company - capacity of around 7,000,000 cubic metres. This site can receive virgin excavated materials, building and demolition wastes, and asphalt wastes only. Cannot receive contaminated wastes.
Spoil transport	Spoil would be transported from construction compounds by road using trucks.

* Quoted spoil volumes are accurate to the nearest 10,000 cubic metres

Wastewater

Tunnel construction would result in significant volumes of groundwater inflow that would require treatment and disposal. Wastewater volumes generated during tunnel construction would vary depending on construction activity, tunnel groundwater infiltration rate and excavated tunnel length. In addition, wastewater would be generated from other construction activities including dust suppression, wash down areas and stormwater runoff from construction compounds (grey water). Indicative total wastewater volumes generated over the duration of the construction period are identified in **Table 24-7.**

Construction water would either be re-used on site wherever feasible (refer **Table 24-3**), or discharged into the local stormwater system in accordance with the requirements of an environmental protection licence (if required). Preference would be given to reusing as much water as is practicable before discharging. Additional information regarding reuse of water during construction is provided in **Chapter 26** (Sustainability).

Table 24-7 Indicative wastewater volumes

Compound	Wastewater volume (mega litres)	Watercourse discharge point
Kingsgrove North construction compound (C1)	86	Wolli Creek
Commercial Road construction compound (C3)	86	Wolli Creek
Bexley Road South construction compound (C5)	340	Wolli Creek
Arncliffe construction compound (C7)	676	Cooks River
Canal Road construction compound (C8)	370	Alexandra Canal
Landfill Closure compound (C9)	108	Alexandra Canal
Total	1,666	

Five water treatment plants would be used during construction of the project. These would be located at the Kingsgrove North compound (C1), the Commercial Road construction compound (C3), the Bexley Road South construction compound (C5), the Arncliffe construction compound (C7) and the Canal Road construction compound (C8). Details of water treatment methods and discharge water quality are provided in **Chapter 16** (Soil and water quality). A leachate treatment system would be installed at the landfill and is discussed in **Chapter 17** (Contamination). For further information on water treatment plants proposed to collect and treat construction water, surface water runoff and groundwater inflows, as well as the expected groundwater discharge volumes during both construction and operation, refer to **Chapter 16** (Soil and water quality).

An updated water balance would be prepared during detailed design. The outcomes of this study would be used to further improve water efficiency during construction and operation.

General construction waste

General construction waste generated by the project would include:

- Demolition waste from existing structures that require removal
- Green waste from the removal of trees, shrubs and ground covers that are unable to be mulched and reused within the project
- General construction waste including:
  - Packaging materials such as crates, pallets, cartons, plastics and wrapping materials
  - Surplus construction material and general site reinstatement such as fencing, sediment, concrete, steel, formwork and sand bags
  - Timber formwork, scrap metal, steel, concrete, and plasterboards
- Site office waste generated by on site personnel such as paper, cardboard, plastic, glass and food waste
- Construction vehicle waste (operation and maintenance) including waste fuels and oil, adhesives, lubricants, engine coolant, roadheader picks, batteries, hoses and tyres
- Sewage waste generated from the use of construction compounds.

Potential adverse impacts arising from waste management associated with construction of the project include:

- Excessive volumes of materials directed to landfill due to insufficient recycling and reuse
- Excessive volumes of materials directed to landfill due to unnecessary or inefficient resource consumption and inadequate collection, classification and disposal of waste
- Dust impacts due to incorrect storage, handling and disposal
- Contamination of soil, surface and / or groundwater from the inappropriate storage, transportation and disposal of liquid and solid waste.

- Demolition waste generated by the project has the potential to contain hazardous materials, in particular asbestos containing materials. Such waste would be managed and disposed in accordance with:
  - *Work Health and Safety Act 2011*
  - Code of Practice for the Safe Removal of Asbestos 2nd Edition
  - Code of Practice for the Management and Control of Asbestos in Workplaces
  - Protection of the Environment Operations (Waste) Regulation 2014, in particular Part 7 Transportation and management of asbestos waste
  - AS2601:2001 Demolition of Structures.

Waste types and volumes generated during construction of the project would be typical of that produced on tunnel construction projects of this scale. Approximately 100,000 cubic metres of non-spoil waste would be disposed of between June 2016 and October 2016, and a further 40,000 cubic metres between April 2017 and March 2018.

Several licenced disposal sites have been investigated for the disposal of non-spoil construction waste. In particular, the Transpacific Waste Management Services site at Erskine Park has capacity for a further approximate 300,000 cubic metres of landfill. Transpacific Waste Management Services are currently seeking development approval to increase the landfill volume of this site by 150,000 cubic metres. Further, Transpacific Waste Management Services have other suitable sites identified and are currently in negotiations to secure these sites to provide ongoing general solid waste disposal services. Consequently, it is expected that existing and proposed metropolitan waste management facilities would have capacity to receive waste streams generated by construction of the project.

Waste management activities associated with construction of the project would not pose a significant risk to the environment with the implementation of standard mitigation measures as provided in **Table 24-10**.

Operation resource consumption

Water resources

Operation of the project would require around four mega litres of water per annum. The majority of water would be required for the operation and regular testing of the tunnel deluge system, which forms part of the fire and life safety system. Other uses of water during operation include water use in buildings and general maintenance activities (for example tunnel washing).

The primary source of water during operation would be potable water. However, alternative sources, such as rainwater harvesting, would be explored during detailed design. Other sustainability initiatives to reduce water consumption are discussed in **Chapter 28** (Sustainability).

Power

The project has been designed to minimise operational energy consumption and maximise efficiency. The vertical alignment of the main alignment tunnels would allow consistent vehicle speeds to be maintained, thereby minimising fuel use. Further, low carbon energy generation options would be investigated as part of the design process in order to reduce the demand on mains electricity where feasible. During operation, the project would consume around 30,000 megawatt hours of electricity per annum as a result of:

- Ventilation, hydraulic and lighting systems in the main alignment tunnels, which would consume the greatest quantity of power
- Daily use of traffic management system and variable message signs
- Building and equipment, eg server and computer equipment, tolling facilities, water pumps, heating, lighting and air conditioning.

For further details of the operational management measures to reduce the project's power consumption, refer to **Chapter 22** (Greenhouse gas).

Peak oil

Peak oil refers to the fact that oil production may peak or has already peaked, and that oil production would decline thereafter. The impact could increase the cost and reduce the availability of transport fuels. Peak oil issues in relation to transport generally include the use of fossil fuels, the energy efficiency of vehicles and construction products derived from fossil fuels.

The environmental impacts of the project have been assessed in accordance with statutory requirements and the SEARs. Although peak oil is not considered in these requirements, Roads and Maritime Services acknowledges that it is prudent to consider peak oil.

Despite efforts to limit demand for road transport, it is expected that the need for transport will continue to grow as described in **Chapter 3** (Strategic context and project need). The WestConnex program of works is intended to link Sydney's west with the airport and the Port Botany precinct, increasing travel speeds, decreasing travel distances and improving travel efficiency. This may result in an overall reduction in the quantity of fuel consumed.

Further, by alleviating road congestion pressures, the project would indirectly facilitate the use and reliability of road based public transport (refer to **Chapter 3**). The project would also be able to be utilised by non-fossil fuel powered vehicles.

Government and industry initiatives relevant to peak oil but outside the scope of this project include the *NSW Government Resource Efficiency Policy* (OEH, 2014a) and the participation of Roads and Maritime, Austroads and industry in research with the goal of developing more sustainable road construction materials and practices reducing reliance on products derived from oil.

24.1.2 Operation waste management

Solid waste

Waste generated by the operation of the project would be limited. Routine maintenance, repair activities, and operation of the motorway control centre would contribute to the majority of operational waste for the project. Predominant operational waste would include:

- General office waste such as paper, plastics and food waste
- Green waste from landscaping activities and waste grit from soil and road sweepers
- Road materials and general litter along the motorway
- Contaminated waste from potential fuel spills and leaks
- Chemicals, oils and liquids used for road maintenance activities.

No additional management measures would be required to accommodate operational waste and it would be managed by standard work practices and existing metropolitan waste management facilities. Waste generation and management during operation of the project would be minimal.

Wastewater

As the tunnels would be drained, there would be a low level of ongoing inflow of groundwater into the tunnels. This would require the ongoing capture, treatment and discharge of groundwater during the operation of the project. The predicted daily groundwater inflow into the main alignment tunnels is about 1,700 kilolitres. Other sources of operational wastewater within the tunnels include stormwater entering the tunnels via the portals, deluge water, washdown water and hydrant water.

Wastewater collected within the tunnels would be captured and treated as follows:

- Wastewater collected from sections of the main alignment tunnels located east of the Cooks River have the potential to be contaminated, and as such would be captured and treated separately via a two-step treatment using a groundwater treatment plant and an artificial wetland. The treated water would be discharged into the Cooks River.
- Wastewater from sections of the main alignment tunnels located west of the Cooks River would be captured and treated at a groundwater treatment plant prior to discharge to Cook's River.

Discharge water quality would be determined in consultation with the NSW Environment Protection Authority and having regard to ANZECC water quality guidelines.

For details regarding leachate management at Alexandria landfill refer to **Chapter 17** (Contamination).

Further information on groundwater inflow, drainage and treatment is provided in **Chapter 16** (Soils and water quality), **Chapter 18** (Flooding and drainage) and **Chapter 19** (Groundwater).

24.2 Environmental management measures

Measures to avoid, minimise or manage resource consumption and waste generation during construction are outlined in **Table 24-8.**

Table 24-8 Environmental management measures – resource and waste

Impact	No	Environmental management measures	Timing
Construction			
Resource consumption	WM01	Construction energy consumption would be reduced through initiatives such as: • Use of roadheaders, which can excavate a more efficient shape for the road tunnel than tunnel boring machines, resulting in less spoil generation and less energy consumption for handling, management and transport of spoil • Local materials procurement where feasible and cost effective to reduce fuel consumption for transport • Selection of efficient construction plant and equipment where possible • Use of recycled materials where feasible • Efficient practices on site (for example, switching off engines when not in use) • Use of energy efficient or solar powered lighting for temporary construction facilities • Investigating the use of biofuel for construction vehicles.	Construction
	WM02	Where feasible and reasonable, construction material would be sourced from within the Sydney region.	Pre-construction and construction
	WM03	Unnecessary resource consumption would be avoided by making realistic predictions of the required quantities of resources such as construction materials	Construction

Impact	No	Environmental management measures	Timing
	WM04	Resource recovery would be applied to the management of construction waste and would include: • Recovery of resources for reuse-reusable materials generated by the project would be segregated for reuse either on-site or off-site where possible, including the reuse of the major waste streams (VENM and ENM) • Recovery of resources for recycling - recyclable resources (such as metals, plastics and other recyclable materials) generated during construction and demolition • Resources would be segregated for recycling • These materials would then be sent to an appropriate recycling facility for processing. • Recovery of resources for reprocessing - cleared vegetation would be mulched or chipped on-site and used for landscaping, in the absence of a higher beneficial use being identified.	Construction
	WM05	Where reasonable and feasible, Packaging Take Back arrangements would be implemented with suppliers.	Construction
Management of waste	WM06	Wastes would be managed (classified, handled and stored) and reused / recycled / disposed of in accordance with relevant State legislation and government policies including the POEO Act*, Waste Avoidance and Resource Recovery Act 2001, Waste Avoidance and Resource Recovery Strategy 2014-2021* (EPA, 2014b), and the sustainable procurement objective of the WestConnex sustainability strategy (WestConnex Delivery Authority, 2015).	Construction
	WM07	A Construction Waste Reuse Recycling and Energy plan (CWRREMP) would be prepared as part of the Construction Environmental Management Plan detailing appropriate procedures for waste management. The Construction Waste Recycling Reuse Environment Management Plan would ensure waste disposal and energy use is minimised by tracking and reporting performance and applying corrective action as required.	Construction

Impact	No	Environmental management measures	Timing
	WM08	Wastes would be managed using the waste hierarchy principles of: • Avoidance of unnecessary resource consumption to reduce the quantity of waste being generated. • Recover resources for reuse on-site or off-site for the same or similar use, without reprocessing. • Recover resources through recycling and reprocessing so that waste can be processed into a similar non-waste product and reused. • Disposal of residual waste.	Construction
	WM09	Residual waste would be disposed of to a suitably licensed landfill or waste management facility where there are no other feasible and reasonable options for waste avoidance, reuse or recycling. Waste materials requiring removal from the site would be classified, handled and stored in accordance with the *Waste Classification Guidelines: Part 1 Classifying Waste* (EPA, 2014a) until collection by a contractor for disposal.	Pre-construction and construction
	WM10	Off-site reuse of waste would comply with relevant NSW Environment Protection Authority resource recovery exemptions and requirements.	Construction
	WM11	Asbestos handling and management would be undertaken in accordance with the project's Asbestos Management Plan and relevant legislation, policies and standards: • *Work Health and Safety Act 2011* • *Code of Practice for the Safe Removal of Asbestos 2nd Edition (NOHSC, 2005a).* • *Code of Practice for the Management and Control of Asbestos in Workplaces (NOHSC, 2005b).* • *Protection of the Environment Operations (Waste) Regulation 2014* – Part 7 Transportation and management of asbestos waste. • Australian Standard AS2601:1991 Demolition of Structures.	Pre-construction
	WM12	Measures would be implemented to manage stockpiles such as potentially locating stockpiles outside of overland flowpaths, riparian corridors and finished and contoured so as to minimise loss of material in flood or rainfall events. Stockpiles left exposed and undisturbed for longer than 28 days would be stabilised by compaction then either sprayed with suitable tackifier, covered with anchored fabrics, or seeded with sterile grass.	

Impact	No	Environmental management measures	Timing
Excess spoil	WM13	A Spoil Management Strategy would be developed prior to the commencement of construction and implemented during construction. The strategy would identify spoil disposal sites and describe the management of spoil on-site and during off-site transport.	Pre-construction
	WM14	Where possible and fit for purpose, spoil would be beneficially reused within the project before off-site reuse or disposal options are pursued.	Construction
	WM15	Before being transported from construction sites, excavated spoil would be classified in accordance with the *Waste Classification Guidelines: Part 1 Classifying Waste* (EPA, 2014a) to ensure appropriate reuse or disposal.	Construction
Wastewater	WM16	Feasible and reasonable opportunities for wastewater reuse on-site or for construction purposes would be pursued (such as dust suppression both in the tunnels and for surface works).	Construction
	WM17	Wastewater not used on-site would be discharged into the local stormwater system in accordance with the requirements of an environment protection licence issued for the project.	Construction
Contaminated soil	WM18	An Unexpected Finds Protocol would be implemented in the event of encountering previously unidentified area(s) or types of contaminated material. Where this happens, all relevant work would cease in the vicinity of the discovery in accordance with a unsuitable spoil management contingency procedure which would be included as part of the Spoil Management Strategy for the project. Relevant works would not recommence until the need for and scope of remedial action(s), if required, is identified in accordance with the requirements of the *Contaminated Land Management Act 1997*.	Construction

Impact	No	Environmental management measures	Timing
Operation			
Management of waste	OPWM01	Wastes would be managed and disposed of in accordance with relevant State legislation and government policies including the POEO Act, *Waste Avoidance and Resource Recovery Act 2001*, *Waste Avoidance and Resource Recovery Strategy 2014-2021* (EPA, 2014b), and the sustainable procurement objective of the *WestConnex sustainability strategy* (WestConnex Delivery Authority, 2015).	Operation
Operational water requirements	OPWM02	Opportunities for reuse of wastewater would be considered in preference to discharge to the local stormwater system.	Detailed design and operation
	OPWM03	In order to reduce demand on local water supplies, options would be investigated for providing water required for operation of the deluge system from wastewater produced through the tunnel drainage system where it meets appropriate quality parameters.	Detailed design and operation

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25 Climate change risk and adaptation

The NSW Government has acknowledged that, despite efforts to reduce greenhouse gas emissions, some climate change is now inevitable. The Government aims to minimise the impacts of climate change on natural and built environments, communities and the economy.

Road networks and infrastructure assets are exposed and vulnerable to climate change because of their long design life, during which many impacts of climate change may become more significant.

Roads and Maritime determined that the assessment of the potential impact of climate change on the project is warranted due to the significant investment required for the project, the long design life of the project, and its exposure to potential flooding impacts.

This chapter outlines the methodology adopted to assess the impacts of climate change on the project and adaptation measures that could be implemented.

The assessment addresses the requirements of the Secretary of the Department of Planning and Environment 9SEARs (**Table 25-1**).

Table 25-1 SEARs – climate change risk and adaptation

SEAR	Where addressed
Identification of potential impacts of the proposal on existing flood regimes demonstrating consideration of the changes to rainfall frequency and/or intensity as a result of climate change…	Changes to rainfall frequency and / or intensity as a result of climate change are discussed in **Appendix W** (Climate change risk assessment framework) and **Section 25.4**.

During detailed design, a detailed Climate Change Risk Assessment would be undertaken in accordance with the Australian Standard AS 5334-2013 *Climate change adaptation for settlements and infrastructure - A risk based approach*, and would be informed by this initial Climate Change Risk Assessment.

25.1 Assessment methodology

Roads and Maritime Services (Roads and Maritime) is currently in the process of finalising a Technical Guide for Climate Change Adaptation for the State Road Network. The Guide is aligned with existing Roads and Maritime processes and broader NSW Government initiatives and programs responding to climate change impacts. This assessment adopts the approach of the latest draft to ensure consistency with Roads and Maritime's approach to climate change adaptation.

Further, this assessment considers the impact of future climate change on the project, rather than the impact of the project on the future of climate change. Impacts of the project on climate change relate to greenhouse gas emissions generated from the construction and operation of the project, which have been assessed in **Chapter 22** (Greenhouse gas). Greenhouse gas calculations are provided in **Appendix U**.

The climate change risk assessment has been carried out in line with the following relevant standards and current guidelines:

- The risk assessment approach set out in AS/NZS ISO 31000:2009 *Risk Management – Principles and Guidelines* and ISO/IEC 31010 *Risk Management – Risk assessment techniques*
- Australian Standard AS 5334-2013 *Climate change adaptation for settlements and infrastructure - A risk based approach* - follows the International Standard ISO 31000:2009 *Risk Management – Principles and guidelines*
- *Australian Green Infrastructure Council, Guideline for Climate Change Adaptation, Revision 2.1* (2011)
- *Draft Technical Guide for Climate Change Adaptation* (RMS (unpublished), 2015d).

The overall approach is focused on risk management and is closely aligned with *AS/NZS 31000:2009 Risk Management* and complements Roads and Maritime's *Guidelines for Risk Management*. The approach comprises the following steps:

- Pre-screening
- Screening
- Detailed risk assessment
- Risk evaluation
- Adaptation (risk treatment).

Each of these steps is described in the following sections.

25.1.1 Pre-screening

A pre-screening process was undertaken by Roads and Maritime before the climate change risk assessment was carried out to determine whether the project is likely to be impacted by climate change. As previously mentioned, it was determined that the assessment of the impact of climate change on the project is warranted due to the significant investment required, the long design life of the project, and exposure of the project to potential flooding impacts.

25.1.2 Screening

Screening aims to identify potential exposure to relevant climate change impacts. Each roads project has a range of engineering components and service provisions and is subject to different climate change impacts, and therefore different risks. As a result, it is not appropriate to consider a generic list of climate change risks.

For the project, specific risks were identified using a screening matrix, which plots relevant elements of the project on one axis and key climate change variables relevant to the region on the other axis. By identifying the intersection between the climate change variables and the elements of the project, relationships can be identified and used to form the basis of potential risk scenarios for further analysis. This step forms part of the 'risk identification' of a typical risk management process as described in Roads and Maritime's *Guidelines for Risk Management* (Roads and Maritime, 2014d).

The climate change risk screening for the project is provided in **Appendix W** (Climate change risk assessment framework).

25.1.3 Detailed risk assessment

The first step of the detailed risk assessment is the formulation of risk scenarios for each of the relationships identified in the screening stage. Each risk scenario is then analysed in detail by assigning a likelihood and consequence rating. The criteria used for likelihood and consequence (following the Roads and Maritime *Guidelines for Risk Management*) are shown in Table 1-1 and Table 1-2 of **Appendix W** (Climate change risk assessment framework). The consequence rating considers the potential consequence of climate change on the project in terms of the physical asset (damages) and in terms of service provision (loss).

By combining the likelihood and consequence rating for each risk scenario, using the risk ranking matrix in **Table 25-2** the level of risk can be determined. These are the original risk levels before any mitigation measures are applied. For example a risk with medium likelihood and low consequence results in a risk level of low.

The detailed risk assessment for the project is provided in **Appendix W** (Climate change risk assessment framework).

Table 25-2 Risk level matrix

Likelihood	Consequence					
		Negligible	**Low**	**Medium**	**High**	**Extreme**
	Extreme	Medium	High	Extreme	Extreme	Extreme
	High	Low	Medium	High	Extreme	Extreme
	Medium	Negligible	Low	Medium	High	Extreme
	Low	Negligible	Negligible	Low	Medium	High
	Negligible	Negligible	Negligible	Negligible	Low	Medium

25.1.4 Risk evaluation

The purpose of risk evaluation is to identify which of the risks require treatment. Treatments designed to mitigate the risks should be applied to those risks evaluated as extreme or high. Risks evaluated as negligible or low do not require any further consideration. As this is a preliminary climate change risk assessment and a subsequent detailed risk assessment will be undertaken, medium risks have been retained for consideration.

The risk evaluation for the project is provided in **Section 25.3.2**.

25.1.5 Adaptation (risk treatment)

This step involves the development of risk treatments that can reduce the original unmitigated risk rating. Some adaptation options have been presented **Section 25.4** for consideration during detailed design.

25.2 Existing environment

An increase in global concentrations of greenhouse gases has led to an increase in the Earth's average temperature (surface temperature) (IPCC, 2013). The most recent Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2013) states that 'human influence on the climate system is clear. This is evident from the increasing greenhouse gas concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system'.

In 2015, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Meteorology (BoM) released an assessment of observed climate change and projected future changes in Australia over the 21st century (CSIRO and BoM, 2015a). This recent assessment confirms the long term warming trend: showing that in Australia, the average surface air temperature has increased by 0.9 degrees Celsius (degrees Celsius) since records began in 1910, with most of the warming occurring since 1950. Australia's warmest year since 1910 was in 2013 (CSIRO and BoM, 2015a).

The AR5 states with high confidence that Australia is already experiencing impacts from recent climate change. Observed trends include changes in the frequency of air temperature extremes, changes in mean and extreme rainfall, changes in the frequency and intensity of storm events, ocean warming, ocean acidification and sea level rise.

Due to the long lag times associated with climate processes, even if greenhouse gas emissions are mitigated and significantly reduced, the warming trend and associated impacts of climate change are expected to continue for centuries (IPCC, 2007).

Key projected trends include:

- Increase in atmospheric carbon dioxide concentrations
- Increase in mean temperature
- Increase in heat extremes
- Decrease in cold extremes
- Changes in mean rainfall
- Changes in the intensity and frequency of extreme rainfall and storm events
- Increase in sea level
- Increase in extreme sea levels (eg storm surges)
- Increase in ocean acidity
- Increase in bushfire weather.

The magnitude of these projected changes will vary both spatially and temporally (IPCC, 2013).

Road networks and infrastructure assets are exposed and vulnerable to climate change because of their long design life, during which many impacts of climate change are likely to become more significant.

The main impacts to road networks and infrastructure assets as a result of climate change are associated with an increase in extreme rainfall intensity and frequency (which can exacerbate flooding or landslides risks, and damage to pavement) and from sea level rise (which will worsen damage from coastal erosion, storm surge and coastal flooding and may even eventually lead to long-term inundation and loss of land). The largest impacts are likely to be borne by roads in upland areas with steep topography, and by coastal roads in areas exposed to coastal erosion and storm surge.

Appendix W (Climate change risk assessment framework) provides information regarding the existing climate and historical climate trends of the project area.

25.2.1 Future climate

This section presents climate projections relevant to the project. The climate projections are based on information published by CSIRO and BoM in 2015. As the project has been designed for a 100 year design life, projections modelled for 2090 (an average of the period 2080-2100) have been selected for the assessment, which are the available projections for the time horizon closest to the end of the project's design life.

Projections for south-east Australia have also been published by the NSW / ACT Regional Climate Modelling (NARCliM) project (2014) in collaboration with the NSW Office of Environment and Heritage (OEH). However, NARCliM projections are not yet available for a number of key climate variables (extreme rainfall, sea level rise, storm surge, wind speed). This presents limitations when considering climate change impacts in road planning.

Projections provided by CSIRO and BoM are considered most appropriate for this project and are recommended in the Roads and Maritime Climate Change Adaptation Practice Note (Roads and Maritime, unpublished, 2015d). It is important that only a single source of projections is used for a climate change risk assessment. This ensures an 'internally consistent climate future' approach is used, whereby a consistent set of assumptions, scenarios, and modelling method is applied to each projection. As such, a combination of NARCliM and CSIRO and BoM projections has not been used.

Projections are presented for two emission scenarios or possible pathways, referred to as 'representative concentration pathways' (RCPs), each of which reflects a different concentration of global greenhouse gas emissions. The two RCPs reported here are intermediate emissions (RCP4.5) and high emissions (RCP8.5). Intermediate emissions projections are only provided in this report for context; the assessment is based on high emissions projections, to account for a worst case scenario based on the precautionary principle (refer to **Chapter 28** (Sustainability) for more information).

The ensemble of projections published by CSIRO and BoM (2015b) are spatially broken down into eight natural resource management 'clusters', which largely correspond to broad-scale climate and biophysical regions of Australia. Projections at this scale are considered appropriate for the consideration of future climate for road projects. The project falls within the east coast cluster. This cluster forms the central part of the eastern seaboard of Australia, straddling the Queensland−NSW border immediately east of the ridgeline of the Great Dividing Range. It extends from south of Sydney in NSW to north of Rockhampton in Queensland.

A summary of projections for the east coast cluster for 2090 for both the Intermediate and high emissions scenarios is provided in **Table 25-3** followed by a description of each climate variable.

Table 25-3 Projections for the East Coast Cluster for 2090

Climate variable	RCP4.5	RCP8.5
Mean surface temperature	Increase of 1.3 degrees Celsius to 2.5 degrees Celsius	Increase of 2.7 degrees Celsius to 4.7 degrees Celsius
Extreme temperature (days per year, Sydney)	Increase of 6.0 (over 35 degrees Celsius) Increase of 0.9 (over 40 degrees Celsius)	Increase of 11 (over 35 degrees Celsius) Increase of 2.0 (over 40 degrees Celsius)
Mean annual rainfall (per cent)	Decrease by 5 per cent to 15%	Decrease by at least 15 per cent
Extreme Rainfall (one in 20 year, per cent)	Increase by 10 per cent to +30 per cent	Increase by +10 per cent to +30 per cent
Mean annual wind speed (per cent)	Between a decrease of 1% and increase of 1%	Between a decrease of 1% and increase of 1%
Bushfire weather (annual cumulative forest fire danger index (FFDI) / number of days with a fire danger rating of severe and above)	Increase of annual cumulative FFDI by 13 per cent Increase of number of days with a fire danger rating of severe and above by 45 per cent	Increase of annual cumulative FFDI by 30% Increase of number of days with a fire danger rating of severe and above by 130 per cent
Sea level (metres) (compared to 1986-2005)	Increase of 0.30 metres to 0.65 metres	Increase of 0.44 metres to 0.88 metres

Source: CSIRO and BoM, 2015b

Mean surface temperature

Mean surface temperature is projected to continue warming during the 21st century, at a rate that strongly reflects the increase in global greenhouse gas emissions (CSIRO and BoM, 2015b). By 2090 mean surface temperatures are projected to increase by 1.3 degrees Celsius to 2.5 degrees Celsius under RCP4.5 and by 2.7 degrees Celsius to 4.7 degrees Celsius under RCP8.5. There is very high confidence in these projections (CSIRO and BoM, 2015b).

Extreme temperature

The trend of increasing extreme temperatures is projected to continue, with increases in the annual number of days over 35 degrees Celsius and 40 degrees Celsius projected for Sydney. The current number of days over 35 degrees Celsius in Sydney is 3.1 and the current number of days over 40 degrees Celsius in Sydney is 0.3. By 2090:

- under intermediate emissions, the annual number of days over 35 degrees Celsius is projected to increase for Sydney by 2.9 days, and the annual number of days over 40 degrees Celsius is projected to increase by 0.6 days (CSIRO and BoM 2015b)

- under high emissions the annual number of days over 35 degrees Celsius and 40 degrees Celsius is projected to increase by 11 and 2.0 days respectively (CSIRO and BoM 2015b). There is very high confidence in these projections (CSIRO and BoM, 2015b).

Mean annual rainfall

By 2090, under intermediate emissions, the change in mean annual rainfall is projected to range from a 15 per cent decrease to a five per cent increase (CSIRO and BoM 2015b). The direction of trend is more clear under high emissions, projecting a drying by more than 15 per cent by 2090 (CSIRO and BoM 2015b).

Despite the projected drying trend for mean rainfall under RCP8.5, it is projected that extreme rainfall events will become more frequent and intense (refer to discussion of extreme rainfall below).

There is generally a high degree of uncertainty in rainfall projections due to the fact that mean rainfall in Australia is influenced by a number of climate drivers and there is no consensus on how these drivers will be affected by and respond to climate change. As such, there is a low confidence in mean rainfall projections (CSIRO and BoM, 2015b).

Extreme rainfall

Projections of extreme rainfall events (wettest day of the year and wettest day in 20 years) are projected to increase in intensity across Australia. By 2090, one in 20 year extreme rainfall events are expected to increase by 10 per cent to 30 per cent under intermediate emissions and high emissions scenarios respectively (CSIRO and BoM, 2015b). There is high confidence that the intensity of extreme rainfall will increase in the east coast cluster. However, the magnitude of the change cannot be reliably projected (CSIRO and BoM, 2015b).

Mean annual wind speed

Projections of annual mean wind speed for the east coast cluster do not indicate much change for 2090. Under both intermediate emissions and high emissions, the projected change in mean wind speed is between plus and minus one per cent (±1%) (CSIRO and BoM, 2015b). There is low to medium confidence in these projections (CSIRO and BoM, 2015b).

Bushfire weather

Projections of fire weather show that projected warming and drying will lead to fuels that are drier, with increases in the average Forest Fire Danger Index (FFDI) and a greater number of days with a severe fire danger rating and above (CSIRO and BOM 2015b). By 2090, under RCP4.5, cumulative FFDI is projected to increase by 13 per cent, and the number of days with severe fire danger is projected to increase by 45 per cent. Under RCP8.5, cumulative FFDI is projected to increase by 30 per cent and the number of days with a fire danger rating of severe and above is projected to increase by 130 per cent. There is a high confidence that climate change will result in a harsher fire weather climate in the future, however there is low confidence in the magnitude of the change, largely due to the uncertainty associated with rainfall projections (CSIRO and BoM 2015b).

Sea level rise

CSIRO and BOM (2015b) state that there is very high confidence that sea levels will continue to rise during the 21st century. By 2090, projections differ significantly between RCPs. Sea levels along the east coast cluster shoreline are projected to rise by 0.30 metres to 0.65 metres under RCP4.5, and by 0.44 metres to 0.88 metres under RCP8.5. The continued increase in sea levels along the east coast is projected with very high confidence (CSIRO and BoM, 2015).

Extreme sea level

For 2090, under RCP8.5 and RCP4.5, CSIRO and BoM (2015b) have calculated an ‘allowance’ which is the minimum distance required to raise an asset to maintain the current frequency of breaches under projected sea level rise. The allowance takes into account the nature of extreme levels along the coastline. This is the parameter which should be used in planning along the coastline. For 2090, along the east coast cluster coastline, the vertical allowance ranges from 0.55 metres to 0.63 metres under RCP4.5 and 0.78 metres to 0.89 metres under RCP8.5.

Increase in atmospheric carbon dioxide

The current concentration of atmospheric carbon dioxide (CO_2) is approximately 400 parts per million (ppm) (National Oceanic and Atmospheric Administration, 2015). RCP8.5 represents a future with little curbing of emissions, with CO_2 concentration continuing to rapidly rise, reaching 940 ppm by 2100. Under RCP4.5 concentrations peak at around 2040 and CO_2 concentrations reach 540 ppm by 2100.

25.3 Assessment of potential impacts

25.3.1 Construction

The potential impacts of climate change would be negligible during the construction phase due to its relatively short timeframe. These potential impacts are therefore not considered further in this assessment and the focus of the chapter is on potential operational impacts.

25.3.2 Assessment of potential operational impacts

Operation Risk Evaluation

As discussed in **Section 25.1.4**, high and extreme risks identified in the detailed risk assessment should be treated. The detailed risk assessment carried out for the project (refer to **Appendix W** (Climate change risk assessment framework)) did not identify any risks rated as high or extreme. Of the 28 risks that were analysed for the project, 13 were identified as having a medium risk. These risks rated as medium are listed in **Table 25-4** for consideration in the subsequent detailed risk assessment to be undertaken during detailed design.

Table 25-4 Climate change risks ranked medium

Risk scenario
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated localised flood risks the crossings over Alexandra Canal.
Increase in atmospheric CO_2 and the frequency and intensity of extreme heat events leads to accelerated deterioration of bridge structures due to corrosion and thermal expansion of steel reinforcement in concrete and thermal expansion of steel, protective cladding, and coatings on bridges.
Increase in the intensity and frequency of extreme rainfall adversely affects performance of the surface drainage system(s) at the western surface works as a result of increased runoff, leading to localised flooding of surface roads, and potential flooding of ancillary infrastructure, substations, landscaped areas and within the main alignment tunnels.
Increase in the intensity and frequency of extreme rainfall combined with sea level rise (and increased extreme sea levels during storm surges) adversely affects performance of the surface drainage system at St Peters interchange and local road upgrades as a result of inundation, leading to localised flooding of surface roads, ancillary infrastructure, substations, landscaped areas and within the main alignment tunnels.
Sea level rise causes reduced performance or failure of water treatment system(s) as a result of increased water levels at the location of the submerged discharge infrastructure in Cooks River and deterioration from saline intrusion.
Increased frequency and intensity of bushfire events due to increased bushfire weather adversely affects performance of tunnel ventilation system as a result of smoke pollution.
Decrease in mean rainfall combined with an increase in mean surface temperature and the frequency and intensity of extreme heat events, leads to exacerbated risk of dust storms adversely impacting the performance of tunnel ventilation system.
Increase in frequency and intensity of extreme heat events causes higher temperatures within the tunnel.
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated risk of flooding of Alexandria Landfill Leachate Treatment System.

Risk scenario
Sea level rise causes failure of the underground cut-off wall at Alexandria Landfill due to raised water table.
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated risk of flooding of Alexandria Landfill gas capture system.
Increase in the intensity and frequency of extreme rainfall leads to exacerbated risk of road incidents.
Increase in frequency and intensity of extreme heat events increases the risk of heat stress conditions for operational personnel.

25.4 Environmental management measures

Table 25-5 provides environmental management measure to be implemented to reduce the risk from climate change on the project during operation.

During detailed design, a detailed Climate Change Risk Assessment would be undertaken (in accordance with the standard AS 5334-2013 *Climate change adaptation for settlements and infrastructure - A risk based approach*). The assessment would identify and implement adaptation measures to comprehensively address high and extreme risks. The decision to implement adaptation measures for medium risks would also be considered during detailed design. **Table 25-6** provides a list of adaptation options which are available for consideration during detailed design and the subsequent detailed climate change risk assessment.

Table 25-5 Environmental management measures – climate change risk and adaptation

Impact	No.	Environmental management measures	Timing
Construction			
The impacts of climate change to the project during construction are negligible.			
Operation			
Climate change impacts	CC01	The risk associated with future climate change on the project would be further considered during detailed design.	Pre-construction
	CC02	Implement adaptation measures (refer to **Table 25-6**) to address high and extreme rated risks identified in the subsequent detailed climate change risk assessment.	Pre-construction
	CC03	Where extreme, high or medium risks have been identified in this assessment or subsequent climate change risk assessments, a review of the existing design policies, specifications or practices would be undertaken to consider the impacts of climate change.	Pre-construction

Table 25-6 Adaptation options for consideration during detailed design

Impact	Adaptation option	Timing
Increase in atmospheric CO_2 leads to accelerated deterioration of concrete structures due to corrosion of steel reinforcement in concrete.	In the detailed design of concrete structures, if reasonable and feasible, consider options to mitigate the potential impacts to concrete from increasing atmospheric CO_2 (eg thicker concrete, sacrificial layers and protective chemical layers etc).	Detailed design
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges) leads to exacerbated localised flood risks for bridge crossings over Alexandra Canal.	Apply a minimum of 10 per cent sensitivity testing (as required by the draft Roads and Maritime Technical Guide) to hydrological / hydraulic modelling on detailed design, combined with extreme sea level scenario incorporating projected sea level rise by 2090. Consider applying 25 per cent sensitivity testing to this model, which is the recommended sensitivity test value (as per the draft Roads and Maritime Technical Guide) for the projected temperature increases and the design life of the asset. During detailed design, consider incorporating additional drainage network features and flood protection measures (e.g. larger drainage network, additional pits, larger pipe diameters, larger sumps etc.) to mitigate a potential increase in flood risks.	Detailed design
Increase in the intensity and frequency of extreme rainfall adversely affects performance of surface drainage system at western surface works.	Apply a minimum of 10 per cent sensitivity testing (as required by the draft Roads and Maritime Technical Guide) to hydrological/hydraulic modelling on detailed design, including drainage design. Consider applying 25 per cent sensitivity testing to this model, which is the recommended sensitivity test value (as per the draft Roads and Maritime Technical Guide) for the projected temperature increases and the design life of the asset. In the detailed design of drainage systems, consider the incorporation of additional drainage network features and flood protection measures (e.g. larger drainage network, additional pits, larger pipe diameters, larger sumps etc.) into drainage systems to mitigate a potential increase in flood risks.	Detailed design
Increase in the intensity and frequency of extreme rainfall combined with sea level rise (and increased extreme sea levels during storm surges) adversely affects performance of surface drainage system at St Peters Interchange and upgraded local roads, and leads to exacerbated risk of flooding of Alexandria Landfill Treatment System and gas capture system.	Apply a minimum of 10 per cent sensitivity testing (as required by the draft Roads and Maritime Technical Guide) to hydrological/hydraulic modelling on detailed design, including drainage design, combined with extreme sea level scenario incorporating projected sea level rise by 2090. Consider applying 25 per cent sensitivity testing to this model, which is the recommended sensitivity test value (as per the draft Roads and Maritime Technical Guide) for the projected temperature increases and the design life of the asset. In the detailed design of drainage systems, consider the incorporation of additional drainage network features and flood protection measures (e.g. larger drainage network, additional pits, larger pipe diameters, larger sumps etc.) to mitigate a potential increase in flood risks.	Detailed design

Impact	Adaptation option	Timing
Sea level rise causes inundation of Arncliffe, St Peters and / or Burrows Road motorway operations complexes.	The potential for inundation due to sea level rise would be considered during detailed design to determine the climate change related flood risks to the project.	Detailed design
Sea level rise causes failure of the underground cut-off wall at Alexandria Landfill due to raised water table.	In the detailed design of the Alexandria Landfill cut-off wall, consider the potential impacts from sea level rise.	Detailed design
Sea level rise causes reduced performance or failure of water treatment system due to increased water levels at the location of the submerged outfall diffuser system in Cooks River, and deterioration from saline intrusion.	In the detailed design of the outfall diffuser system in Cooks River, consider the potential impacts from sea level rise.	Detailed design
Increased risk of bushfire smoke and dust affecting the performance of tunnel ventilation system.	Consider the implementation of operational procedures for emergency planning and management, in consultation with emergency management services, local governments and other relevant agencies, during bushfire and dust storm events, and other extreme climate events.	Operation
Increase in frequency and intensity of extreme heat events increases the risk of heat stress conditions for operational personnel, and causes higher temperatures within the tunnel.	In the refinement of Work Health and Safety Management Plans further consider the increased potential for heat stress among operational personnel (eg a stop work threshold could be implemented for operation and maintenance activities).	Operation
	Consider the implementation of operational procedures for management when tunnel temperatures are high.	
Increase in the intensity and frequency of extreme rainfall leads to exacerbated risk of road incidents.	Consider the implementation of operational procedures to increase safety during extreme rainfall events, such reduced speed limits.	Operation

Note: During the consideration of any the above adaptation options, analyses of costs and benefits should be undertaken.

26 Hazard and risk

Environmental hazards resulting from the construction and operation of the project, and the identification of measures to avoid, mitigate or manage these risks, are addressed throughout the environmental impact statement (EIS).

Hazards arising from incidents during project construction and operation could pose to a risk to the surrounding community or the environment. Potential risks and appropriate management measures are discussed below.

26.1 Assessment of potential impacts

26.1.1 Construction

The following hazards and risks may be associated with the project during construction:

- Potential hazards resulting from the accidental release or improper handling and storage of dangerous goods and hazardous substances within construction compounds
- Potential hazards resulting from the accidental release of dangerous goods or hazardous substances from vehicles transporting those materials to and from construction compounds in the event of a crash
- Workplace and public health and safety hazards, such as dangers to construction workers, road users and the general public
- Potential hazards to road users and the general public relating to:
  - Potential rupture or interference with underground services
  - Bushfires
  - Aviation hazards.

Storage and handling of dangerous goods and hazardous substances

The storage, handling and use of dangerous goods and hazardous substances would be undertaken in accordance with the *Work Health and Safety Act 2011* (WHS Act), the *Storage and Handling of Dangerous Goods Code of Practice* (WorkCover NSW, 2005) and relevant Australian Standards.

The types and estimated quantities of dangerous goods and hazardous substances that would be stored and used within the construction compounds are outlined in **Table 26-1**. The location and purpose of each construction compound are detailed in **Chapter 6** (Construction work). Minor quantities of other materials may also be used at the construction compounds from time to time.

State Environmental Planning Policy No. 33 – Hazardous and Offensive Development (SEPP 33) does not apply to the project (refer to **Chapter 2** (Assessment process)). However, the principles of SEPP 33 have been followed to consider potential hazards associated with the project.

The thresholds specified in *Hazardous and Offensive Development Application Guidelines: Applying SEPP 33* (Applying SEPP 33) (Department of Planning, 2011) have been applied to the inventories of dangerous goods to be stored at each construction compound. These screening thresholds represent the level at which dangerous goods may present a credible off-site consequence that requires a further, more detailed assessment of risks. Application of the screening thresholds specified in Applying SEPP33 is included in **Table 26-1**.

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Table 26-1 Indicative dangerous goods and hazardous substances used onsite during the construction period (quantities are indicative only)

Material and Australian Dangerous Goods (DG) Code class	Kingsgrove North (C1)	Commercial Road (C3)	Bexley Road North (C4)	Bexley Road South (C5)	Bexley Road East (C6)	Arncliffe (C7)	Canal Road (C8)	Campbell Road (C9)	Landfill closure (C10)	Burrows Road (C11)	Burrows Road bridge (C12)	Gardeners Road bridge (C13)	Sydney Park (C14)	Assessment against Applying SEPP 33 inventory thresholds
Acetylene (litres) DG class 2.1	1040	1000	1000	1000	1000	1000	1040	40	-	40	40	40	40	Individual cylinders containing acetylene would not trigger the Applying SEPP 33 thresholds (100 kilograms). Maximum stored inventories (1,040 litres) would also be located more than 50 metres away from the nearest construction compound boundary and would also not trigger the Applying SEPP 33 thresholds if considered in aggregate.
Ammonium nitrate emulsion DG class 5.1	4000L for the whole tunnel.													Ammonium nitrate would not trigger the Applying SEPP 33 thresholds (five tonnes) if considered as individual containers or in aggregate.
Concrete bonding agent base (litres) DG class N/A	20	-	-	-	-	-	20	20	-	20	20	20	20	Concrete bonding agent bases are not dangerous goods and therefore do not trigger the Applying SEPP 33 thresholds.

Material and Australian Dangerous Goods (DG) Code class	Kingsgrove North (C1)	Commercial Road (C3)	Bexley Road North (C4)	Bexley Road South (C5)	Bexley Road East (C6)	Arncliffe (C7)	Canal Road (C8)	Campbell Road (C9)	Landfill closure (C10)	Burrows Road (C11)	Burrows Road bridge (C12)	Gardeners Road bridge (C13)	Sydney Park (C14)	Assessment against Applying SEPP 33 inventory thresholds
Concrete bonding agent hardener (litres) DG class 8	20	-	-	-	-	-	20	20		20	20	20	20	Concrete bonding agent hardener would not trigger the Applying SEPP 33 thresholds (25 tonnes) if considered as individual containers or in aggregate.
Concrete surface retarder (litres) DG class 3 PGIII	200	-	-	-	-	-	200	200	-	200	200	200	200	Concrete surface retarder would not trigger the Applying SEPP 33 thresholds (five tonnes) if considered as individual containers or in aggregate.
Construction grout (kilograms) DG class N/A	60	-	-	-	-	-	60	60	-	60	60	60	60	Construction grout is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.
Curing compound (litres) DG class N/A	1000	600	600	600	600	600	1000	400	-	400	400	400	400	Curing compounds are not dangerous goods and therefore do not trigger the Applying SEPP 33 thresholds.

Material and Australian Dangerous Goods (DG) Code class	Kingsgrove North (C1)	Commercial Road (C3)	Bexley Road North (C4)	Bexley Road South (C5)	Bexley Road East (C6)	Arncliffe (C7)	Canal Road (C8)	Campbell Road (C9)	Landfill closure (C10)	Burrows Road (C11)	Burrows Road bridge (C12)	Gardeners Road bridge (C13)	Sydney Park (C14)	Assessment against Applying SEPP 33 inventory thresholds
Diesel DG class C1 PGIII	60,200	60,000	60,000	60,000	60,000	60,000	60,200	200	200	200	200	200	200	Diesel would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Epoxy paste part A (litres) DG class 3 PGIII	20	-	-	-	-	-	20	20	-	20	20	20	20	Epoxies would not trigger the Applying SEPP 33 thresholds (five tonnes) if considered as individual containers or in aggregate
Epoxy paste part B (litres) DG class 3 PGIII	20	-	-	-	-	-	20	20	-	20	20	20	20	Epoxies would not trigger the Applying SEPP 33 thresholds (five tonnes) if considered as individual containers or in aggregate.
Form oil (litres) DG class C2	600	400	400	400	400	400	600	200		200	200	200	200	Form oil would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Grease (kilograms) DG class C2	10	-	-	-	-	-	10	10	10	10	10	10	10	Grease would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Hydraulic oil (litres) DG class C2	2100	2000	2000	2000	2000	2000	2100	100	100	100	100	100	100	Hydraulic oil would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.

Material and Australian Dangerous Goods (DG) Code class	Kingsgrove North (C1)	Commercial Road (C3)	Bexley Road North (C4)	Bexley Road South (C5)	Bexley Road East (C6)	Arncliffe (C7)	Canal Road (C8)	Campbell Road (C9)	Landfill closure (C10)	Burrows Road (C11)	Burrows Road bridge (C12)	Gardeners Road bridge (C13)	Sydney Park (C14)	Assessment against Applying SEPP 33 inventory thresholds
Injectable mortar (kilograms) DG class N/A	10	-	-	-	-	-	10	10	-	10	10	10	10	Injectable mortar is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.
Joint sealant (kilograms) DG class N/A	12	-	-	-	-	-	12	12	-	12	12	12	12	Joint sealant is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds.
Line marking aerosol (kilograms) DG class 2.1	18	-	-	-	-	-	18	18	-	18	18	18	18	Individual cylinders containing line marking aerosol would not trigger the Applying SEPP 33 thresholds (100 kilograms).
Liquid nails (kilograms) DG class 3 PGII	7	-	-	-	-	-	7	7	-	7	7	7	7	Liquid nails would not trigger the Applying SEPP 33 thresholds (five tonnes) if considered as individual containers or in aggregate.
Oxygen (litres) DG class 2.2	1100	1000	1000	1000	1000	1000	1100	100	-	100	100	100	100	Industrial grade oxygen is a Class 2.2 dangerous good and is therefore not subject to the Applying SEPP 33 thresholds.

Material and Australian Dangerous Goods (DG) Code class	Kingsgrove North (C1)	Commercial Road (C3)	Bexley Road North (C4)	Bexley Road South (C5)	Bexley Road East (C6)	Arncliffe (C7)	Canal Road (C8)	Campbell Road (C9)	Landfill closure (C10)	Burrows Road (C11)	Burrows Road bridge (C12)	Gardeners Road bridge (C13)	Sydney Park (C14)	Assessment against Applying SEPP 33 inventory thresholds
Polyurethane foam (kilograms) DG class 2.1	15	-	-	-	-	-	15	15	-	15	15	15	15	Individual cylinders containing polyurethane foam would not trigger the Applying SEPP 33 thresholds (100 kilograms) if considered as individual containers or in aggregate.
Sodium hydroxide (litres) DG class 8 PGII	3000	3000	3000	3000	3000	3000	3000	-	-	-	-	-	-	Sodium hydroxide would not trigger the Applying SEPP 33 thresholds (25 tonnes) if considered as individual containers or in aggregate.
Sulfuric acid (litres) DG class 8 PGII	3000	3000	3000	3000	3000	3000	3000	-	-	-	-	-	-	Sulfuric acid would not trigger the Applying SEPP 33 thresholds (25 tonnes) if considered as individual containers or in aggregate.
Unleaded Petrol (litres) DG class 3 PGII	600	500	500	500	500	500	600	100	100	100	100	100	100	Epoxies would not trigger the Applying SEPP 33 thresholds (five tonnes) if considered as individual containers or in aggregate.

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Table 26-1 demonstrates that the dangerous goods ad hazardous substances proposed to be stored at each construction compound would not exceed the Applying SEPP 33 inventory thresholds. This indicates that the proposed storage of dangerous goods and hazardous substances at construction compounds would not pose a credible off-site consequence, in the unlikely event of an incident at the proposed construction compound locations.

In each construction compound:

- Liquid dangerous goods and hazardous chemicals would be stored within a bunded storage container or spill tray
- Gases would be secured and stored in a storage cage in a well-ventilated area
- Storage areas would be located away from natural or built drainage lines to minimise the likelihood of pollutants entering adjacent watercourses in the unlikely event of a spill or leak escaping the bunded area
- Self bunded fuel storage areas would be located within or adjacent to acoustic sheds.

A register and inventory of the dangerous goods and hazardous substances to be stored at each construction compound would be kept as part of the Incident Response Management Plan for the project. Material Safety Data Sheets would also be provided for each relevant material.

Implementation of environmental management measures for the storage and handling of dangerous goods and hazardous substances, as detailed in **Table 26-6**, would reduce the risk to the environment, construction personnel and the public.

Transport of dangerous goods and hazardous substances

Transportation of dangerous goods would not exceed the Applying SEPP 33 thresholds and would be undertaken in accordance with supplier's instructions.

Table 26-2 outlines the dangerous goods and hazardous substances that would be transported to construction compounds. Potential hazards and risks associated with the transportation of dangerous goods and hazardous substances have been considered by comparing the type, quantity and frequency of dangerous goods and hazardous substances with the thresholds presented in Applying SEPP 33.

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Table 26-2 Dangerous goods and hazardous substances that are expected to be transported to construction compounds

Material and Australian Dangerous Goods Code class	Transport quantity and frequency	Construction compound destination	Assessment against Applying SEPP 33 inventory thresholds
Acetylene DG class 2.1	40 litres per month	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Industrial grade acetylene would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of two tonnes, more than 30 times per week.
Ammonium nitrate emulsion DG class 5.1	4000 litres once during the project	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8)	Ammonium nitrate emulsion would trigger the Applying SEPP 33 transportation thresholds for minimum transport load of two tonnes. However it would not trigger the threshold for transport frequency (more than 30 times per week) and thus is unlikely to be significant.
Concrete bonding agent base DG class N/A	20 litres per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Concrete bonding agent base is not subject to the Applying SEPP 33 transportation thresholds.
Concrete bonding agent hardener DG class 8	20 litres per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Concrete bonding agent hardener would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of two tonnes, more than 30 times per week.
Concrete surface retarder DG class 3 PGIII	200 litres per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Concrete surface retarder would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of 10 tonnes, more than 60 times per week.
Construction grout DG class N/A	60 kilograms per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Construction grout is not subject to the Applying SEPP 33 transportation thresholds.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency	Construction compound destination	Assessment against Applying SEPP 33 inventory thresholds
Curing compound DG class N/A	200 litres per month	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Curing compounds are not subject to the Applying SEPP 33 transportation thresholds.
Diesel DG class C1 PG III	1000 litres * per day	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8), Landfill closure (C8) Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Diesel would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the Applying SEPP 33 transportation thresholds
Epoxy paste part A DG class 3 PGIII	20 litres per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Epoxies would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of 10 tonnes, more than 60 times per week.
Epoxy paste part B DG class 3 PGIII	20 litres per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Epoxies would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of 10 tonnes, more than 60 times per week.
Form oil DG class C2	200 litres per month	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Form oil is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the Applying SEPP 33 transportation thresholds.
Grease DG class C2	5 kilograms per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Landfill closure (C10), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Grease is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the Applying SEPP 33 transportation thresholds

Material and Australian Dangerous Goods Code class	Transport quantity and frequency	Construction compound destination	Assessment against Applying SEPP 33 inventory thresholds
Hydraulic oil DG class C2	100 litres per month	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8), Landfill closure (C8) Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Hydraulic oil is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it would not be subject to the Applying SEPP 33 transportation thresholds.
Injectable mortar DG class N/A	10 kilograms per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Injectable mortar is not subject to the Applying SEPP 33 transportation thresholds.
Joint sealant DG class N/A	6 kilograms per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Joint sealant is not subject to the Applying SEPP 33 transportation thresholds.
Line marking aerosol DG class 2.1	18 kilograms per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Line marking aerosol would not trigger the Applying SEPP 33 transportation threshold for minimum transport load or transport frequency of two tonnes, more than 30 times per week.
Liquid nails DG class 3 PGII	7 kilograms per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Liquid nails would not trigger the Applying SEPP 33 transportation threshold for minimum transport load or transport frequency of three tonnes, more than 45 times per week.
Oxygen DG class 2.2	200 litres per month	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Industrial grade oxygen is not subject to the Applying SEPP 33 transportation thresholds.

Material and Australian Dangerous Goods Code class	Transport quantity and frequency	Construction compound destination	Assessment against Applying SEPP 33 inventory thresholds
Polyurethane foam DG class 2.1	8 kilograms per month	Kingsgrove North (C1), Canal Road (C8), Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Polyurethane foam would not trigger the Applying SEPP 33 transportation threshold for minimum transport load or transport frequency of two tonnes, more than 30 times per week.
Sodium hydroxide DG class 8 PGII	3000 litres per month	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8)	Sodium hydroxide would not trigger the Applying SEPP 33 transportation thresholds of 25 tonnes as individual containers or in aggregate.
Sulfuric acid DG class 8 PGII	3000 litres per month	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8)	Sulfuric acid would not trigger the Applying SEPP 33 transportation thresholds of 25 tonnes as individual containers or in aggregate.
Unleaded petrol DG class 3 PGII	200 litres * per week	Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8), Landfill closure (C8) Campbell Road (C9), Burrows Road (C11), Burrows Road bridge (C12), Gardeners Road bridge (C13), Sydney Park (C14)	Unleaded petrol would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of three tonnes, more than 45 times per week.

1 Quantities are indicative only

* Note: for some construction compounds the quantity of diesel and unleaded petrol delivered to site would greater than the quantity stored within the compound at any time because the delivery volume takes into the account fuel which is brought to the compound by mini-tanker and used to directly refuel plant. As this fuel is “in use” in the plant it is not classified as “stored”

Construction workplace hazards

Factors contributing to construction workplace hazards in tunnelling projects include uncertainty in the nature and variability of ground conditions, the restricted tunnel environment, difficulty in communications and the use of compressed air.

Hazards include:

- Partial or complete tunnel collapse with potential associated surface impacts
- Tunnel fires or explosions
- Rock falls at cuttings
- Exposure to airborne pollutants such as asbestos fibres during demolition work and dust during tunnelling.

Design of the main alignment tunnels has taken into account a number of parameters including separation of the tunnels, cross passage locations and connectivity, maximum spans at merges and diverges, depth of cover to minimise settlement risk, and areas to avoid due to potentially poor tunnelling conditions. The majority of the tunnel alignment would be constructed at depths between 15 metres and 60 metres, within Hawkesbury Sandstone. The geology of Hawkesbury Sandstone is an excellent tunnelling medium due to its high strength and infrequent defects.

During tunnelling, a 'permit to tunnel' system would be developed and implemented. As part of this system, geological conditions at the tunnel face would be confirmed against the expected geological conditions and the project design prior to advancing tunnel excavation. This would ensure that the planned tunnel support proposed to be implemented is appropriate for the encountered geological conditions. The requirements of the WorkCover Code of Practice for Tunnels would be met to ensure that no persons would work under unsupported ground without an adequate overhead protection structure. The structural integrity of the tunnel would be assured during construction through the implementation of appropriate construction methodology for the tunnelling conditions and ongoing tunnel support by way of rockbolts and / or shotcrete lining. In certain locations, a passive support system comprising a thick temporary support in combination with a permanent sprayed lining may also be adopted.

Combustible materials within a tunnel have the potential to cause tunnel fires and explosions. The rapid consumption of oxygen and production of noxious fumes and gases can make tunnel fires severe. Diesel equipment fire precautions, hot work procedures and electrical equipment procedures would be followed and adequate training would be provided to minimise risks associated with fire and explosion. Temporary construction compounds would be maintained in a tidy and orderly manner, with the aim of minimising potential fuel loads and isolating fuel sources from ignition sources.

Rock falls can occur during excavation of the portals if the portal breakthrough area is not secured before excavation. Rock falls have the potential to injure construction workers and cause damage to construction equipment. The interchange dive structures at the eastern and western portals have the potential to create rock fall hazards. This is because steep slope sites have the potential to pose slip, fall, and unsecured equipment hazards. The risk of rock fall would not be limited to the eastern and western portals.

Standard construction and mitigation measures would be applied to manage rock fall risk, including the use of appropriate personal protective equipment, frequent tunnel inspections, scaling, installation of properly secured ground support, safety fencing and overhead protection.

During construction, airborne pollutants have the potential to occur including dust and toxic gas. If this were to occur, it may result in oxygen deficient environments and health risks for construction workers. Dust generation in the tunnels would be minimised by wetting down the cutting face and the use of temporary fans and dry dust scrubbers. Standard ventilation, dust extraction and monitoring procedures would be carried out when appropriate.

Hazardous materials including asbestos may be encountered during demolition works and utility relocations. Microscopic asbestos fibres that become airborne can become a health risk if inhaled into the lungs. Areas that potentially include asbestos are described in **Chapter 17** (Contamination). The management of potential asbestos waste is described further in **Chapter 24** (Resource use and waste minimisation).

Gases within the tunnel such as carbon monoxide (CO), carbon dioxide (CO_2) and nitrogen dioxide (NO_2) have the potential to be a hazard to construction workers and would be properly monitored.

Road user and general public hazards

Services

All services near the project would be identified prior to the commencement of construction.

The potential rupture of underground services during excavation could pose a hazard in the form of electrocution, release of sewage from a wastewater main or fire if a gas main is impacted.

The risk associated with these hazards would be minimised before starting work by:

- Undertaking utility checks (such as dial before you dig)
- Consulting relevant service infrastructure providers
- Tagging and potholing identified services via markers
- Relocating and / or protecting utilities as required (ie temporary protection at surface level by placing steel plates over the service).

Consultation with service infrastructure providers would commence during the design phase of the project and continue during construction to mitigate the risk of unplanned and unexpected disturbance of utilities. The relocation of utilities may result in short term outages of some services to surrounding areas. Services that would be directly impacted and require protection and / or relocation as a result of the project are detailed in **Chapter 13** (Land use and property).

Bushfire

The project would not be located in or near bushfire prone land. Of the local government areas traversed by the project, only Hurstville local government area contains land mapped as being bushfire prone. However, mapping within the *Hurstville Local Environmental Plan 2012* does not identify bushfire prone land as being present within the project corridor. Other local government areas are highly urbanised and do not contain large areas of vegetation that are associated with bushfire risk. As such, bushfire risks to the project are considered to be minor.

Temporary construction compounds and construction infrastructure would be generally less sensitive to bushfire risks than operational facilities, given the temporary nature of the construction compounds and the absence of critical infrastructure within the compounds.

Notwithstanding, the low likelihood of bushfire events within the project corridor, measures to mitigate and manage bushfire risks would be developed and included as part of site-specific hazard and risk management measures within Construction Environmental Management Plan.

Temporary construction compounds would be maintained in a tidy and orderly manner to minimise potential fuel loads in the event that the compounds are affected by fire. Storage and management of dangerous goods and hazardous materials would occur in a safe, secure location consistent with the requirements of applicable Australian Standards.

Construction activities involving flammable materials and ignition sources (for example, welding) would be proactively managed to ensure that fire risks are effectively minimised. High risk construction activities, such as welding and metal work, would be subject to a risk assessment on total fire ban days and restricted or ceased as appropriate.

Aviation risks

The *Airports (Protection of Airspace) Regulations 1996* (Commonwealth) (Airspace Regulations) were established for the protection of airspace at and around regulated airports in Australia including Sydney Airport. The Airspace Regulations define the 'prescribed airspace' for Sydney Airport as the airspace above any part of either an obstacle limitation surface or procedures for air navigation services – aircraft operations surfaces for the airport.

Under the *Airports Act 1996* (Commonwealth), 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 Commonwealth Department of Infrastructure and Regional Development or is otherwise exempt under the Airspace Regulations. Controlled activities include (depending on the precise event or occurrence):

- The construction of buildings and structures that intrude into prescribed airspace
- Artificial light sources that exceed specified intensity levels
- Activities that result in air turbulence that exceed specified levels
- Activities that involve the emission of smoke, dust, other particulate matter, steam or other gas that exceed specified levels.

The obstacle limitation surfaces define the airspace to be protected for aircraft operating during the initial and final stages of flight, or manoeuvring in the vicinity of Sydney Airport. They have been established in accordance with International Civil Aviation Organisation specifications, as adopted by Australia's Civil Aviation Safety Authority. The construction activities would be carried out to ensure that equipment, such as cranes, and materials do not intrude into the obstacle limitation surfaces or the procedures for air navigation services – aircraft operations surfaces.

The Civil Aviation Safety Authority has been consulted during the development of the project design and would be consulted further prior to commencement of construction to ensure that the construction activities proposed for the Arncliffe surface works, St Peters interchange and local roads upgrades are undertaken in line with the *Airports (Protection of Airspace) Regulations 1996* (Cth) and *Airports Act 1996* (Commonwealth), in a manner that satisfies the requirements of the Civil Aviation Safety Authority.

The Civil Aviation Safety Authority, under the *Civil Aviation Regulations 1988*, also regulates ground lighting where it has the potential to impact airport operations (such as causing confusion or distraction from glare to pilots in the air). The *Sydney Airport Master Plan 2033* outlines the requirements for external lighting. Lighting during construction would adhere to the established guidelines on the location and permitted intensities of ground lights within a six kilometre radius of Sydney Airport.

26.1.2 Operation

During operation, the following potential hazards and risks may be associated with the project:

- Hazards resulting from the accidental release or improper handling and storage of dangerous goods and hazardous substances
- Potential hazards resulting from the accidental release of dangerous goods or hazardous substances from vehicles transporting those materials to and from motorway operations complexes in the event of a crash
- Crashes and incidents in the main alignment tunnels or on tunnel on and off-ramp
- Crashes and incidents on surface roads
- Risks from electric and magnetic fields from the project substations
- Potential risks from bushfires
- Potential aviation hazards.

Storage and handling of dangerous goods and hazardous substances

Dangerous goods and hazardous substances stored and used during operation of the project would be limited and may include coagulants, polymers, acid and bases (outlined in **Table 26-3**). Additional small quantities of other materials may be required onsite occasionally to support maintenance activities.

A comparison of the likely types and quantities of dangerous goods and hazardous substances to be stored onsite with thresholds in Applying SEPP 33 indicates that operational inventories would not be potentially hazardous.

Transport of dangerous goods and hazardous substances

Dangerous goods and hazardous substances that would be transported to the project during operation are outlined in **Table 26-4**. Additional small quantities of other materials may occasionally be required onsite to support maintenance activities. A comparison of the likely types and quantities of dangerous goods and hazardous materials to be transported with thresholds in Applying SEPP 33 indicates that the transport of operational inventories would not be potentially hazardous. In the event that thresholds are exceeded, transport frequency is likely to be well below the frequency threshold and as such, risks are unlikely to be significant.

Table 26-3 Indicative dangerous goods and hazardous substances stored onsite during operation

Material and Australian Dangerous Goods (DG) Code Class	Storage method	Assessment against Applying SEPP 33 inventory thresholds
Sodium Hydroxide, DG class 8 PGII	12,000 litres feed tank in an undercover bunded area	Sodium hydroxide would not trigger the Applying SEPP 33 thresholds of 25 tonnes if considered as individual containers or in aggregate.
Coagulant, DG class N/A	12,000 litres feed tank in an undercover bunded area	Coagulant is not a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Polymers, DG class N/A	20 kilograms bags stored in a undercover container	Polymers are not a dangerous good and do not trigger the Applying SEPP 33 thresholds.
Diesel, DG class C1 PGIII	Bunded tanks	Diesel would not be stored with Class 3 materials and would therefore not be subject to the Applying SEPP 33 thresholds.
Acetylene, DG class 2.1	Size G cylinders	Individual cylinders containing acetylene would not trigger the Applying SEPP 33 thresholds of 100 kilogram. Maximum stored inventories would not trigger the Applying SEPP 33 thresholds if considered in aggregate.
Oxygen, DG class 2.2	Size G cylinders	Industrial grade oxygen is a Class 2.2 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Grease, DG class C2	400g cartridge, 20 litre container stored undercover	Grease would not be stored with Class 3 materials and would not be subject to the Applying SEPP 33 thresholds.
Adhesives, DG class 3 PGIII	375 grams cartridge, 20 litre container	Adhesives would not trigger the Applying SEPP 33 thresholds of five tonnes if considered as individual containers or in aggregate.
Bitumen, DG class 9	15,000 litre tanker (brought onto site as required for days operation)	Bitumen is a Class 9 dangerous good and not subject to the Applying SEPP 33 thresholds.
Kerosene, DG class 3 PGIII	20 litre container stored undercover in bunded area	Kerosene would not trigger the Applying SEPP 33 thresholds of five tonnes if considered as individual containers or in aggregate.
Non shrink grout, DG class N/A	20 kilogram bags stored under cover	Non shrink grout is not a dangerous good
Release agent (Lanolin based), DG class N/A	20 litre drums stored undercover	Release agent (Lanolin based) is not a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Line marking aerosol, DG class 2.1	375 millilitre aerosol container stored undercover	Line marking aerosol would not trigger the Applying SEPP 33 thresholds (100 kilograms).

Table 26-4 Dangerous good and hazardous substances transported during operation

Material and Australian Dangerous Goods Code Class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 inventory thresholds
Sodium Hydroxide, DG class 8 PGII	Six monthly	10,000 litres	Sodium hydroxide would not trigger the Applying SEPP 33 transportation thresholds (25 tonnes) as individual containers or in aggregate.
Coagulant, DG class N/A	Quarterly	10,000 litres	Coagulant is not a dangerous good and does not trigger the Applying SEPP 33 thresholds.
Polymers, DG class N/A	Quarterly	1000 kilograms	Polymers are not a dangerous good and do not trigger the Applying SEPP 33 thresholds.
Diesel, DG class C1 PGIII	As required	As required	Diesel would not be transported with Class 3 dangerous goods. It is not subject to the Applying SEPP 33 transportation thresholds
Acetylene, DG class 2.1	Weekly	50 cylinders	Industrial grade acetylene would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of two tonnes, more than 30 times per week.
Oxygen, DG class 2.2	Weekly	50 cylinders	Industrial grade oxygen is a Class 2.2 dangerous good and is not subject to the Applying SEPP 33 thresholds.
Grease, DG class C2	Monthly	50 cartridges (20 kilograms)	Grease is not a dangerous good and would not be transported with Class 3 dangerous goods. Therefore, it is not subject to the Applying SEPP 33 transportation thresholds
Adhesives, DG class 3 PGIII	Weekly	50 cartridges (19 kilograms)	Adhesives would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of 10 tonnes, more than 60 times per week.
Bitumen, DG class 9	Quarterly	15,000 litres	Bitumen would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of no limit, more than 60 times per week.
Kerosene, DG class 3 PGIII	Monthly	100 litres	Kerosene would not trigger the Applying SEPP 33 transportation thresholds for minimum transport load or transport frequency of 10 tonnes, more than 60 times per week.
Non shrink grout, DG class N/A	Monthly	2000 kilograms	No shrink grout is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds

Material and Australian Dangerous Goods Code Class	Transport frequency	Transport quantity	Assessment against Applying SEPP 33 inventory thresholds
Release agent (Lanolin based), DG class N/A	Two monthly	200 litres	Release agent (Lanolin based) is not a dangerous good and therefore does not trigger the Applying SEPP 33 thresholds
Line marking aerosol, DG class 2.1	Quarterly	50 cans	Line marking aerosol would not trigger the Applying SEPP 33 thresholds for minimum transport load or transport frequency of two tonnes, more than 30 times per week.

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Incidents in the project tunnels

The project has been designed to provide for efficient, free flowing traffic with physical capacity to accommodate predicted traffic volumes. The preferred design has incorporated all feasible and reasonable design measures including those relating to geometry, pavement, lighting and signage, and is consistent with current Australian Standards, road design guidelines and industry best practice. In doing so, the design of the project has been developed to minimise the likelihood of incidents and crashes.

As with the operation of all roads, there is an inherent risk of vehicle collision in the project tunnels and on surface roads. Factors that contribute to the hazard of vehicle collisions within the operation of the project include:

- The design of the project
- The traffic types and volumes using the tunnels
- Driving conditions, including light conditions and weather
- Human factors, including compliance with road rules, attention to driving conditions and fatigue
- Vehicle failure and breakdown.

The design is equivalent to, or exceeds, the fire safety measures recommended by NFPA502 (American) and Permanent International Association of Road Congress (European) standards, the fire safety measures recommended by AS4825 (Australian) – Tunnel fire safety and Roads and Maritime (NSW) standards, and is consistent with recent Australian industry practice.

Key fire and life safety project features, which have been developed using applicable standards and guidelines, include:

- The main alignment tunnels are uni-directional, reducing the likelihood of vehicle crashes
- Prohibition of vehicles carrying dangerous goods entering the tunnels, reducing the likelihood of fire and release of toxic materials
- Fires in the tunnels would be detected automatically through a closed circuit television monitoring system and linear heat detection
- A deluge fire suppression system would be activated manually or automatically at the fire source. Automatic foam suppression systems would be used in the tunnel drainage sump and activated through hydrocarbon detectors. Automatic fire sprinkler systems located in the fire pump rooms (located on the surface near the western portal and St Peters interchange) would be activated by pre-set temperature sprinkler heads
- Longitudinal ventilation would direct smoke in the direction of traffic flow from the fire source towards an extraction point or tunnel exit portal
- The inclusion of stop lights, portal closure barriers, moveable median barriers, lane control units and variable message signs
- The New M5 motorway control centre located at the Burrows Road motorway operations complex (MOC5) including:
  - Two simulation and training servers
  - A data storage system
  - Four operator workstations
  - A video wall system
  - Two large monitors and CCTV controls to display CCTV footage.

The likelihood of a fire incident during operation of the project cannot be entirely removed. Uncontrollable human factors inherently lead to a residual risk of incidents and accidents, albeit the likelihood of such events would be low.

The tunnel would be well equipped to effectively manage crash or incident and more so than crashes or incidents on surface roads. The tunnel would be continuously monitored, allowing for much faster response times for emergency services and in the event of an accident involving a fire, the tunnel deluge system would quickly put the fire out rather than needing to wait for emergency services to arrive on the scene.

In the event of an incident:

- Approaching vehicles would be prevented from entering both tunnels using stop lights, portal closure barriers, moveable median barriers, lane control units and variable message signs
- Motorists involved in the fire event, or upstream of the fire source, would be instructed to stop their vehicles, and exit on foot in the opposite direction along the carriageway / ramp (as this region would be protected by the smoke management system), or through an exit door to an egress passage leading to a place of relative safety
- Motorists downstream of the fire source are encouraged to continue driving out of the tunnel. If this is not possible (e.g. congested traffic) and they must evacuate on foot, using an exit door to an egress passage leading to the non-incident carriageway/ramp
- Emergency services would reach the fire source via the non-incident tunnel (by vehicle or foot), or from the upstream direction in the incident tunnel (by foot).

The smoke extraction points would operate, removing smoke from the tunnels. If the fire is upstream of the smoke extraction point, the smoke would be ventilated to the smoke exhaust point and extracted to reduce the length of the tunnel affected by smoke. If the fire is downstream of the smoke extraction point, the smoke would be ventilated to the portals and discharged via the portals.

Depending on the location of the incident, smoke would be emitted from the project tunnels at one or more of the following locations:

- Bexley Road South motorway operations complex (MOC2)
- Arncliffe motorway operations complex (MOC3)
- The western and eastern tunnel portals.

Probability of tunnel fires

A summary of available tunnel fire incident data for Australia is provided in **Table 26-5**. An historical tunnel fire frequency based on a vehicle-kilometre basis for two of the tunnels listed in **Table 26-5** can be calculated:

- For the Lane Cove Tunnel, historical fire frequency has been around 0.61 fires per 100 million vehicle kilometres (all vehicles)
- For the CityLink Tunnels, historical fire frequency has been around 0.5 fires per 100 million vehicle kilometres (all vehicles).

Based on traffic forecasts, the main alignment tunnels are anticipated to experience around 92 million vehicle kilometres in 2019 and around 110 million vehicle kilometres in 2031. Applying similar tunnel fire frequencies to forecast traffic volumes for the project indicates:

- An expected annual tunnel fire frequency of 0.47 to 0.56 is expected in 2021 (equivalent to about one fire incident every 1.8 to 2.1 years)
- An expected annual tunnel fire frequency of 0.55 to 0.66 is expected in 2031 (equivalent to one fire incident every 1.5 to 1.8 years).

These values are comparable to observed annual tunnel fire incident rates for other Australian tunnels present in **Table 26-5**, which range from around 0.06 to 0.93 per year, or around 0.5 to one per 100 million vehicle kilometres.

Details regarding traffic volumes with and without the project are provided in **Chapter 9** (Traffic and Transport).

Table 26-5 Tunnel fire frequency based on available data for Australian tunnels (up to 2014)

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

Tunnel	Length	Opened to traffic	Comments on fire incidents	Traffic volumes	Incident frequency
Cross City Tunnel	Two tunnels, each 2.1 kilometres	August 2005	Two fires recorded since the tunnel was opened in 2005 (around 0.22 per year). Of these fire incidents, one required the operation of the deluge system. The second fire was extinguished without the need for deluge.	Around 30,000 vehicles per day Around 23 million kilometres per annum	1.0 per 100 million vehicle kilometres
CityLink Tunnels (Burnley Tunnel and Domain Tunnel)	Burnley Tunnel – two tunnels each 3.4 kilometres Domain Tunnel – two tunnels each 1.6 kilometres	December 2000	A total of 13 fires recorded since the tunnels were opened in late 2000 (around 0.93 per year). Of these fires, seven related to vehicle fires where there vehicle was driven through and exited the tunnels without incident. Three of the fires required use of the deluge system and the remaining three fires required use of extinguishers. The most significant fire to occur was a result of a major car/ truck collision in the Burnley Tunnel in 2007. This incident resulted in three fatalities and required closure of the tunnel for four days.	Around 55,000 (Burnley) and 45,000 (Domain) vehicles per day Around 94 million vehicle kilometres per annum (combined)	0.5 per 100 million vehicle kilometres (fires within the tunnel only)
Lane Cove Tunnel	Two tunnels, each 3.6 kilometres	March 2007	A total of three fires recorded since the tunnels were opened in 2007 (around 0.43 per year). All of these fires required use of the deluge system.	Around 66,000 vehicles per day Around 87 million vehicle kilometres per annum	0.5 per 100 million vehicle kilometres

Incidents on surface roads

As with underground components of the project, surface roads and infrastructure have been designed to provide an efficient and safe road network.

The project is expected to result in the following traffic related benefits:

- Improved travel times and reliability
- Improved movement of freight to and from the Port Botany area
- Provide an express route between South-western Sydney and Sydney Airport.

These traffic related benefits would result in an improved safety environment and a reduction in incidents along the corridor. The project would facilitate an overall improvement in road safety performance of the Princes Highway, Canal Road / Ricketty Street / Gardeners Road and Bourke Road around the St Peters interchange and local road upgrade as a result of charged traffic volumes and proposed intersection upgrades.

An increase in the total number of crashes is expected on Euston Road due to an increase in forecast traffic. However about 85 per cent of crashes on Euston Road occur at the Euston Road / Sydney Park Road intersection. This intersection would be signalised as part of the local roads upgrades and would be an effective approach to reducing the number of accidents.

Forecasted crash statistics on local roads around the St Peters interchange are described in **Section 9.3.2** (**Chapter 9** (Traffic and Transport)).

Electric and magnetic fields

The *Draft Radiation Standard – Exposure Limits for Magnetic Fields* (Australian Radiation Protection and Nuclear Safety Agency, December 2006) was released in 1996 based on a large body of scientific research since 1989 and proposed a series of exposure standards to replace the *Interim Guidelines on Limits of Exposure to 50 / 60 Hz Electric and Magnetic Fields* (National Health and Medical Research Council, 1989).

Although the Draft Radiation Standard has never been finalised and published, the exposure limits presented are typically applied when considering electric and magnetic fields from new development. The project would include the provision of four aboveground substations, located at Kingsgrove motorway operations complex (MOC1), Bexley Road South motorway operations complex (MCO2), Arncliffe motorway operations complex (MOC3) and St Peters motorway operations complex (MOC4).

The detailed design of project substations would ensure that the exposure limits for the general public in the *Draft Radiation Standard – Exposure Limits for Magnetic Fields* (Australian Radiation Protection and Nuclear Safety Agency, December 2006) would not be exceeded at the boundary of the substation sites.

Bushfire

It is unlikely that a bushfire would occur within the project corridor, due to the urbanised nature of the area. Bushfire prone land mapping for the Hurstville local government area does not identify bushfire prone land within the project corridor. Other local government areas relevant to the project are highly urbanised and do not contain large areas of vegetation that are associated with a larger bushfire risk.

The operational infrastructure of the project is largely invulnerable to bush fire due to its incombustible nature (road surface materials, retaining walls, road barriers) and the fact that a lot of the infrastructure is in tunnels underground.

The project would not increase the extent of bushfire prone land.

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* (Commonwealth), 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 Commonwealth Department of Infrastructure and Regional Development or otherwise exempt under the Airspace Regulations. Controlled activities under the *Airports Act 1996* (Commonwealth) include (depending on the precise event or occurrence):

- The construction of buildings and structures that intrude into prescribed airspace
- Artificial light sources that exceed specified intensity levels
- Activities that result in air turbulence that exceed specified levels
- Activities that involve the emission of smoke, dust, other particulate matter, steam or other gas that exceed specified levels.

The St Peters interchange and associated local road upgrades, Arncliffe motorway operations complex (MOC3), St Peters motorway operations complex (MOC4), Burrows Road motorway operations complex (MOC5) and other ancillary infrastructure around the eastern portal would be located near flight paths used for Sydney Airport.

No buildings and structures that form part of the project are designed to intrude into prescribed airspace. The ventilation outlets at Kingsgrove, Arncliffe and St Peters motorway operations complexes (MOC1, MOC3 and MOC4) are also designed to be below prescribed airspace heights.

However, as a result of the proposed operation of the Arncliffe and St Peters ventilation facilities, including discharge of tunnel emissions, the project has been deemed a controlled activity and an assessment under the *Airport Act 1996* will be required to consider impacts of the project on airport operations. Further, approval of the project by the Secretary of the Commonwealth Department of Infrastructure and Regional Development is required.

An aviation impact assessment has been carried out to assess the impacts of the operation of the ventilation outlets at Kingsgrove, Arncliffe and St Peters ventilation facilities (MOC1, MOC3 and MOC4). This assessment included a plume rise assessment and considered the building induced windshear and turbulence assessment that would occur during operation of the ventilation facilities. Predictive modelling results indicate that the maximum velocity at would be less than the (procedures for air navigation services – aircraft operations) limit of 4.3 metres per second. The results of the Aviation Impact Assessment have been submitted to the Civil Aviation Safety Authority for determination of whether the requirements of Civil Aviation Safety Authority have been met to the satisfaction of the Department of Infrastructure and Regional Development.

The application for approval of the project under the *Airports Act 1996* has been made concurrently with the preparation of this EIS. The project has been designed to satisfy requirements set by the Civil Aviation Safety Authority (refer to **Section 4.6.1** and **Section 5.8.2**).

Aviation hazard lighting may be required on ventilation outlets at Arncliffe and St Peters motorway operations complexes (MOC3 and MOC4). Surface road lighting would include an 'aeroscreen' type lens to minimise upwards waste light. Aviation hazard lighting and surface road lighting would be in accordance with the requirements of the Civil Aviation Safety Authority and Sydney Airport.

26.2 Environmental management measures

As described throughout this chapter, the project has been designed to minimise the likelihood of incidents and accidents. Environmental management measures relating to hazards and risk are outlined in **Table 26-6**. In addition to these measures, a Work health and Safety Plan would be implemented during construction of the project. This would support the management measures and procedures included in the Construction Environmental Management Plan for the project and would be supplemented by site and activity specific Safe Work Method Statements.

Table 26-6 Environment management measures – hazards and risk

Impact	No.	Environmental management measure	Timing
Construction			
General	HR01	Site-specific hazard and risk management measures would be included within the Construction Environmental Management Plan (CEMP), which may include items such as: • Details of the hazards and risk associated with construction activities for both surface and subsurface works • Procedures to comply with legislative and industry standard requirements • Contingency plans, as required.	Pre-construction / construction
Storage of dangerous goods and hazardous substances	HR02	Storage of dangerous goods and hazardous materials would occur in accordance with suppliers' instructions and relevant Australian Standards and may include bulk storage tanks, chemical storage cabinets / containers or impervious bunds.	Construction
	HR03	Storage, handling and use of dangerous goods and hazardous substances would be in accordance with the *Work Health and Safety Act 2011* and the *Storage and Handling of Dangerous Goods Code of Practice* (WorkCover NSW, 2005).	Construction
	HR04	Secure, bunded areas would be provided around storage areas for oils, fuels and other hazardous liquids.	Construction
	HR05	Bunds would be provided around activities such as vehicle refuelling, servicing, maintenance or wash-down, where there is a potential for spills and contamination.	Construction
	HR06	Material Safety Data Sheets would be obtained for dangerous goods and hazardous substances stored onsite prior to their arrival.	Construction

Impact	No.	Environmental management measure	Timing
Transportation of dangerous goods and hazardous substances	HR07	Transport of dangerous goods and hazardous substances would be conducted in accordance with relevant legislation and codes, including the Dangerous Goods (*Road and Rail Transport) Regulation 2014* and the Australian Code for the *Transport of Dangerous Goods by Road and Rail* (National Transport Commission, 2008).	Construction
Aviation Measures	HR08	The project would be constructed in line with Civil Aviation Safety Authority requirements, to the satisfaction of the Secretary of the Commonwealth Department of Infrastructure and Regional Development.	Construction
Aviation Measures - lighting	HR09	The project would be constructed in in accordance with the requirements of the Civil Aviation Safety Authority and the *Sydney Airport Master Plan 2033*, with respect to lighting used during construction.	Construction
Operation			
Fire and life safety	OpHR01	The fire and safety systems and measures adopted for the project would be equivalent to or exceed the fire safety measures recommended by NFPA502 (American), PIARC (European), AS4825 (Australian) and Roads and Maritime standards.	Detailed Design
Storage of dangerous goods and hazardous substances	OpHR02	Storage of dangerous goods and hazardous materials would occur in accordance with supplier's instructions and relevant Australian standards and may include bulk storage tanks, chemical storage cabinets / containers or impervious bunds.	Operation
	OpHR03	Storage, handling and use of dangerous goods and hazardous substances would be in accordance with the Work Health and Safety Act 2011 and the Storage and Handling of Dangerous Goods Code of Practice (WorkCover NSW, 2005).	Operation
	OpHR04	Secure, bunded areas would be provided around storage areas for oils, fuels and other hazardous liquids. Impervious bunds would be of sufficient capacity to contain at least 110 per cent of the volume of the largest stored container.	Operation

Impact	No.	Environmental management measure	Timing
	OpHR05	Bunds would be provided around activities such as vehicle refuelling, servicing, maintenance or wash-down, where there is a potential for spills and contamination.	Operation
	OpHR06	Material Safety Data Sheets would be obtained for dangerous goods and hazardous substances stored onsite prior to their arrival.	Operation
Transportation of dangerous goods and hazardous substances	OpHR07	The transport of dangerous goods and hazardous substances would be prohibited through the main alignment tunnels and on and off-ramp tunnels.	Operation
Incident response	OpHR08	An Incident Response Plan would be developed and implemented in the event of an accident or incident.	Operation
	OpHR09	The response to incidents within the motorway would be managed in accordance with the memorandum of understanding between Roads and Maritime and the NSW Police Service, NSW Rural Fire Service, NSW Fire Brigade and other emergency services.	Operation
Electric and magnetic fields	OpHR10	The detailed design of the project substations would ensure that the exposure limits for the general public suggested by the Draft Radiation Standard (*Australian Radiation Protection and Nuclear Safety Agency*, *2006*) would not be exceeded at the boundary of the substation sites.	Detailed Design
Aviation Measures	OpHR11	The project would be operated in line with Civil Aviation Safety Authority requirements, to the satisfaction of the Secretary of the Commonwealth Department of Infrastructure and Regional Development.	Detailed Design
Aviation Measures - lighting	OpHR12	Aviation hazard lighting, building lighting and surface road lighting would be designed and operated in accordance with the requirements of the Civil Aviation Safety Authority and the *Sydney Airport Master Plan 2033*.	Detailed Design and Operation

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27 Cumulative impacts

This chapter provides a summary of the cumulative impacts associated with the project.

Table 27-1 identifies the Secretary's Environmental Assessment Requirements (SEARs) as they relate to cumulative impacts, and identifies where they have been addressed in this environmental impact statement (EIS).

Table 27-1 SEARS – cumulative impacts

SEARs	Where addressed
An analysis of the proposal including an assessment, with a particular focus on the requirements of the listed key issues, in accordance with clause 7(1)(d) of Schedule 2 of the Regulation (where relevant), including an identification of how relevant planning, land use and development matters (including relevant strategic and statutory matters) have been considered in the impact assessment (direct, indirect and cumulative impacts) and/or in developing mitigation measures (to avoid, manage, offset and monitor impacts and where relevant, improve the existing environment).	An assessment of cumulative impacts associated with the project is provided in **Section 27.4**.
Details of the proposal's relationship to and consistency with the broader WestConnex, and an assessment of the cumulative impacts taking into consideration the WestConnex program of works.	An assessment of the cumulative impacts of the project with other components of the WestConnex program of works is detailed within **Section 27.4**.
Consideration of the potential cumulative impacts due to other development in the vicinity (completed, underway or proposed).	An assessment of the cumulative impacts of the project with other components of the WestConnex program of works is detailed within **Section 27.4**.

27.1 Nature of cumulative impacts

An assessment of cumulative impacts considers projects being planned, constructed or operated at the same time as the project. In isolation, a particular impact from one project may be considered minor, but when the impact of multiple projects on the same receivers is considered, the impacts may be more substantial. Impacts can be either adverse or beneficial. Beneficial impacts of the project as a result of the overall WestConnex program of works are provided in **Chapter 3** (Strategic context and project need).

Cumulative impacts typically include:

- Impacts on local, regional and State traffic, transport and road users
- Social and economic effects, including changes to land use, access, settlements, employment and businesses
- Changes to local and regional amenity, including noise, vibration, visual quality and air quality
- Environmental changes including effects on water quality, hydrology and biodiversity.

Another type of cumulative impact is construction fatigue. This concept relates to sensitive receivers that experience construction impacts from a variety of projects over a long period of time with few or no breaks between construction periods. Construction fatigue typically relates to amenity impacts from projects that are constructed consecutively or 'back to back'.

The impacts associated with the construction and operation of the project and other relevant projects are the subject of this cumulative impact assessment. Prediction and evaluation of cumulative impacts is not a straightforward process as information relating to other proposed projects may not be publicly available.

The following sections provide an assessment based on the most current and publicly available information.

27.2 Assessment methodology

Cumulative impacts have been assessed in two categories: impacts related to the overall WestConnex program of works and impacts from other developments in the vicinity of the project.

Impacts associated with the WestConnex program of works have been assessed assuming that all components (refer to **Section 27.3.1** for discussion) are constructed.

The identification of other developments that could occur in the vicinity of the project only included 'major' projects, as identified by the NSW Department of Planning & Environment, and included in its public register of applications for State significant development and State significant infrastructure.

Consideration was also given to other 'strategic' projects being considered by government. This cumulative impact assessment considered developments located within the suburbs of Narwee, Beverly Hills, Kingsgrove, Bexley North, Earlwood, Bardwell Park, Bardwell Valley, Arncliffe, Turrella, Wolli Creek, Tempe, Sydenham, St Peters, Alexandria and Mascot.

27.3 Existing and proposed projects

27.3.1 WestConnex program of works

The project is a component of the WestConnex program of works, which would provide a 33 kilometre motorway linking Sydney's west and south-west with Sydney Airport and the Port Botany precinct. The location of WestConnex is shown in **Figure 1.1** in **Chapter 1** (Introduction) of this EIS. The individual components of WestConnex are:

- M4 Widening – Pitt Street at Parramatta to Homebush Bay Drive at Homebush (planning approval granted and under construction)
- M4 East – Homebush Bay Drive, Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield (planning application lodged and subject to planning approval)
- New M5 – (the subject of this EIS)
- King Georges Road Interchange Upgrade (planning approval granted and work has commenced)
- Future M4-M5 Link – Haberfield to St Peters (undergoing concept development and subject to planning approval)
- Future Sydney Gateway (undergoing concept development and subject to planning approval)
- Future Southern extension (undergoing concept development and subject to planning approval).

Separate applications for approval have been (or will be) lodged for each component project and each project will be assessed separately. **Table 27-2** outlines the anticipated timing of each of the WestConnex projects and shows that there is potential for the construction phases of projects to overlap.

The two other WestConnex components most likely to result in cumulative impacts during construction of the project are the King George Road Interchange project and the future M4-M5 Link, as they are located directly adjacent to the project and would potentially involve overlapping construction periods.

Other component projects, such as the M4 Widening and M4 East, are located further from the project and are more likely to impact the M4 corridor during construction. The likelihood of significant cumulative impacts being generated by construction of the project, the M4 Widening and the M4 East is therefore low.

Table 27-2 also identifies the respective environmental impacts identified for the individual components of the WestConnex program of works. As the environmental assessment process for the future M4–M5 Link has not yet formally commenced, there are limited details of specific impacts that would potentially contribute to cumulative impacts.

Construction impacts would be minimised through further consideration during detailed design and construction planning, application of appropriate management and mitigation measures, and consultation with affected residents.

The construction strategy for the project (and the wider WestConnex program of works) focuses on balancing the need for construction to occur in a safe and efficient manner while managing constructability constraints and minimising cumulative impacts on the environment, road users and the surrounding road network.

Prior to the commencement of construction, more detailed construction planning would be undertaken for the New M5. General principles of the construction strategy are as follows:

- Achieve safe, efficient and convenient access for construction vehicles, plant and equipment along the length of the project and to and from public roads while at the same time minimising impacts
- Consider impacts to road users, the effect on urban amenity and the suitability of local road pavements
- Manage risks to existing infrastructure including roads, railways, utilities and services
- Minimise disruptions to traffic on the existing road network. The construction strategy allows for construction staging and night works to allow safe construction while maintaining vehicle movements and minimising impacts to amenity
- Manage community and environmental issues including noise, access, amenity and general disruption.

The design of the project has been carefully considered to minimise construction fatigue as far as practical. This includes completing the necessary local road upgrades and building the interchange and stubs to accommodate the future M4-M5 Link. The intent is to reduce the overall cumulative or repeat impacts on the community over a longer period.

Table 27-2 Timing of WestConnex components and Identified environmental impacts

Project	Key dates	Construction	Operation
M4 Widening	Approved on 21 December 2014 Work started in 2015 Operational late 2016	During construction of the project, potential impacts may include: • Noise and vibration, including potential night time disturbance associated with works outside standard construction hours • Dust and construction vehicle emissions • Traffic and access impacts • Impacts on three threatened ecological communities (Swamp Oak floodplain forest, Shale gravel transition forest and Freshwater wetlands on coastal floodplains). This would be limited to a total of approximately 0.17 hectares of moderate condition vegetation and 0.35 hectares of low condition habitat.	During operation of the project, potential impacts may include: • Traffic noise requiring new noise barriers and property treatments in some cases • Visual impacts associated with new viaducts and bridges • Changes in traffic patterns on Parramatta Road and the surrounding road network • Minor changes in flooding patterns along A'Becketts Creek.
M4 East	Determination expected in early 2016 Work to start mid 2016 (subject to approval) Operational early 2019	During construction of the project, potential impacts may include: • Traffic and access impacts due to construction traffic and changes to the road network • Noise and vibration, including potential night time disturbance associated with works outside standard construction hours • Dust and construction vehicle emissions • Impacts on non-Aboriginal heritage items located within the project footprint • Vegetation clearance.	During operation of the project, potential impacts may include: • Traffic noise requiring new noise barriers and property treatments in some cases • Visual impacts of new infrastructure • Property impacts due to acquisition for operational components of the project • Groundwater drawdown impacts due to inflow into the drained tunnels.
This project (New M5)	Determination expected in early 2016 Work to start mid 2016 (subject to approval) Operational late 2019	During construction of the project, potential impacts may include: • Traffic and access impacts due to construction traffic and changes to road network • Noise and vibration, including potential night time disturbance associated with works outside standard construction hours • Dust and construction vehicle emissions • Habitat for the Green and Golden Bell Frog	During operation of the project, potential impacts may include: • Traffic noise requiring property treatments in some cases • Visual impacts of new infrastructure • Property impacts due to acquisition for operational components of the project • Groundwater drawdown impacts due to inflow into the drained tunnels.

Project	Key dates	Construction	Operation
King Georges Road Interchange Upgrade	Approved 3 March 2015 Work started July 2015 Operational in 2017	During construction of the project, potential impacts may include: • Noise and vibration, including potential night time disturbance associated with works outside standard construction hours • Dust and construction vehicle emissions • Traffic and access impacts • Changes to existing cycle routes.	During operation, potential impacts may include: • Traffic noise, requiring a combination of new noise barriers, adjustments to the height of one existing noise barrier, and treatments at six residential properties • Visual impacts associated with new bridge structures and retaining walls • Changes to existing cycle routes.
Future M4-M5 Link	Potential approval in 2017/18 Work to start 2019 Operational 2023	As the environmental approvals process for the future M4–M5 Link has not commenced, there are limited details of any specific impacts that may potentially contribute to cumulative impacts. Environmental impacts of the whole of the WestConnex program of works were identified in the Strategic Environmental Review (Sydney Motorways Project Office, 2013b), and the following potential impacts are considered relevant to the future M4–M5 Link project: • Construction and operation noise and vibration impacts, particularly in a highly urbanised area • Socio-economic impacts on the surrounding community • Construction traffic impacts associated with spoil removal • Visual impacts of construction areas and operational facilities • Groundwater drawdown impacts due to inflow into the drained tunnels.	
Future Sydney Gateway	Construction early 2018 Operation 2023	Subject to environmental planning approval, there is the potential for construction of the future M4-M5 Link to commence in 2019 when the New M5 would be in the late stages of construction. The future Sydney Gateway may also commence in early 2018. It is expected that peak construction of the New M5 would be complete, and the construction activities would largely comprise mechanical and electrical fit-out and landscaping and rehabilitation works. There is the potential for localised cumulative construction works around the St Peters interchange as a result of the future M4-M5 Link or Sydney Gateway. This includes a portion of the site potentially used for a construction compound for the future M4-M5 Link. As the New M5 and these projects would likely be at different stages and unlikely to have concurrent peak construction periods, and the local road upgrades would be complete, it is expected that the potential for significant cumulative noise impacts would be limited. During construction, ongoing consultation would be undertaken with local communities potentially affected by concurrent construction of projects that form part of the WestConnex program of works. Additionally, consultation would be undertaken with proponents of other nearby projects to increase the overall awareness of project timeframes and impact.	

27.3.2 Other nearby developments

The project has the potential to have cumulative impacts with other nearby developments that are not related to the WestConnex program of works. **Table 27-3** identifies major and strategic projects as identified in the Department of Planning & Environment's major projects register in suburbs along and around the project alignment. Discussion of these major and strategic projects in relation to the existing environment is provided in the following sections.

Table 27-3 Other nearby developments

LGA	Suburbs	Major projects and other strategic projects
Canterbury	• Narwee • Kingsgrove • Earlwood	No major or strategic projects were identified
Hurstville	• Beverly Hills	No major or strategic projects were identified
Rockdale	• Bexley North • Bardwell Park • Bardwell Valley • Arncliffe • Turrella • Wolli Creek	A number of mixed use and residential developments have been identified around the Wolli Creek redevelopment area. Key developments include: • The Discovery Point Precinct • A multi-unit residential development, located at 12-40 Bonar Street and 5 Loftus Street • A mixed use retail / residential development located at 78-96 Arncliffe Street and 31-45 Princes Highway. The Princes highway corridor between Arncliffe and Banksia has been identified as including priority precincts for development.
Marrickville	• Sydenham • Tempe • St Peters	Marrickville Metro Shopping Centre is located north-west of Camdenville Park (approved 2015), and lies just outside the suburbs affected by the project.
Botany Bay	• Mascot	Mascot Station Town Centre Precinct Masterplan
Sydney	• Alexandria	Green Square Development

Development precincts

Wolli Creek redevelopment area

Developments have been proposed within and in the vicinity to the Wolli Creek redevelopment area, which is an initiative of Rockdale City Council. Historically an industrial precinct, the area is being transformed to a high density urban environment for living, working and recreation and forms part of a growing redevelopment zone extending along the Airport Rail line linking Wolli Creek to Sydney Airport, Mascot, Green Square and the Sydney CBD.

A concept plan approval was obtained for the establishment of a mixed use development within the 'Discovery Point Precinct' at 1 Princes Highway, Wolli Creek on 5 May 2011. This area is bounded by the Princes Highway, Cooks River, the Illawarra and East Hills Railway lines and Magdalene Terrace. The original concept plan was granted approval for the following development proposal:

- Building envelopes for 14 sites including maximum heights, total gross floor area, mix and size of apartments, total parking numbers and parking rates
- Landscaping of the site including completion of discovery point park, new plazas, common open space, station park, waterfront park and new neighbourhood park
- Road layout and streetscape treatments.

The concept plan identified environmental impacts that could be effectively managed through mitigation and management measures detailed in the statement of commitments. A number of modifications and project applications have since been submitted in relation to the Discovery Point Precinct with the most recent modification being approved 5 June 2015.

Key issues identified in the environmental assessment report prepared by the Department of Planning & Environment included density, built form, car parking, residential amenity, public benefits and design guidelines.

Specialist studies accompanying this report are of a level of detail to demonstrate the suitability of the site for the concept plan. The studies demonstrate that future development is capable of being implemented without resulting in adverse environmental impacts. Subsequent project applications for the site would be subject to further environmental assessment to identify issues that may arise as the result of more detailed designs. Such issues may then be addressed in order to ameliorate impacts.

Arncliffe to Banksia priority precincts

Rockdale City Council nominated the Princes Highway Corridor between Arncliffe and Banksia as a 'priority precinct' following a study into the renewal of the Princes Highway corridor around the Arncliffe and Banksia railway stations.

Community facilities being considered in this area include new walkways, cycle ways, playgrounds, multipurpose community centres and public art. The government will invest up to $5 million in local infrastructure, with a precinct proposal currently being drafted. No further details are currently available but it is possible that there may be some overlap with construction of the New M5.

Green Square development

The Green Square development covers 278 hectares and includes part of Alexandria (among other suburbs). A number of projects are associated with this development. The Green Square Centre (2014 – 2024) is the closet component of the Green Square development precinct to the project and being built next to the Green Square railway station, bordered by Bourke Street to the north and Joynton Avenue to the south (located within one kilometre from the New M5 local roads works). Construction works include:

- Soil remediation
- Construction of a library, plaza, streets, retaining walls and housing
- Demolition of the Waverley depot
- Refurbishment of the green infrastructure centre.

Based on the anticipated duration of the construction period, it is likely that there would be some overlap of construction activities with the New M5.

Mascot Station Town Centre precinct

The Mascot Station Town Centre Precinct has been identified as an appropriate location for increased growth and to meet the population targets of the City of Botany Bay within the Metropolitan Plan for Sydney 2036, the Draft East Sub-Regional Strategy 2007 and recent planning strategies for the City of Botany Bay.

These studies have identified the need to relate growth targets to the appropriate provision of public transport, public open space and desirable built form outcomes, to create a sustainable and efficient town centre with high levels of amenity.

New streets, parks and pedestrian connections would be designed to provide suitable access and amenity to new, relatively fine grained urban blocks. Concepts of street proportions, daylight to streets, view corridors and sun access to parks would inform the design of the built form and public domain. Transport measures including the provision of cycleways, traffic movement patterns, public transport measures and pedestrian links are integrated into the design of the public domain.

Marrickville Metro shopping centre

The Marrickville Metro expansion concept plan was approved on 19 March 2012. A modification was approved 23 April 2015 to split the staging of construction. The site comprises two parcels of land at 34 Victoria Road and 13-55 Edinburgh Road. Overall the approved development includes:

- Demolition of existing warehouse buildings and associated structures on the Edinburgh Road site
- Refurbishment and construction of a first floor addition to the existing retail building on the Victoria Road site and construction of a new building providing for two levels of retail on the Edinburgh Road site
- 528 additional car parking spaces to provide a total of 1628 spaces in two levels of roof top parking over both buildings
- Staging of development into two stages.

The key issues identified during assessment of the project included economic impact, traffic, access, public transport and car parking, height and built form, residential amenity and landscaping.

Qantas land at Mascot

On 9 December 2013, Qantas Airways Limited submitted a planning proposal that proposes amendments to the Botany Bay Local Environmental Plan (BBLEP) 2013 in respect of Qantas' land at Mascot. The Qantas Land is located immediately to the north of Sydney Airport and is bounded by Qantas Drive and Sydenham-Botany Railway Line to the south and Coward Street to the north.

The proposal will enable a range of uses that will support Sydney Airport; strengthen the economic activity of the Global Economic Corridor and Sydney Airport & Environs Specialised Centre; generate additional employment opportunities for the Botany Bay LGA; have minimal adverse impacts to the environment; and result in positive social and economic effects.

27.4 Cumulative impacts of WestConnex component projects

The King Georges Road Interchange Upgrade project is scheduled for completion by around late 2016/ early 2017. There may be an overlap of construction periods of around six to nine months with the New M5 (construction commencing early to mid-2016 pending approval).

The future M4-M5 Link is anticipated to commence construction in 2019 (subject to approval) and this would result in a short term overlap with construction of the New M5 (about six months).

There is potential for construction fatigue and cumulative impacts associated with the King Georges Road Interchange Upgrade project and the future M4-M5 Link, as discussed in **Section 27.4.1**.

The M4 East (is anticipated to be completed in early 2019, pending approval) and M4 Widening (anticipated to be completed by 2017) projects are located further from the New M5 project and are more likely to utilise the M4 corridor during construction and therefore have limited potential to generate cumulative impacts with the project.

Significant cumulative impacts relating to greenhouse gases, soil, water, flooding, human health, visual amenity, contamination, groundwater, resources and waste are not expected to occur. Further details on potential impacts to these environmental values are provided in the respective chapters of this EIS.

27.4.1 Traffic and transport

Construction

Construction haulage routes and vehicle access routes are expected to be similar between the project and the King Georges Road Interchange Upgrade project given the location and nature of construction. During the overlap period, construction vehicle movements associated with the King Georges Road Interchange Upgrade project would reduce, as the peak workforce demand would have subsided. As a result, the combined impact during this period is expected to be less than during the peak construction period for the project alone.

Subject to planning approval, the project currently has a projected construction timetable extending from around early to mid-2016 until late 2019. This is only about six months later than the construction period for the M4 East project. There is therefore a large overlap between the construction periods for these two projects. The majority of heavy vehicle and other routes associated with the M4 East would use the existing Parramatta Road corridor, and would therefore have limited potential for cumulative construction traffic impact with the project.

Operation

Traffic modelling undertaken for the 2031 'with project' scenario models the impacts on the road network with all components of WestConnex program of works constructed (i.e. M4 Widening, M4 East, M4–M5 Link, New M5 and the King Georges Road Intersection Upgrade project). **Chapter 4** (Project development and alternatives) describes the various alternative scenarios defined for the project. Traffic modelling is discussed in **Chapter 9** (Traffic and transport).

The modelling identified that under the full WestConnex program of works scenario in 2031, there would be a significant increase in total traffic demand during the AM and PM peak. Although total traffic demand would increase, the completion of the WestConnex program of works, including the future Sydney Gateway, would provide enough additional capacity on the road network to effectively distribute and accommodate the predicted increases in traffic on the local road network around St Peters interchange.

As a result, there would be a cumulative benefit of the projects, resulting in significant increases in travel speeds through the local road network, and a reduction in the average travel times.

27.4.2 Air quality

Construction

Potential air quality impacts during construction of the King Georges Road Interchange Upgrade project and the future M4-M5 Link would result from similar construction activities as the New M5 project.

These include clearing of vegetation and topsoil, excavation and levelling of soil, haulage of spoil and fill, wind erosion from unsealed surfaces and stockpiles, and construction vehicles using unsealed roads in some cases.

However, cumulative construction impacts are unlikely to significantly vary from those discussed in **Chapter 10** (Air Quality) following the application of mitigation and management measures adopted for this project.

Operation

By 2031, the New M5 is predicted to accommodate about 34,500 vehicles per day and about 81,500 vehicles per day if the full WestConnex program of works are completed. This would be a 134 per cent increase and would be due to traffic using the future M4-M5 Link and the future Southern extension, with the traffic volume including traffic heading east / west on the New M5 and south west / north-east on the future Southern extension.

If the full WestConnex program of works is completed, the two-way daily volume on Stoney Creek Road is forecast to reduce and two-way daily traffic on the Princes Highway, north of the M5 East interchange, is forecast to decrease from 79,000 vehicles per day without the project to about 25,000 vehicles per day. This 69 per cent decrease is a substantial reduction along this congested section of the strategic road network

In the majority of cases the ambient air quality results for the expected traffic scenarios (ground level concentrations) for community receptors in the 2031 'cumulative scenario' were very similar to those for the 2031 'with project' scenario. The results for the 2031 'cumulative scenario' at the recreational, workplace and residential receptors were also broadly similar to those for the 2031 'with project' scenario.

Changes in annual mean $PM_{2.5}$ concentrations in the 2031 'cumulative scenario' were considered for elevated receivers at heights of 10 metres above Australian Height Datum (AHD) and 30 metres AHD. At a height of 30 metres AHD, the increases in concentration were larger than at 10 metres AHD, but they were much more localised around the ventilation outlets.

No recreational, workplace or residential receptors were predicted to experience a change in annual average PM2.5 of more than 0.8 µg/m3 at a height of 10 metres AHD. The largest increase was 0.8 µg/m3. At a height of 30 metres AHD, the increase in PM2.5 was greater than 0.8 µg/m3 at 38 receptors. There were 17 recreational, workplace or residential receptors that were predicted to have a change in annual average PM2.5 of more than 1.6 µg/m3. All these receptor locations were very close to the assumed location of the future Southern extension ventilation facility. However, the precise location and design of the future Southern extension ventilation outlets has not yet been determined and therefore potential impacts to elevated receivers from PM2.5 are not able to be quantified. Potential impacts and any necessary management or mitigation measures would be considered as part of the future Southern extension air quality assessment.

27.4.3 Noise and vibration

Construction

Construction of the King Georges Road Interchange Upgrade project would potentially overlap with construction of the New M5 for about six to nine months in 2016. There is potential for receivers around the western surface works to be affected by cumulative construction noise impacts from these two projects. Potential cumulative construction noise impacts may involve:

- Finishing works for King Georges Road Interchange Upgrade project, and potentially some road works scheduled for late in the construction program
- Early works, site establishment and potentially the initial phases of tunnelling for the New M5.

Based on the nature of the potential concurrent project works, and the anticipated noise impacts from each, it is expected that the dominant noise source during this period would be the New M5.

Subject to the progress of both projects, specific measures would be developed to coordinate mitigation and management of construction noise from concurrent construction activities. These measures would be detailed in the construction environmental management plan(s) for the project, and would include consideration of both physical and program measures (such as coordinating periods of respite).

The M4 East Project would be carried out at a significant distance from the New M5 and therefore there is unlikely to be any cumulative noise impact between the two projects.

Subject to environmental planning approval, there is the potential for construction of the future M4-M5 Link to commence in 2019 when the New M5 would be in the late stages of construction.

It is expected that peak construction of the New M5 would be complete, and the construction activities would largely comprise mechanical and electrical fit-out and landscaping and rehabilitation works.

There is the potential for localised cumulative construction works around the St Peters interchange, with a portion of the site potentially used for a construction compound for the future M4-M5 Link. As both projects would be outside of peak construction periods, and the local road upgrades would be complete, it is expected that the potential for significant cumulative noise impacts would be limited.

During construction, ongoing consultation would be undertaken with local communities potentially affected by concurrent construction of projects that form part of the WestConnex program of works. Additionally, consultation would be undertaken with proponents of other nearby projects to increase the overall awareness of project timeframes and impact.

Operation

The operational noise assessment undertaken as part of the project included an assessment of 2031 traffic volumes, which included the cumulative noise impacts of vehicles using WestConnex when all projects are completed. The assessment is discussed in **Chapter 12** (Noise and vibration).

Noise levels have been predicted at sensitive receiver locations throughout the project area for both the daytime and night-time scenarios. The opening of the full WestConnex program of works (including the future M4-M5 Link) and the future Southern extension would increase direct traffic flows on infrastructure delivered as part of this project. Therefore, a noise assessment was completed for the most stringent scenario, which is the design year for WestConnex Stage 2 (2031) assuming the full WestConnex program of works and the future Southern extension is operational.

Around the M5 East Motorway, in the Kingsgrove area, road traffic volumes would reduce. This would result in an appreciable reduction in noise levels throughout the study area along the alignment of the project and M5 East Motorway (between Beverly Hills and Kingsgrove). However, road traffic noise levels are predicted to be 'acute' at one noise sensitive receiver. This receiver would be eligible for consideration of additional noise mitigation.

For the St Peters interchange the night-time period was the more stringent time period. Road traffic noise levels at a total of 145 residential sensitive receivers exceeded the $LA_{eq(9hour)}$ noise criterion. In accordance with the Noise Mitigation Guideline (Roads and Maritime, 2015) it was not considered reasonable to consider additional noise mitigation measures at receivers that would experience an increase in road traffic noise levels of 2 dB(A) or less, and were not considered 'acute'. As such a total of 144 residential receivers were considered for additional noise mitigation measures. In addition two school buildings (St Peters Public School) are eligible during the daytime only.

A cumulative noise assessment of operational facilities, or 'fixed' facilities, was also undertaken and found that these facilities would comply with the applicable criteria at the most affected residential receivers. This would be confirmed during the detailed design phase.

27.4.4 Economic impacts

Construction

Cumulative benefits on local businesses and the economy would result from overlapping construction periods for the project, the King Georges Road Interchange Upgrade project and the M4 East.

The construction of multiple projects would intensify the beneficial economic impacts that have been identified for the project only, and described in **Chapter 15** (Social and economic). In particular, these impacts relate to employment opportunities and economic stimulus.

The labour demand from WestConnex and other major projects in the area (and across wider Sydney) would increase employment opportunities for local residents. An increased demand for construction workers would also potentially increase wages.

The opportunity for local businesses to supply goods or services during the construction of these multiple projects, both to the projects directly and to their workforces has the potential to increase business turnover.

In contrast, however, there is the potential for businesses located close to the project and other WestConnex projects to experience impacts on amenity, which could result in a temporary downturn in their usual business.

The staggered nature of the WestConnex projects (in particular the King Georges Road Interchange Upgrade project and the New M5, for which some works would occur in a similar location) results in an extension of the period of construction and the impacts experienced in any one area. For example, the area of Kingsgrove around the Kings Georges Road interchange would experience a construction period which would potentially last five years.

There is the potential for construction vehicles associated with other projects to contribute further to congestion on the road network and further increase travel times along the M5 Motorway corridor. This would further affect the movement of freight via these routes during the construction periods, resulting in delays and potentially leading to increased costs. Such impacts would also flow on to motorists, who may spend longer in transit. These impacts would be temporary for the duration of construction only, with long term improvements in travel times expected during operation.

Operation

The operation of WestConnex would result in beneficial impacts on the economy and businesses in the vicinity of the project. The freight industry would benefit from WestConnex enabling the efficient movement of freight from Western Sydney to Sydney Airport and Port Botany (and vice versa), thus improving access to interstate and international markets.

WestConnex provides one of the missing links in the Sydney motorway network by creating a connection between the M4 and M5 motorways. The resulting benefits for freight include the opportunity to streamline interstate movements around and through Sydney. This provides businesses with connections to service more diverse and dispersed markets across the Sydney metropolitan area and potentially beyond.

Other key benefits would include a reduced demand on alternative routes on the existing road network, including the M5 East Motorway, which in turn would improve connectivity and amenity for communities along these routes. The beneficial cumulative impact of WestConnex would lead to improvements in connections between employment and population centres along the M5 Motorway corridor and beyond, catering for existing and future demand.

This would include a direct connection to employment zones within Sydney's global economic corridor generally and specifically near Sydney Airport and Port Botany via the St Peters interchange.

27.4.5 Social impacts

Construction

Construction of the project and the King Georges Road Interchange Upgrade project would overlap, resulting in extended durations of construction impacts in the vicinity of Kingsgrove. Social impacts related to travel delays, diversions and inconvenience, exposure to visual and noise amenity impacts would be prolonged for commuters, public transport users, pedestrians and cyclists.

Additionally, during construction of the future M4–M5 Link, sensitive receivers in the vicinity of St Peters would again be subject to construction impacts. However, the project includes preparatory works in this location for the future M4–M5 Link in order to minimise the amount of work which is required during future stages. This would reduce impacts to the community.

Operation

The M5 East Motorway currently experiences heavy traffic congestion, slow speeds and unreliable travel times especially in the morning and afternoon peaks, and increasingly at other times of the day and also on weekends.

Sydney's population is expected to increase by more than 1.6 million people by 2031 and without major investment in road network infrastructure this growth would result in worsening road congestion, potentially leading to increased anxiety and stress.

The project, in combination with the wider WestConnex scheme, has the ability to connect residential communities with employment centres, due to reduced congestion and decreased travel times. The project also provides greater accessibility for residents of south and south-west Sydney to access Sydney Airport and the Sydney CBD.

Cumulative impacts are therefore anticipated to be largely beneficial from a social perspective.

27.4.6 Non-Aboriginal heritage impacts

The King Georges Road Interchange Upgrade heritage assessment included a review of statutory and non-statutory heritage registers and a site inspection. The site inspection did not find any unlisted heritage items. The assessment found that there are no statutory items or conservation areas within or in close proximity to the upgrade works.

Two non-statutory conservation areas are adjacent to the existing M5: the Pallamanna Parade and Welfare Avenue Urban Conservation Area. These are listed on the Register of the National Estate, which has ceased to be a statutory list. These areas are separated from the M5 Motorway by noise walls and roadside vegetation. The New M5 is not expected to have any direct or indirect impacts on these areas.

There are no cumulative impacts to Non-Aboriginal heritage expected as a result of the WestConnex program of works.

27.4.7 Biodiversity impacts

WestConnex projects such as the King Georges Road Interchange Upgrade project and the future M4-M5 link (subject to planning approval) would result in removal of planted vegetation and fauna habitats. The M4 East project would involve the removal of small patches of highly fragmented planted vegetation.

The King Georges Road Interchange Upgrade project includes the removal of a small area (0.01 hectares) of Cook River / Castlereagh Ironbark Forest in the Sydney Basin endangered ecological community, the removal of low quality habitat (3.23 hectares) with potential food habitat for the Grey headed flying fox (*Pteropus poliocephalus*) and removal of nine affected Downy Wattle (*Acacia pubescens*) individuals. Given the small areas, poor condition and low site value scores, impacts on biodiversity would be minor for the King Georges Road Interchange project.

No significant cumulative impacts to the habitat for the Green and Golden Bell Frog (*Litoria aurea*) are expected to occur as a result of other WestConnex projects. Overall these projects and other developments would result in some further loss of habitat from an already modified environment with only limited natural biodiversity value. Cumulative impacts to biodiversity are therefore unlikely to be significant.

27.5 Cumulative impacts of nearby projects

As outlined in **Section 27.3.2**, there are few major developments in the vicinity of the project that would potentially be under construction at a similar time as the New M5.

The following sections outline the potential cumulative impacts associated with other non-WestConnex developments. Given the nature of these developments and their distance from the project, the main potential cumulative impacts relate to traffic and amenity.

27.5.1 Traffic and transport

Construction

The construction of nearby projects has the potential to result in additional construction traffic on the surrounding road network.

The Marrickville Metro Shopping Centre gained planning approval in April 2015 and although no certain construction dates have been indicated, it is assumed that construction would likely take place during the same period as the project.

Traffic from the construction of the Marrickville Metro Shopping Centre, north-west of Camdenville Park, may contribute to cumulative impacts, most notably during the construction of the St Peters interchange and local road upgrades.

No construction traffic numbers for the Marrickville Metro Shopping Centre are currently available to allow a quantitative assessment of potential traffic impacts. While the Marrickville Metro Shopping Centre project would likely result in an increase in the number of vehicles in the locality, it is likely that the number associated with this development would not significantly contribute to overall traffic numbers.

The greatest increase in traffic flows to the Marrickville Metro Shopping Centre are likely to be caused by the main approach routes; being Edinburgh Road, Victoria Road, Enmore Road and Belmore Road. These roads would not be used as major routes for construction traffic for New M5.

Intersections surrounding the Marrickville Metro would operate at a satisfactory level provided the Marrickville Metro Shopping Centre incorporates the recommended improvements to Unwins Bridge Road, Bedwin Road, May and Campbell Street intersection, as well as providing a new roundabout to Edinburgh and Sydney Steel Road, as stated in the Environmental Assessment Report (July 2010) for the Marrickville Metro Shopping Centre Concept Plan Application (Ref: MP 09_0191).

The Green Square Development, Mascot Station Town Centre Precinct Masterplan and Wolli Creek redevelopment area would all be developed progressively (i.e. staged) and are generally located away from areas affected by the project. Traffic from these developments is therefore unlikely to contribute substantially to cumulative traffic impacts in the vicinity of the project during its construction phase.

The Qantas Land at Mascot was required to undertake a traffic impact assessment as part of the application to Council. The traffic impact assessment indicated that the additional traffic generated from the Qantas Land as a result of the planning proposal would have “a negligible impact on the surrounding network taking into account the number and spread of access points to the road system. The assessment predicts the additional floor space would result in an additional 887 employees on the Qantas Land with a resultant traffic generation of 168 AM peak hour trips. This increase represents a 3.3% increase in employees across the Mascot precinct and 2.1% increase in peak hour vehicle trips” (City of Botany Bay, 2014)

The traffic assessment also took into consideration Stage 2 of the WestConnex and future road widening project on O’Riordan Street in Mascot. The report concludes that these projects have the “potential to provide regional traffic relief to enable development potential under the Local Environment Plan 2013 planning control” (City of Botany Bay, 2014).

Operation

During operation, the developments outlined in **Section 27.3.2** would contribute some traffic to the road network; however, this traffic is likely to disperse via the arterial road network. Where possible, the modelling undertaken (described in **Chapter 9** (Traffic and transport)) has factored in growth in the surrounding area which could lead to increases in vehicle numbers on the road network. The results of the modelling are outlined in Section 9.3.2 of **Chapter 9** (Traffic and transport).

In summary, the modelling identified that the project would reduce vehicle delays along the M5 Motorway corridor, the area around the St Peters interchange and local roads.

27.5.2 Amenity impacts

The timing and positioning of the developments outlined in **Section 27.3.2** mean that cumulative noise, air quality, traffic and visual impacts are likely to be limited.

However, longer term developments, such as the Green Square Urban Renewal Area and the Mascot Station Town Centre Precinct, would potentially occur during the later stages of the project or directly after the project is complete.

Although not directly located within the project footprint, these developments have the potential to create construction fatigue impacts, which occur when impacts from multiple construction projects extend over a longer period of time than would be experienced from a single project.

Such impacts are likely to be more evident in the vicinity of St Peters and Kingsgrove, where the project would include the establishment of construction ancillary facilities. Following the construction period for the project, there is the potential for the redevelopment of these areas to result in extended impacts on the surrounding community over a greater period of time.

During construction, ongoing consultation would be undertaken with local communities potentially affected by concurrent construction of other nearby projects to increase the overall awareness of project timeframes and impacts.

27.6 Management of impacts

Environmental management measures relating to cumulative impacts during construction and operation are provided in **Table 27.4**. Measures provided in **Chapter 9** (Traffic and transport) would also assist in minimising cumulative impacts, as the majority of potential impacts are traffic related.

Table 27.4 Environmental management measures – cumulative

Impact	No.	Environmental management measure	Timing
Construction			
Cumulative impacts	CI01	Consultation would be undertaken with local communities potentially affected by the impacts of multiple projects in addition to the project.	Construction
	CI02	Where relevant, consultation would be undertaken with proponents of other nearby developments to increase the overall awareness of project timeframes and impacts.	Construction

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28 Sustainability

This chapter explains how sustainability aims and principles have been applied to the design, construction and operation of the project. The chapter:

- Provides an overview of the concept of sustainability as context for the sustainability principles that have been adopted
- Presents the sustainability policy framework that has been applied for the project
- Details the proposed Sustainability Management Plan for the project and specific sustainability initiatives that would be used to guide the management and implementation of sustainability objectives during construction and operation of the project.

The assessment of sustainability has been prepared to address the relevant requirements of the Secretary of the Department of Planning and Environment, as detailed in **Table 28-1**.

Table 28-1 Secretary's environmental assessment requirements – Sustainability

Secretary's environmental assessment requirement	Where addressed
Detail how the principles of ecologically sustainable development will be incorporated in the design, construction and ongoing operational phases of the proposal.	The principles of ecologically sustainable development and how they have been incorporated into the project throughout its design, construction and operation is discussed in **Section 28.4**.

28.1 What is sustainability?

The World Commission on Environment and Development report *Our Common Future* (Brundtland, 1987) identifies sustainable development as being 'development which meets the needs of the present, without compromising the ability of future generations to meet their own needs'. Although this early definition of sustainable development is succinct, the concept of sustainable development is actually dynamic; changing in response to the limitations imposed on environmental resources at any time as a result of technology, social organisation and by the ability of the biosphere to absorb the effects of human activities.

The Commonwealth Government refers to ecologically sustainable development as 'using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased' (Commonwealth Department of the Environment, 1992).

The provision of properly functioning infrastructure is essential for sustained economic growth, international competitiveness, public health and overall quality of life (Mirza, 2006). The Infrastructure Sustainability Council of Australia (ISCA) defines sustainable infrastructure as that which is designed, constructed and operated to optimise environmental, social and economic outcomes over the long-term (ISCA, 2012).

28.2 Sustainability policy framework

The sustainability policy framework, relevant to the project, is made up of the following documents:

- Long Term Transport Master Plan (Transport for NSW, 2012a)
- NSW Government Resource Efficiency Policy (OEH, 2014a)
- NSW Waste Avoidance and Resource Recovery Strategy 2014-21 (EPA, 2014b)
- WestConnex sustainability strategy (WestConnex Delivery Authority, 2015).

Together these documents provide the sustainability principles which have informed the design of the project and against which the construction and operation of the project would be measured in terms of sustainability.

28.2.1 Long Term Transport Master Plan

The NSW Long Term Transport Master Plan (Transport for NSW, 2012a) is the guiding transport planning and policy document supporting NSW 2021. The Plan provides a framework for delivering an integrated, modern transport system by identifying NSW's transport actions and investment priorities for the next 20 years. Under the Plan, the WestConnex program of works is identified as a critical link in Sydney's motorway network and an immediate priority for the NSW Government.

The Plan states that 'promoting sustainability and protecting the environment in our transport planning, decisions and projects' is a state wide challenge that must be addressed. The Plan focuses on achieving the following environmental and sustainability objectives:

- Enhancing environmental and sustainability outcomes
- Minimising damage to our environment
- Adapting our transport infrastructure to be resilient (to climate change and natural disasters)
- Maintaining Sydney's air quality
- Reducing emissions and managing energy use.

In addition the Plan includes the following relevant specific environmental and sustainability 'actions':

- Develop and promote Transport Infrastructure Sustainable Design Guidance (includes trialling the Infrastructure Sustainability (IS) rating tool)
- Incorporate sustainability principles in procurement policy
- Consider the air quality impacts of transport projects
- Assess transport climate resilience
- Mitigate noise from road projects.

28.2.2 NSW Government Resource Efficiency Policy

The *NSW Government Resource Efficiency Policy* (July 2014) aims to drive resource efficiency, with a focus on energy, water and waste, and reducing harmful air emissions. The policy aims to ensure NSW Government agencies show leadership by incorporating resource efficiency in decision-making.

The policy includes specific measures, targets and minimum standards to drive resource efficiency. Refer to Chapter 22 (Greenhouse gas) for information regarding how the project aligns with the Resource Efficiency Policy.

28.2.3 NSW Waste Avoidance and Resource Recovery Strategy 2014-21

The *NSW Waste Avoidance and Resource Recovery Strategy 2014-21* (December 2014) provides a framework for waste management and aligns with the NSW Government's waste reforms in NSW 2021.

The *NSW Waste Avoidance and Resource Recovery Strategy 2014-21* includes the following six key result areas: avoid and reduce waste generation; increase recycling; divert more waste from landfill; manage problem wastes better (including asbestos); reduce litter; and reduce illegal dumping.

Consistency of the project with the key result areas of the NSW Waste Avoidance and Resource Recovery Strategy 2014-21, is demonstrated in **Table 28-2**.

Table 28-2 Project consistency with key result areas of the NSW Waste Avoidance and Resource Recovery Strategy 2014-21

Key result area	Comment
Avoid and reduce waste generation	During construction of the project, unnecessary resource consumption would be avoided by making realistic predictions of the required quantities of resources such as construction materials. Resource recovery would be applied to the management of construction waste and would include for reuse, recycling, and reprocessing. Further details are provided in **Chapter 24** (Resource use and waste minimisation).
Increase recycling; divert more waste from landfill	
Manage problem wastes better (including asbestos)	During construction of the project, there would be potential to encounter contaminated soil, which would require remediation or disposal. This potential impact is discussed in **Chapter 17** (Contamination) and **Chapter 24** (Resource use and waste minimisation), along with mitigation measures, including the ways in which disposal of contaminated waste would be managed.
Reduce litter	Waste generated by the construction workforce would be disposed of appropriately.
Reduce illegal dumping.	Waste generated by the project would be managed and disposed of in accordance with relevant State legislation and government policies including the *Protection of the Environment Operations Act 1997*, *Waste Avoidance and Resource Recovery Act 2001*, and the *Waste Avoidance and Resource Recovery Strategy 2014-21* (NSW EPA, 2014b).

28.2.4 WestConnex sustainability strategy

The WestConnex Sustainability Strategy (the Sustainability Strategy) (WestConnex Delivery Authority, 2015) describes how sustainability initiatives will be integrated into the design, construction and operation of projects across the WestConnex program of works. The Sustainability Strategy outlines a sustainability vision, commitments, guiding principles, objectives and overarching targets across a range of sustainability themes, and was prepared to align with the Transport for NSW Sustainability Framework as well as other relevant Government sustainability instruments.

Due to the large scale of the WestConnex program of works, and by virtue of the fact that it will be delivered in discrete stages over several years, the Sustainability Strategy aims to ensure that sustainability is consistently applied across all projects and teams.

The Sustainability Strategy provides a framework to implement sustainability objectives and targets through the project's contract requirements, competitive tender evaluation process and project specific Sustainability Management Plans during the design and construction stage. The Sustainability Strategy also shows the relationship between the sustainability vision, commitments, guiding principles and broader NSW Government sustainability instruments.

The project would achieve an Infrastructure Sustainability rating of 'Excellent' for the design and construction phases of the project. The Sustainability Strategy has been prepared to guide the implementation of sustainability across the WestConnex program of works and to facilitate the ISCA rating process.

The IS rating scheme was developed and is administered by ISCA. The IS rating scheme is a comprehensive rating system for evaluating sustainability across the design, construction and operation of infrastructure.

A project-specific Sustainability Management Plan would be prepared to guide the implementation of sustainability throughout the design and construction phases, and to facilitate the achievement of the ISCA rating.

The WestConnex Sustainability Strategy Framework is shown in **Figure 28-1**. Details of how the project is consistent with WestConnex Sustainability Strategy Framework, and how the project would meet or where possible, exceed the objectives and targets outlined in the Sustainability Strategy is summarised in **Table 28-3**.

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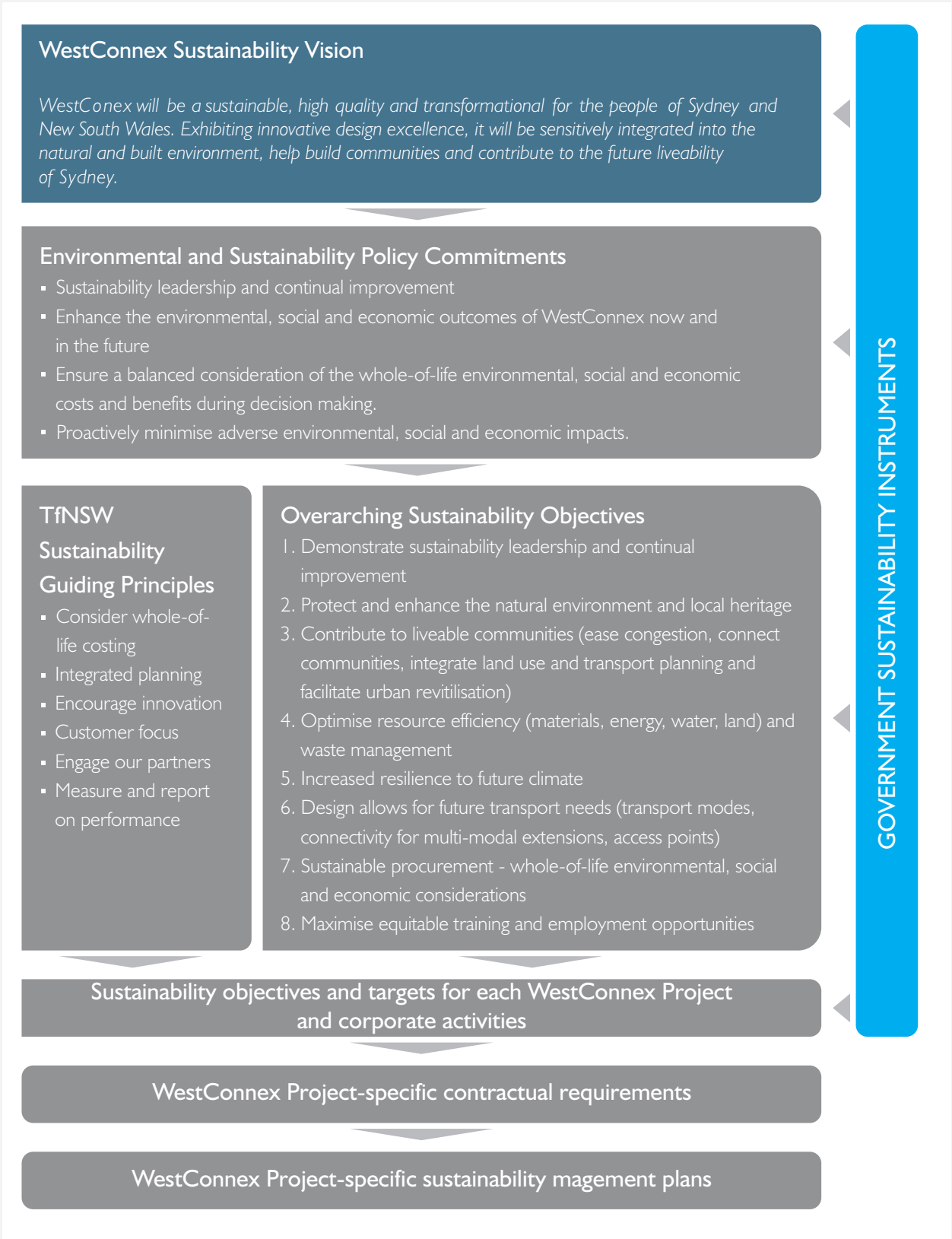


Figure 28-1 WestConnex sustainability strategy framework

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Table 28-3 Project consistency with the WestConnex Sustainability Strategy Framework objectives and targets

Sustainability targets	Project consistency
Overarching sustainability objective: Demonstrate sustainability leadership and continual improvement.	
• Achieve an IS rating of at least Excellent for the design and construction phases • Prepare quarterly project progress reports and an annual WestConnex Sustainability Report. Annual review of the WestConnex Sustainability Report and WestConnex Environment and Sustainability Policy by Senior Management. • Share sustainability knowledge and lessons learnt across WestConnex component projects and other Roads and Maritime projects. Participate in sustainability workshops during design and construction phases and document lessons learnt • Appoint a Sustainability Representative with relevant experience to drive the achievement of sustainability outcomes.	• An IS rating of at least Excellent would be achieved for the design and construction phases of the project. • Quarterly project progress reports and an annual WestConnex Sustainability Report would be prepared during the design and construction phases. • During the design and construction phases, knowledge and lessons learned would be shared across the WestConnex component projects through participation at regular sustainability workshops. • The Environment and Sustainability Manager and Sustainability Advisor will drive the achievement of sustainability outcomes during design and construction phases.
Overarching sustainability objective: Protect and enhance the natural environment and local heritage	
• Ensure no serious pollution incidents occur during construction • Proactively manage any impacts to flora and fauna in accordance with the RMS Biodiversity Guidelines • Heritage items are avoided where possible and proactively managed during construction.	Construction activities would be managed in line with the mitigation measures outlined in this EIS to avoid serious pollution incidents. A biodiversity assessment has been prepared in accordance with the *Framework for Biodiversity Assessment* (OEH, 2014b) and the *NSW Biodiversity Offset Policy for Major Projects* (OEH, 2014c). This considers measures to avoid and minimise impacts to biodiversity in a biodiversity assessment report (BAR), and the preparation of a biodiversity offsets strategy (BOS) to offset residual impacts. Project impacts would be managed in accordance with the Roads and Maritime biodiversity guidelines. Additional detail is provided in **Chapter 21** (Biodiversity), **Appendix S** and **Appendix T**. Items of Aboriginal and non-Aboriginal heritage significance were identified early in the project design and assessment. Impacts to these items have been avoided and mitigated where practicable and management measures to be implemented throughout construction of the project have been provided. An assessment of potential impacts and proposed mitigation and management measures with regards to non-Aboriginal and Aboriginal heritage are provided in **Chapter 20** and **Chapter 23** respectively. The Technical working paper: Non-Aboriginal heritage and Technical working paper: Aboriginal heritage are provided in **Appendix R** and **Appendix V** respectively.

Sustainability targets	Project consistency
Overarching sustainability objective: Contribute to liveable communities (ease congestion, connect communities, integrate land use and transport planning and facilitate urban revitalisation)	
• Design the motorway to reduce road congestion and travel times • Ensure appropriate air quality outcomes. The tunnel ventilation systems of the WestConnex program of works will be designed and operated to comply with best-practice criteria for in-tunnel and ambient air quality • Maintain or improve pedestrian and cycle paths and connections. • Create/enhance public open space.	The project would contribute to reducing congestion on the existing road network and would save time on a typical journey along the M5 Motorway corridor. Details of how the project and ventilation design ensures that concentrations of air emissions meet NSW, national and international best practice for in-tunnel and ambient air quality are presented in **Chapter 4** (Project development and alternatives) and **Chapter 10** (Air quality). Existing pedestrian and cycle paths would be modified during construction to maintain the existing connections provided at Kingsgrove and Mascot. Cycling and pedestrian facilities at St Peters and Mascot would be improved as part of upgrades to the local road network; including the construction of a regional cycling connection between Mascot and Marrickville, a grade separated pedestrian and cycle bridge along Campbell Road with connections into Sydney Park, and cycling provisions along all local roads which are to be upgraded as part of the project.
Overarching sustainability objective: Optimise resource efficiency (materials, energy, water, land) and waste management.	
Materials • Identify and implement opportunities to reduce material use and maximize the use of materials with low embodied environmental impact • Maximise the use of all timber products from either reused/recycled timber or from sustainably managed forests that have obtained Forest Management Certification • Optimise the amount of cement replacement material (measured by mass) used in concrete • Optimise the amount of recycled material used in road base and sub base.	Recycled products would be used during construction of the project to reduce the demand on resources, in instances where the use of such materials is cost and performance competitive. This may include the use of fly ash and slag within concrete mixes. Resource recovery principles would be applied to the construction of the project, including recovery of resources for reuse, recycling and reprocessing, where possible. It is anticipated that up to 10 per cent of the pavement would comprise reclaimed asphalt, sourced from existing road pavements to be removed / replaced as part of the project and up to 10 per cent of virgin materials may be able to be substituted with recycled materials during construction. Additionally, geopolymer concrete (a low calcium, fly-ash based concrete product) would be considered for use in structural elements of the project, such as pre-cast, high-strength box culverts. Additional detail is provided in **Chapter 22** (Greenhouse Gas) and **Chapter 24** (Resource use and waste minimisation) .

Sustainability targets	Project consistency
Energy and carbon • Prepare an Energy Efficiency and Greenhouse Gas Emissions Strategy detailing processes and methods to improve energy efficiency and reduce greenhouse gas emissions • Percentage of energy sourced from renewable energy generated onsite and/or accredited GreenPower. The current target is to source a minimum of six per cent of energy from renewable energy generated onsite and/or accredited GreenPower • Optimise the design and operation of the motorway to minimise energy used by vehicles using the motorway.	At least six per cent of construction energy required for the project would be sourced where possible from an accredited GreenPower energy supplier. It is expected about two per cent of construction phase power requirements would be offset in accordance with the Commonwealth Government's National Carbon Offset Standard. This would be reviewed during detailed design to refine the approach to offsetting energy requirements and to identify whether additional power consumption can be offset. An Energy Efficiency and Greenhouse Gas Emissions Strategy would be prepared as an attachment to the Sustainability Management Plan during detailed design. The strategy would identify initiatives to be implemented during construction of the project to reduce carbon emissions, energy use and embodied life cycle impacts. The main alignment tunnels would be designed to minimise fuel use for motorists using the road. For example, the project would provide a vertical alignment that allows consistent vehicle speeds to be maintained. Further, low carbon energy generation options would be investigated as part of the design process in order to reduce the demand on mains electricity where feasible. Additional detail regarding energy efficiency is provided in **Chapter 22** (Greenhouse gas).

Sustainability targets	Project consistency
Water • Undertake a Water Balance Study and identify opportunities to reduce water use (in particular potable water use) and reuse water (eg rainwater, stormwater, wastewater, and groundwater) during construction and operation • Reuse, recycle or reclaim water (eg rainwater, stormwater, wastewater, groundwater, tunnel inflow water) generated/collected.	Water efficiency measures would be implemented with a focus on achieving water savings and targeting water recycling and re-use. Rainwater would be harvested on-site at construction compounds and re-used as part of the project where possible. It is anticipated that about five per cent of water generated / collected during construction would be re-used, recycled or reclaimed including truck wash water which would be treated and recycled and any rainwater collected on site. During construction, non-potable water sources would be given preference over potable sources where appropriate. Non-potable water would be obtained from other non-potable sources where possible, although this is expected to be limited to about three per cent of the overall water use. This is because the two main sources of non-potable water are: • Water from the treatment plant (including both groundwater and first use construction water), which is expected to be too saline to use for purposes other than dust suppression, • Collected rainwater, which would not generate the quantities needed to meet the non-potable water demand for the project. The extent to which non-potable water can be used during the project would be reviewed and refined during detailed design. Construction water would either be re-used on site wherever feasible, or discharged into the local stormwater system in accordance with the requirements of an Environment Protection Licence. Preference would be given to reusing as much water as is practicable before discharging. Additional information regarding surface water and water quality is provided in **Chapter 16** (Soils and water quality). An updated water balance would be prepared during the detailed design stage of the project. The outcomes of this study would be used to further improve water efficiency throughout construction and operation of the project.

Sustainability targets	Project consistency
Land • Minimise the project's surface land footprint and acquisition of properties • Identify contaminated sites within the project's construction footprint and remediate to a standard for post construction use (as applicable).	The project has been designed to maximise the use of land already owned by Roads and Maritime, and operational elements of the project would be located within existing road corridors as much as feasible. A number of additional known and potentially contaminated sites would be impacted by the project, including the Alexandra Canal. The project would enhance land where possible, including the closure of the Alexandria Landfill site. The Alexandria landfill site would be subject to a Landfill Closure Management Plan, and would be made suitable for redevelopment of the site for a road.
Waste and Spoil • Reuse/recycle a minimum of 80 per cent usable spoil (uncontaminated surplus excavated material) • Reuse/recycle a minimum of 80 per cent of construction and demolition waste (uncontaminated) • Implement packaging take-back arrangements with suppliers (lead contractor to pass target onto sub-contractors, where practical).	Where possible, and fit for purpose, spoil would be beneficially re-used within the project before off-site re-use or disposal options are investigated. A spoil management strategy would be developed for the project prior to the commencement of construction and would identify spoil disposal sites and the management of excess spoil. Usable spoil (uncontaminated surplus excavated material) would be re-used and / or recycled as part of the project, where possible. The management and disposal of excess spoil is discussed further in **Chapter 24** (Resource use and waste minimisation). About 80 per cent of construction and demolition waste is anticipated to be reused and / or recycled as part of the project. A Waste Management Plan would be prepared as part of the Construction Environmental Management Plan for the project, detailing the appropriate procedures for waste management. Residual waste that cannot be re-used or recycled would be disposed of to a suitably licenced landfill or waste management facility. Additional detail regarding resource management and waste minimisation is provided in **Chapter 24** (Resource use and waste minimisation).
Overarching sustainability objective: Increased resilience to future climate	
• Undertake a climate change risk assessment • Identify and implement adaptation measures to mitigate all high and extreme residual climate change risks.	A climate risk assessment has been prepared as part of the environmental impact assessment for the project in line with relevant standards and current guidelines and is included in **Chapter 25** (Climate change risk and adaptation). The risks of future climate change would be further considered during the detailed design of the project. Mitigation and measures relating to climate change risk and adaptation are provided in **Chapter 25** (Climate change risk and adaptation).

Sustainability targets	Project consistency
Overarching sustainability objective: Design allows for future transport needs (transport modes, extensions, access points)	
• Preserve an area of land for future safe pedestrian and cyclist connectivity across and adjacent to the motorway. • Allow for future extensions to the road network and access points.	The project has been designed to maintain and improve pedestrian and cycling paths, and does not preclude potential future upgrades of or additions to pedestrian and cycling paths. The main alignment tunnels include stub tunnels to provide potential access to the future Southern extension and the future M4-M5 Link. Further, the St Peters interchange would include the construction of ramps to provide access to and from local roads to the potential future Sydney Gateway and M4-M5 Link (refer to **Chapter 5** (Project description) for more detail).
Overarching sustainability objective: Sustainable procurement - whole of life environmental, social and economic considerations	
• Incorporate sustainability criteria into project contracts and tender evaluation criteria • Prepare and implement an Australian Industry Participation Plan.	A number of sustainability-specific criteria were used as part of the evaluation of tender designs during the competitive design and construct tender process for the project. Specifically, tenderers were required to: • Demonstrate how the project would meet an 'excellent' rating for the design and As-built components of the project under the ISCA IS rating scheme. • Detail how sustainability initiatives would be implemented throughout the project. • Explain how sustainability targets would be achieved or improved on throughout the project. • Provide a Sustainability Management Plan, describing how the overarching sustainability objectives for the WestConnex program of works would be achieved. An Australian Industry Participation Plan would be developed for the overall WestConnex program of works.

Sustainability targets	Project consistency
Overarching sustainability objective: Maximise equitable training and employment opportunities	
• Employ the equivalent of 155 apprentices/trainees for 18 months during the design and construction phases of the project • Maximise employment and training opportunities for young people, disadvantaged groups, Aboriginal and Torres Strait Islanders, the unemployed, locals and people who live in Western Sydney and along the project's alignment • Provide structured training to 20 per cent of the construction workforce • Provide initiatives to improve Aboriginal and Torres Strait Islander participation in construction and provide opportunities to Aboriginal and Torres Strait Islander enterprises.	About 155 apprentices/trainees would be employed during the design and construction phase. A Training Management Plan would be prepared before construction, detailing initiatives to maximise employment and training opportunities (including apprenticeships/traineeships/structured training), in particular for young people, disadvantaged groups, Aboriginal and Torres Strait Islanders, the unemployed, locals and people who live in Western Sydney. An Aboriginal Participation Plan would be prepared before construction, detailing initiatives to improve Aboriginal and Torres Strait Islander participation in construction of the project and provide opportunities to Aboriginal and Torres Strait Islander enterprises during the design and construction phases.

28.3 Sustainability management on the project

The overarching sustainability objectives for the project (**Table 28-3**) would be met through the implementation of a sustainability management plan and project-specific sustainability initiatives. The implementation of these initiatives would contribute to the project achieving an IS rating of Excellent.

28.3.1 Sustainability management plan

The WestConnex sustainability objectives and targets would be met through the implementation of a project specific Sustainability Management Plan and sustainability initiatives.

The construction contractor would develop and implement a Sustainability Management Plan during detailed design. The Sustainability Management Plan would establish governance structures, processes and systems that ensure integration of all sustainability considerations (vision, commitments, principles, objectives and targets), initiatives, monitoring and reporting during the detailed design and construction phases of the project.

The aims of the Sustainability Management Plan would be to:

- Demonstrate sustainability leadership and continuous improvement
- Protect and enhance the natural environment and local heritage
- Contribute to liveable communities and facilitate urban revitalisation by easing congestion, connecting communities and integrating land use and transport planning
- Optimise resource efficiency (materials, energy, water and land) and waste management
- Increase resilience to future climate
- Design for future transport needs
- Procure sustainably, considering whole of life environmental, social and economic factors
- Maximise equitable / fair training and employment opportunities.

Principles in the Sustainability Management Plan would extend across the whole project, through both the design and construction phases. These principles would also be embedded across all management disciplines throughout detailed design and the construction contractor's project team, ensuring that decision making processes consider whole-of-life, environmental, social and economic costs and benefits over the life of the project.

The Sustainability Management Plan would form part of the project's integrated management system to be implemented on the project. The plan would be revised and updated regularly to reflect changing designs and sustainability initiatives through each of the project phases.

The Sustainability Management Plan would include an ISCA IS Management Sub-plan to guide the achievement of an IS rating of excellent for the project. The Sub-plan would detail implementation protocols, including:

- ISCA IS assessment and registration process and timeframes
- Proposed consultation and engagement with ISCA and other stakeholders
- The IS rating process and requirements for the provision of documentation to ISCA
- Key sustainability management roles and responsibilities.

In addition to the key project sustainability management roles, there would be a sustainability 'champion' within the construction contractor's construction, design, community involvement, procurement and commercial teams. These champions would engage with the sustainability advisor and sustainability and environment manager regarding sustainability initiatives associated with the design and construction of the project.

28.3.2 Project-specific sustainability initiatives

Project-specific sustainability initiatives have been identified during the design of the project. These initiatives aim to improve sustainability performance during construction and operation of the project. Sustainability targets incorporated into the design of the project in accordance with the WestConnex Sustainability Strategy are provided in **Table 28-3**.

In addition to those discussed in **Table 28-3**, the following sustainability initiatives were identified during the design of the project to improve sustainability performance throughout construction and operation:

- Excavation using a roadheader as opposed to a tunnel boring machine, reducing energy consumption, material use and spoil generation
- Incorporation of energy efficient equipment for tunnelling activities, including variable speed drives, power correction, efficient fans, pumps, conveyors, compressors and cooling systems to reduce operational energy use
- Selection of larger diameter, low flow fans for tunnel ventilation to reduce the amount of noise attenuation and operational power requirements during operation
- Incorporation of energy efficient tunnel lighting to reduce operational energy requirements
- Selection of locally sourced materials and pre-fabricated assets where possible, to reduce greenhouse gas emissions
- Consideration of climate change projections and risks, in particular as part of the flooding assessment, and associated recommended mitigation and management measures
- Establishment of a wetland as part of the surface water treatment for the project
- Use of water efficient fixtures and reuse of water where possible during construction and operation
- Using plants with low water requirements as part of landscaping and site rehabilitation for the project, thereby minimising irrigation requirements and supporting local biodiversity
- Enhanced reflectivity and luminance as part of the tunnel design so as to reduce the required level of lighting and associated power requirements
- Six per cent of the total electricity requirements for construction would be Green Power (renewable energy) purchased.

28.4 Ecologically sustainable development

The Commonwealth Government refers to ecologically sustainable development as ‘using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased’ (Commonwealth Department of the Environment, 1992).

In NSW, the commitment to the concept of environmental sustainability is expressed in current legislation. It is an object of the *Environmental Planning and Assessment Act 1979* (EP&A Act) (section 5 ((a) vii) to encourage ecologically sustainable development through the implementation of the four principles of ecologically sustainable development:

- The precautionary principle
- Inter-generational equity
- Conservation of biological diversity and ecological integrity
- Improved valuation and pricing and incentive mechanisms.

The principles of ecologically sustainable development have been an integral consideration throughout the design of the project. This includes the effective integration of the economic and environmental considerations in the decision making process, as defined by Section 6(2) of the *Protection of the Environment Administration Act 1991* (PEA Act).

The four main principles of ecologically sustainable development, including how they have been recognised and incorporated throughout the design, construction and ongoing operation phases of the project are discussed below.

28.4.1 Precautionary principle

The precautionary principle deals with certainty in decision making. It provides that 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.

The precautionary principle has been applied during the design and development of the project. Potential environmental impacts associated with the New M5 were considered in the alternatives and options analysis as part of the M5 Transport Corridor Feasibility Study, the industry partners design program and the design and construct tender process for the project. This included identifying opportunities to avoid and minimise surface disturbance, and potential impacts to national parks and reserves and other ecologically sensitive areas (refer to **Chapter 4** (Project development and alternatives) for additional detail regarding the options considered as part of the project's design).

The design and construct tender process for the project aimed to avoid, to the greatest extent practicable, known areas or items of environmental value. These areas included the Cooks River / Castlereagh Ironbark Forest of the Sydney Basin Bioregion at Kingsgrove, the Wolli Creek Regional Park and the Green and Golden Bell Frog Key Population of the Lower Cooks River. Where it has not been possible to avoid these environmentally sensitive areas, practicable measures have been identified to mitigate and manage these risks.

This EIS details the evaluation of environmental impacts associated with the project. The EIS was prepared adopting a conservative approach, which included assessing the worst case impacts and scenarios It has been undertaken using the best available technical information and has adopted best practice environmental standards, goals and measures to minimise environmental risks. The environmental assessment has been undertaken in collaboration with key stakeholders and relevant statutory and agency requirements.

The threat of serious or irreversible environmental damage is one of the essential preconditions to the engagement of the precautionary principle. Potential environmental risks associated with the project were identified and considered to ensure that an appropriate amount of time was afforded for detailed specialist reports as part of the environmental assessment (refer to **Chapter 29** (Environmental risk analysis) for more detail). Safeguards and management measures have been developed to manage impacts identified in these assessments. In addition, impacts to threatened ecological communities and threatened fauna as a result of construction and operation of the project would be offset in accordance with the biodiversity offsets policy (OEH, 2014c) (refer to **Chapter 21** (Biodiversity) for more detail). The safeguards and management measures would result in an acceptable residual risk and no significant serious or irreversible environmental harm.

28.4.2 Inter-generational equity

In broad terms, the notion of inter-generational equity refers to the premise that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit or future generations. The project has been considered in terms of intergenerational equity, with the management of potential environmental impacts discussed throughout this environmental impact statement.

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 practical. For example:

- Recycled products would be used during construction of the project to reduce the demand on resources, in instances where the use of such materials is cost and performance competitive
- At least six per cent of construction energy required for the project would be sourced from an accredited GreenPower energy supplier
- Water efficiency measures would be implemented with a focus on achieving water savings and targeting water recycling and re-use
- About 80 per cent of construction and demolition waste is anticipated to be reused and / or recycled as part of the project.

The project would benefit current and future generations by improved air quality within the existing M5 East Motorway tunnel and a reduction in greenhouse gas emissions.

Under expected traffic conditions the contribution of project tunnel ventilation outlets to pollutant concentrations was found to be negligible for all sensitive receivers identified. Exceedances of some air quality criteria were predicted to occur at a small proportion of sensitive receivers both with and without the project. However, the total number of receivers with exceedances decreased slightly with the project. The exception to this was annual mean $PM_{2.5}$ for which concentrations were already above the relevant criterion. There are predicted to be substantial reductions in concentrations of criteria pollutants along the M5 East Motorway, both to the east and west of the M5 East Motorway tunnels, as well as along General Holmes Drive and other roads around the airport. Reductions in concentrations have also predicted along the section of King Georges Road to the north of the M5 East Motorway, around the northern perimeter of Sydney Park, and on a number of other roads.

Some small increases in concentration of criteria pollutants were predicted for King Georges Road to the south of the M5 East Motorway, Stoney Creek Road, Bexley Road to the south of the M5 East Motorway, Harrow Road, Forest Road, and around the southern perimeter of Sydney Park, amongst other roads. Some small increases in concentration were also predicted for Bay Street near the future Southern extension. Impacts associated with the Southern extension are based on a strategic concept and are therefore indicative only, would be subject to further design, as well as separate planning and approval. More detail regarding the air quality assessment is provided in **Chapter 10** (Air quality) and **Appendix H**.

The project aims to reduce construction and operational greenhouse gas emissions. A greenhouse gas assessment has been undertaken to quantify emissions and identify mitigation measures to reduce emissions. With reference to the project, traffic modelling has indicated that the project would improve network performance along the M5 Motorway corridor. The operational road use assessment undertaken as part of the greenhouse gas assessment (refer to **Chapter 22** (Greenhouse gas)) notes that emissions estimated to be generated during construction and the annual emissions from the operation and maintenance of road infrastructure would be offset against emissions savings as a result of improved road performance in 2031. Further information on greenhouse gas emissions and savings are provided in **Chapter 22** (Greenhouse gas) and **Appendix U**.

Notwithstanding the benefits of the project for intergenerational equity, the project may impact on intergenerational equity through the consumption of fuel resources during operation, potentially resulting in the decline of available fuel resources. Roads and Maritime note that it is prudent to consider that oil production may peak and then decline which could increase the cost and reduce the availability of transport fuels and construction materials derived from oil. For transport, the solutions to the problem of “peak oil” are similar to those for climate change. Alternatives to fossil fuels need to be found and transport must become more energy efficient. There are moves to establish alternatives to oil as a fuel for transport and to improve energy efficiency. This would enable the economic benefits provided by road transport to continue to be delivered with a reduced need for fossil fuels.

Roads and Maritime is also participating with Austroads and industry in research and trials with the goal of developing more practices and reducing reliance on products derived from oil. As road transport is a significant and necessary element of the NSW economy, that also provides many social benefits, Roads and Maritime will continue to ensure that all potential impacts on this system, such as peak oil, are identified and action is taken to manage these risks. Peak oil in the context of operational resource consumption is discussed in **Chapter 24** (Construction resource use and waste minimisation).

28.4.3 Conservation of biological diversity and ecological integrity

Conservation of biological diversity and ecological integrity is a fundamental consideration of the project. The design and assessment of the project has been undertaken with the aim of identifying, avoiding, minimising and mitigating impacts.

The construction of the project would result in the clearance of:

- 1.4 hectares of the Cooks River / Castlereagh Ironbark Forest of the Sydney Basin Bioregion at Kingsgrove and indirectly affect 0.4 hectares of this critically endangered ecological community
- 0.09 hectares of Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest in sandstone gullies of western Sydney, Sydney Basin
- 1.82 hectares of Paperbark Swamp Forest of the Coastal Lowlands of the NSW North Coast Bioregion and the Sydney Basin Bioregion
- 7.45 hectares of urban native and exotic vegetation.

The current project design avoids impacts to areas of high ecological value where practical. For example, the design has avoided direct impacts to Wolli Creek Regional Park (refer to **Section 4.3** of **Chapter 4** (Project development and alternatives) for more information about motorway options development).

This environmental impact statement provides a detailed biodiversity assessment which identifies impacts to biodiversity, and provides a range of mitigation measures which would be implemented in order to further avoid and minimise potential impacts to biodiversity.

Additionally, preliminary calculations have been provided in order to offset the impacts identified to the Cooks River / Castlereagh Ironbark Forest of the Sydney Basin Bioregion at Kingsgrove. The Biodiversity Offset Strategy addresses residual impacts that cannot be mitigated; particularly in relation to the clearance of 1.4 hectares of the Commonwealth listed critically endangered Cooks River / Castlereagh Ironbark Forest of the Sydney Basin Bioregion vegetation community at Kingsgrove as well as impacts to the Green and Golden Bell Frog Key Population of the Lower Cooks River.

Potential impacts to biodiversity are detailed further in **Chapter 21** (Biodiversity). The technical paper: Biodiversity is provided in Appendix J.

28.4.4 Improved valuation and pricing of environmental resources

Environmental factors should be included in the valuation of assets and services, including:

- Polluter pays (ie those who generate pollution and waste should bear the cost of containment, avoidance or abatement).
- The users of goods and services should pay prices based on the full life cycle of costs of providing the goods.
- Environmental goals, having been establishment, should be pursued in the most cost effective ways.

Environmental factors have been considered throughout the feasibility assessment and tender evaluation process for the detailed design and construction and operation of the project.

As a consequence, environmental impacts have been avoided or minimised where practical during the design development for the project. Mitigation measures outlined in this environmental impact statement would be implemented during construction and operation of the project.

The value placed on avoiding and minimising environmental impacts is demonstrated in the design features incorporated into the project, as well as the extent of environmental investigations undertaken to inform this environmental impact statement. Additionally, the costs associated with the planning and design of measures to avoid / minimise adverse environmental impacts and the costs to implement them have been included in the overall project costs.

The location of the eastern interchange at St Peters within the Alexandria Landfill site was identified as the preferred location over alternative sites north of the Princes Highway, within the Cooks River container terminal site, west of Canal Road or along Burrows Road (refer to **Section 4.4** of **Chapter 4** (Project development and alternative) for more information). Locating the eastern interchange at the Alexandria Landfill site would result in increased construction costs. However, this site was preferred as:

- Construction could largely be undertaken offline from the local road network,
- Property acquisition would be minimised
- The preferred location would provide connectivity to the wider WestConnex program of works and the local road network
- Impacts of the project on the local social environment, including reducing impacts on homes and open spaces would be minimised.

The closure of the Alexandra Landfill site, as part of the project, would result in the beneficial reuse of the site as the St Peters interchange, enhancing pedestrian and cycle path connectivity between Sydney's south and Sydney Park.

Including a toll on the project supports the concept of users of goods and services paying prices based on the full life cycle of costs of providing the goods. While upfront capital costs would be provided by a combination of funding by the New South Wales and Commonwealth Governments, this funding would be recouped through a toll to cover the upfront construction, and ongoing operational and maintenance costs.

The project would also include measures for the abatement, avoidance and / or containment of pollution and waste, including works associated with the Alexandria Landfill closure.

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29 Environmental risk analysis

A detailed environmental risk analysis was conducted as part of this environmental impact statement (EIS). This chapter outlines the environmental risk analysis process and identifies the key environmental issues.

Table 29-1 sets out the Secretary's Environmental Assessment Requirements (SEARs) as they relate to risk analysis and where the SEARs are addressed in the EIS.

Table 29-1 SEARs – environmental risk analysis

SEAR	Where addressed
The EIS must include an environmental risk analysis to identify potential environmental impacts associated with the proposal (construction and operation), proposed mitigation measures and potentially significant residual environmental impacts after the application of proposed mitigation measures. Where additional key environmental impacts are identified through this environmental risk analysis, an appropriately detailed impact assessment of this additional key environmental impact must be included in the EIS.	**Chapter 29** Environmental risk analysis. **Section 29.4** Risk analysis summary.

29.1 Environmental risk analysis process

An environmental risk analysis was carried out to identify the potential environmental issues associated with the project. Issues were categorised as 'key' or 'other', with key issues being those where the project may have moderate or major impacts (actual or perceived).

Key issues require detailed assessment to determine the severity of potential impacts and to identify suitable mitigation and management measures.

The environmental risk analysis process carried out for the project included:

- A preliminary environmental assessment, carried out as part of the State significant infrastructure application report (AECOM, 2015a), to allow early identification of the key environmental issues and to inform the State significant infrastructure application
- An assessment of the key issues identified in the SEARs for the project (**Appendix A**)
- An environmental risk review undertaken to confirm the key environmental issues based on the results of the detailed investigations presented in this EIS.

As required by the SEARs, the process of environmental risk analysis continued during the course of preparing the EIS. Emphasis was placed on using the detailed information gathered for the project to review the environmental aspects of the project. More specifically, the analysis:

- Identified environmental issues, including key issues in the SEARs, and any other issues
- Examined potential impacts and proposed mitigation measures in relation to the identified issues
- Identified the nature and extent of impacts likely to remain after mitigation measures are applied.

Based on this analysis, an environmental risk category was assigned to each potential impact. This enabled the identification of any matters that might be considered as additional key issues, and provided a basis for an appropriately detailed assessment of these additional key issues in this environmental assessment. The environmental risk categories are described in **Table 29-2**.

Table 29-2 Environmental risk categories

Risk category	Description
Key issue	High or moderate impact (actual and perceived) requiring further investigation to identify specific management and mitigation measures
Other	Moderate or low impact that can be managed effectively with standard and best practice management and mitigation measures

29.2 Preliminary environmental assessment

A preliminary environmental assessment was undertaken to inform the State significant infrastructure application for the project. The outcomes of this preliminary assessment identified the following key environmental issues for the project:

- Traffic and transport
- Air quality
- Human health
- Noise and vibration
- Biodiversity
- Visual impacts and urban design
- Land use and property
- Social and economic
- Geology and groundwater
- Soils, surface water and flooding
- Non-Aboriginal heritage
- Resource management and waste minimisation.

The outcomes of the preliminary environmental assessment were documented in the State significant infrastructure application report (AECOM, 2015a), which was submitted to the Secretary of the Department of Planning and Environment under section 115X of the *Environmental Planning and Assessment* Act *1979* (NSW) to assist with the formulation of SEARs for the project.

29.3 Assessment of the key issues identified in the SEARs

The key issues identified in the SEARs were largely consistent with the key issues identified in the State significant infrastructure application report. The SEARs added a few key issues to be assessed. The SEARs identified the following as the key issues to be addressed in the EIS for the project:

- Traffic and transport
- Air quality
- Human health
- Noise and vibration
- Biodiversity
- Urban design and visual amenity
- Land use, social and economic
- Soil, water and hydrology
- Contaminated sites
- Non-Aboriginal heritage
- Aboriginal heritage.

These identified issues have been assessed in detail and the results have been presented in **Chapter 9** to **Chapter 23** of this EIS.

29.4 Risk analysis summary

A summary of the environmental risk analysis is provided in **Table 29-3.** Two additional environmental issues that were not specified as key issues in the SEARs were identified through the environmental risk analysis:

- Greenhouse gas
- Hazard and risk

These issues have been addressed in this EIS.

Table 29-3 Environmental risk analysis

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Traffic and transport	**Yes**				
Construction risks					
Public safety		Potential for reduced safety to pedestrians, cyclists and road users.	Implement measures to address safety risks as part of the traffic management and safety plan.	Safety measures will address safety risks for construction workers and motorists. With mitigation, residual safety impacts are considered to be low.	**Section 9.3**
Changes to local traffic movements due to increased construction traffic		Temporary disruptions and delays to traffic due changes to access, reduction in speed zones, alterations to traffic conditions at construction compound locations, the St Peters interchange, tie-ins and local roads.	Implement measures to address construction related delays as part of the traffic management and safety plan.	Moderate residual impacts are likely to remain with periodic delays associated with temporary road closures, lane occupancy and heavy vehicle movements.	**Section 9.3**
Impacts to bus routes		Temporary disruptions to bus/public infrastructure due to deterioration in network performance (construction traffic) or potential direct impacts on bus infrastructure (eg bus stops along Canal Road and Euston Road, St Peters).	Changes in bus stops would be undertaken in consultation with Transport for NSW and bus operators, with the community to be informed of any potential changes in advance.	Moderate residual impact due to increase in bus service travel times as a result of slower travel speeds and increased intersection delays.	**Section 9.3**
Changes to pedestrian and cycle routes		Temporary disruptions to pedestrian and cycle routes in the vicinity of construction works, requiring re-routing/diversions.	Pedestrian and cyclist access to be maintained where possible throughout construction. Where not feasible, alternative routes are to be provided and communicated to the community	Low residual impacts are likely to remain with minor delays expected for pedestrians and cyclists and potentially longer journeys.	**Section 9.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Operational risks					
Impacts to existing road network and surrounding areas		Impacts at the St Peters interchange and western surface works resulting in additional traffic and changes in current movements.	A review of existing Sydney Co-ordinated Adaptive Traffic System (SCATS) infrastructure at key intersections in the study area, including detectors, would be undertaken and upgrades would be implemented where appropriate to mitigate any impacts resulting from the project.	Active mitigation would result in low residual impacts.	**Section 9.3**
		Impacts to the traffic performance on local and regional roads.			
		Impacts of the project on performance at key intersections relevant to the project.			
		Impacts of additional east-west traffic movements (which would be introduced by the project) along local roads.			
		Impacts from land use change (eg Mascot Station Precinct, Green Square Town Centre and Ashmore Precinct).			
		Generation of additional traffic on the local road network as a result of the project.			
		Impacts from staging of delivery of the wider WestConnex program of works.			

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Air Quality	**Yes**				
Construction risks					
Fugitive dust emissions from construction activities including emissions from construction plant and equipment.		Potential health impacts for workforce and nearby sensitive receivers.	A dust management plan would be produced and implemented to cover all construction phases of the project. This plan would contain details of site-specific mitigation measures to be applied, including ensuring that all construction vehicles comply with their relevant emission standards.	Even with a rigorous dust management plan being implemented, it is not possible to guarantee that the dust mitigation measures would be effective all of the time. However, any effects would be temporary and relatively short-lived, and would only arise during dry weather with the wind blowing towards a receptor. With mitigation the effects would be low and not significant.	**Sections 10.6** and **10.7**
Operational risks					
In-tunnel air quality exceeds limits.		Potential health impacts for tunnel users and nearby sensitive receivers.	In-tunnel air quality would be managed through appropriate tunnel design, ventilation design and control, air treatment systems; and emission controls (including continuous in tunnel monitoring).	Model simulations of traffic scenarios have demonstrated that in-tunnel pollution concentrations could be maintained at levels below the required limits, under all conditions with mitigation measures implemented. Residual impacts are therefore considered to be low and not significant.	**Section 10.8**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Ambient air quality exceeds limits.		Potential health impacts at nearby sensitive receivers.	Ventilation outlets have been designed and sized to ensure compliance with criteria. Air quality monitoring would be undertaken to demonstrate that emissions from the ventilation outlets will have no significant impact on local air quality.	Emissions from the project ventilation outlets, even in the regulatory worst case scenarios, would be unlikely to result in adverse impacts on local air quality. The effects of the project on surface road emissions would be similar to the projected reductions in emissions with time without the project. Residual impacts are therefore considered to be low and not significant.	**Section 10.8**
Human health	**Yes**				
Construction risks					
Property acquisition		Potential short term impacts on the health of individuals induced by stress resulting from property acquisition.	Provision of access for affected households to a counselling service, WestConnex Assist. This would support affected households in negotiating the land acquisition process and relocation.	Even with the application of mitigation, short term adverse residual impacts are expected to remain.	**Section 11.3**
Noise and vibration	**Yes**				
Construction risks					
Construction activities		Noise and vibration from road construction activities within the corridor and from the operation of construction site compounds.	A construction noise and vibration management plan would be prepared and implemented in accordance with the *Interim Construction Noise Guideline* (DECC, 2009).	Mitigation would reduce impacts, but intrusive construction noise and vibration is still likely to occur at some locations. Residual impacts are considered to be moderate with the application of a construction noise and vibration management plan.	**Section 12.4**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Operational risks					
Increase in road traffic noise		There would be an increase in noise impacts around the proposed interchanges as a result of the roads moving closer to properties, increased traffic numbers and the removal of structures which previously provided screening.	Noise barriers and low noise pavement would be considered during detailed design to maximise the number of receivers which receive a reduction in exceedances of noise criteria. At-property acoustic treatments would be considered for sensitive receivers where low noise road surfaces and noise barriers do not reduce noise impacts. Active noise monitoring would also be undertaken to determine whether additional mitigation is required.	The implementation of mitigation measures is expected to reduce the number of impacted receivers. Residual impacts are therefore considered to be moderate.	**Section 12.4**
Ancillary facilities		Noise from operational ancillary facilities.	Operational ancillary facilities would be designed to meet project specific noise criteria derived in accordance with the *NSW Industrial Noise Policy.*	Adherence to operational noise criteria would result in low residual noise impacts to nearby sensitive receivers.	**Section 12.4**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Biodiversity	**Yes**				
Construction risks					
Native flora and fauna		Potential to impact threatened flora and fauna species protected by the *Threatened Species Conservation Act 1995* (NSW), *Fisheries Management Act 1994* (NSW) or *Environment Protection and Biodiversity Conservation Act 1999* (Cth).	A flora and fauna management plan would be developed for the construction phase. Biodiversity offset options would be explored to mitigate the impacts of habitat loss from construction works.	Engaging a suitably qualified ecologist to assist managing any unexpected flora or fauna would mean that the potential for residual impacts is low. If fauna handling is undertaken according to this guideline, the potential for residual impacts would be low.	**Section 21.3**
Green and Golden Bell Frog		Potential impacts to Green and Golden Bell Frog Key population and habitat located within the proposed project footprint. Potential to impact an important Green and Golden Bell Frog population located in the vicinity of the lower Cooks River estuary immediately west of Sydney's Kingsford Smith Airport. The population consists of one main population within the Kogarah Golf Course as well as the wetlands and recreation corridor at Arncliffe.	The Green and Golden Bell Frog Management Plan would be implemented to minimise and manage impacts to the Arncliffe key population. The Green and Golden Bell Frog Management Plan would be approved by the Commonwealth Department of the Environment and OEH. Biodiversity offset options would be explored to mitigate the impacts of habitat loss from construction works.	With the Green and Golden Bell Frog Plan of Management Plan in place, the potential for residual impacts to this species would be low.	**Section 21.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Groundwater dependent ecosystem		Groundwater drawdown impacting groundwater dependent ecosystems.	A groundwater monitoring program would be prepared and implemented to monitor groundwater impacts during construction. The program would be developed in consultation with the EPA, DPI (Fisheries), NoW and relevant councils.	With mitigation, residual impacts are expected to be low.	**Section 21.3**
Land use and property	**Yes**				
Construction risks					
Property acquisition		Impacts on residents, businesses and public as a result of the total, partial or temporary acquisition and relocation of properties.	Early and on-going consultation with impacted individuals and businesses. Acquisition would be undertaken in accordance with the *Land Acquisition (Just Terms Compensation) Act 1991* and the Land Acquisition Information Guide (Roads and Maritime, 2014b).	Even with the application of mitigation, adverse residual impacts are expected to be high.	**Section 13.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Property access		Changes and disruption of access to properties located adjacent to the project.	Where property access is to be impacted (either long or short term), consultation with the landowners or occupiers would be undertaken to determine their requirements and to discuss alternative access to be provided.	Residual impacts would occur for property owners / public space and road users whose properties / transport routes are temporarily affected in this manner. However, when combined with the mitigation measures outlined in **Chapter 9** (Traffic and transport), residual impacts resulting from restricted access to private properties are considered to be low.	**Section 13.3**
Settlement		Potential impacts to buildings and other structures such as cracks, leaning, etc.	A settlement monitoring plan would be prepared, including building condition surveys as well as a settlement monitoring program.	Given the range of contingencies that would be provided for in the settlement monitoring plan, the potential for residual risks not covered by the plan is considered to be low.	**Section 13.3**
Operational risks					
Altered property use and access		The operation of the project may impact on the access to and from some properties (eg realigned driveways or partially acquired garden / reserve areas).	Property accesses that are affected as a result of the project would be reinstated in consultation with the affected landowners including relocation if required.	Residual impacts may occur for property owners whose properties are permanently altered in this manner. However, these impacts are expected to be low.	**Section 13.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Visual impacts and urban design	**Yes**				
Construction risks					
Site compounds / construction works		Visual changes due to motorway, tunnel and bridge construction. Visual impacts associated with construction site compounds.	Site compounds and work areas would be screened, organised and managed to minimise visual impacts. Vegetation clearance would be minimised where possible. Built structures would be designed to minimise impacts and to integrate into the surrounding area. Landscaping of the project footprint in line with the urban design to minimise impacts.	Some receivers would experience moderate to high visual impacts during the construction of the project. However, construction impacts are temporary and therefore the overall residual impacts are considered to be low.	**Section 14.3**
Temporary lighting		Impacts to sensitive receivers from temporary lighting within/surrounding construction areas and compounds.	Use of cut-off and direction lighting to ensure glare and light spill is minimised. Lighting would only be used when sites are in use.	Residual impacts would vary depending on the location of the sensitive receiver. Some receivers would experience moderate to high night lighting impacts during the construction of the project. However, overall residual impacts on sensitive receivers is considered to be low to moderate.	**Section 14.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Shared pathway diversion		Visual impacts to users of parks, cycleways and pedestrian pathways due to the temporary diversion of shared pathways.	Separation distances would be maximised as far as is reasonable and feasible between the Kingsgrove North construction compound to the adjoining residential areas to improve sight lines and safety for path users. A signage strategy would be developed during detailed design for temporary wayfinding.	Shared path users at the M5 Linear Park would experience moderate to high visual impacts during the construction of the project.	**Section 14.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Operational risks					
Structures (tunnels, interchanges, retaining walls, surface infrastructure etc).		Impacts to views and vistas from the introduction of built project elements including tunnel portals, bridges, noise barriers, retaining walls and ancillary surface infrastructure.	The visual impact of noise barriers would be reduced through high quality urban design treatments in accordance with the *Noise Wall Design Guideline* (RTA, 2006). Street tree plantings and landscaping would be used to visually soften operational motorway complexes.	Residual impacts would vary depending on the location of the sensitive receiver. Some receivers would experience moderate to high visual impacts during the operation of the project.	**Section 14.3**
Operational lighting		Impacts to receivers from the introduction of operational lighting, including residences and Sydney Airport.	Lighting design to minimise light spill on to adjacent properties.	Some receivers would experience moderate to high night lighting impacts during the operation of the project. However, operational lighting impacts would occur in areas generally already subject to lighting impacts due to existing roads and buildings. With careful design the residual impacts are considered to be low.	**Section 14.3**
Visual impacts to localities		Impacts of views and vistas to and from the project in visual catchments.	Where relevant, a landscaping strategy would consider the use of larger screening shrubs and increasing the width of the band of plantings in this location.	Residual impacts would vary depending on the location of the sensitive receiver. Some receivers would experience moderate to high visual impacts during the operation of the project. However, overall residual impacts on sensitive receivers would be low to moderate.	**Section 14.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Social and economic	**Yes**				
Construction risks					
Acquisition of businesses		Disruption to local businesses.	Acquisitions would be under the terms of the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW). A business management plan would also be developed to effectively communicate with businesses during the construction of the project.	Residual impacts to businesses after the application of mitigation are considered to be low.	**Section 15.3**
Operational risks					
Access		Reduced community cohesion and connectedness due to new infrastructure which alters access around the community.	Opportunities for providing increased pedestrian and cyclist connectivity would be explored.	Residual impacts following mitigation are considered to be low.	**Section 15.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Soils and water quality	**Yes**				
Construction risks					
Modifying waterways		The geomorphology of receiving waterways may be altered by temporary water treatment plant discharges.	Construction work activities within and / or adjacent to waterways would be minimised using appropriate drainage and discharge outlet infrastructure.	Standard construction management measures would minimise any residual impacts to waterway geomorphology. Residual impacts are therefore considered to be negligible.	**Section 16.3**
Water quality		Construction spills, exposed contamination or erosion and sedimentation may enter waterways and alter the surface water quality of the receiving environment. Temporary water treatment plant discharges would also enter into waterways.	A soil and water management plan would be developed in accordance with 'The Blue Book' and in consultation with the EPA and NSW Office of Water. A water quality monitoring program would be undertaken for the duration of the construction, commencing six months prior to construction. Temporary water treatment plant discharges would be in accordance with the water quality reference criteria developed for the project.	With mitigation, residual impacts are expected to be low.	**Section 16.3**
Soil exposure		Removal of vegetation and soil exposure during constriction may cause erosion, sedimentation, and mass movement within and around watercourses.	An erosion and sedimentation management plan would be prepared as outlined in Erosion and Sedimentation Risk Assessment Procedure (RTA, 2004).	With the implementation of standard Roads and Maritime policies to manage soil and erosion, the potential for residual impacts is considered negligible.	**Section 16.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Leachate		Runoff within the Alexandria Landfill site may be contaminated leachate.	Runoff from the Alexandria Landfill would be directed to a leachate treatment plant and discharged to sewer under a trade waste agreement with Sydney Water. Finalising and implementing the draft landfill closure management plan for the Alexandria Landfill would ensure that the project complies with the *Contaminated Land Management Act 1997* and the *Protection of the Environment (Operations) Act 1997*.	With mitigation, residual impacts are expected to be low.	**Section 16.3**
Acid sulfate soils		Disturbing acid sulfate soils during construction works could cause: • Weakening of concrete and steel infrastructure • Damage to aquatic environments • Mobilisation of aluminium, iron and manganese from soils.	Acid sulfate soils would be stored temporarily in a bunded area, treated and disposed of off-site at a licensed facility. Management of acid sulfate soils would be in accordance with the Guideline for the Management of Acid Sulfate Materials (RTA, 2005c).	Following the *Guideline for the Management of Acid Sulfate Materials* (RTA, 2005) would mean that any residual impacts related to encountering acid sulfate soils would be low.	**Section 16.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Operational risks					
Surface runoff		Operational spills and maintenance erosion and sedimentation may enter waterways and alter the surface water quality of the receiving environment.	The operational water treatment plant would be designed with the aim of meeting the project's water quality reference criteria, the pollution reduction targets from the *Botany Bay and Catchment Water Quality Improvement Plan* (SMCMA, 2011), and the project's Environment Protection Licence. Measures to prevent runoff, stormwater or spillage being directed onto other roadways outside of the project footprint would be implemented.	With mitigation, residual impacts are expected to be low.	**Section 16.3**
Modifying waterways		New and existing drainage outlets have the potential to cause scouring and sediment suspension.	Operational water treatment plant discharge volume and velocity would be regulated and managed to ensure impacts to the receiving environment are as anticipated.	Residual impacts to waterway geomorphology are expected to be negligible.	**Section 16.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Contamination	**Yes**				
Construction risks					
Landfill closure		Inappropriate disturbance of the Alexandria Landfill site (ie otherwise than in accordance with the *Contaminated Land Management Act 1997*) has the potential to expose contaminated soil and groundwater, as well as allow leachate and landfill gas to migrate offsite.	A site specific management plan would be prepared for the Alexandra Landfill to manage the exhumation of parts of the landfill during construction. The closure and ongoing management of the Alexandria Landfill would be undertaken in line with the draft landfill closure management plan, the *Contaminated Land Management Act 1997* and the *Protection of the Environment (Operations) Act 1997*.	With mitigation, residual impacts are expected to be low.	**Section 17.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Unearthing, disturbing or spreading contaminated soil		Disturbance and disposal of contaminated land potentially resulting in environmental pollution.	Procedures to manage unexpected contamination finds and hazardous materials identified during site preparation and/or construction works would be prepared. Potentially contaminated areas directly affected by the project would be investigated and managed in accordance with the requirements of the *Contaminated Land Management Act 1997* (NSW) and *Contaminated Sites: Guidelines for Consultants Reporting on Contaminated Sites* (Office of Environment and Heritage, 2011).	Adherence to the nominated mitigation measures would result in limited exposure of contaminated land. Residual impacts are therefore expected to low.	**Section 17.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Hazardous materials		Management of demolition waste including asbestos containing material.	Demolition works would be undertaken in accordance with Australian and NSW WorkCover Standards. Stockpiling and management of potentially contaminated material would be undertaken at building demolition sites to prevent movement of material into receiving waters. Asbestos management (handling, stockpiling, transport and disposal) would be undertaken in accordance with an asbestos management plan and relevant State legislation, government policies and Australian Standards.	Residual impacts are expected to be low and not significant as a result of the controls that would be established during demolition.	**Section 17.3**
Operational risks					
Ongoing management of the previous Alexandria Landfill site		Inappropriate disturbance of the Alexandria Landfill site (ie otherwise than in accordance with the *Contaminated Land Management Act 1997*) has the potential to expose contaminated soil and groundwater, as well as allow leachate and landfill gas to migrate offsite.	The closure and ongoing management of the Alexandria Landfill will be undertaken in line with the draft landfill closure management plan. Finalising and implementing the draft landfill closure management plan for the Alexandria Landfill would ensure that the project complies with the *Contaminated Land Management Act 1997* and the *Protection of the Environment (Operations) Act 1997*.	With mitigation, residual impacts are expected to be low.	**Section 17.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
General contamination		Contamination caused by spills, leaks and tunnel washing etc. during operations.	Procedures to address spills, leaks and tunnel washing would be developed and implemented during operation of the project.	Standard operational management measures would be adequate to ensure any residual contamination impacts are negligible.	**Section 17.3**
Flooding and drainage	**Yes**				
Construction risks					
Flooding impacts to construction works		Flooding impacts to construction compounds and tunnel dive shafts.	A flood and stormwater management plan would be prepared to manage flooding and stormwater related issues.	The potential for the project to result in residual impacts is considered to be low.	**Section 18.3**
Flooding impacts on new drainage infrastructure		Exacerbated flooding impacts during the changeover to new drainage infrastructure during construction works.	Where transverse drainage structures are to be upgraded or replaced, any existing transverse drainage structures would be left in place for operation during construction. If this is not feasible, temporary drainage would be adopted.	With this proposed construction sequencing in place, the potential for residual impacts is considered to be low.	**Section 18.3**
Operational risks					
Flooding		Flooding during operation of the project resulting in damage to infrastructure or impacts to environment.	The project design includes measures to prevent and mitigate flooding during operation that would achieve the hydrologic standard requirements for key components of the project.	With the proposed management measures in place, residual impacts would be low.	**Section 18.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Groundwater	**Yes**				
Construction risks					
Groundwater flow and quality		Altered groundwater flow and quality potentially impacting registered boreholes users and sensitive environmental receptors.	A groundwater monitoring program would be prepared and implemented to monitor groundwater impacts during construction. The program would be developed in consultation with the EPA, DPI (Fisheries), DPI Water and relevant councils.	With mitigation, residual impacts are expected to be low.	**Section 19.3**
Leachate		Failure of the leachate pumping system for the Alexandria Landfill causing groundwater levels to rise above the construction levels.	Contingency measures to address leachate management at the Alexandria Landfill during construction and prior to the commissioning of the new leachate treatment plant would be explored during detailed design. Identified measures would be detailed in the Construction Environmental Management Plan and implemented during construction.	Implementation of the mitigation measures would make the potential for residual risks from leachate at the Alexandria Landfill negligible.	**Section 19.3**
Release of groundwater		Unsustainable release of groundwater resources.	Treated waste water would be stored and re-used for project purposes wherever possible. Groundwater reuse would be in accordance with the policies of sustainable water use of the Office of Water, such as dust suppression and earthworks.	With mitigation, residual impacts are expected to be low	**Section 19.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Excessive inflows		Excessive inflows during construction may exceed the design inflow criterion.	Sections of the tunnel would be grouted and reinforced with rock bolts where saturated faults and fractures are intersected. In some cases, where higher than expected inflows are experienced, longer rock bolts or an increased density may be required in combination with an increased shotcrete thickness.	With the proposed management measures in place, the potential for residual impacts as a result of excessive inflows would be low.	**Section 19.3**
Aggressive groundwater chemistry		Aggressive groundwater chemistry such as elevated sodium, chloride, ammonia, low pH conditions that are aggressive to concrete and steel.	Building materials that are resistant to aggressive groundwater conditions would be selected.	The selection of suitable building materials would be sufficient to prevent risks occurring as a result of aggressive groundwater chemistry. Residual impacts are therefore considered to be low.	**Section 19.3**
Registered bores		Licensed bore drawdown and impacts to groundwater users.	Management of licensed bores identified as being at risk of drawdown would include monitoring and, where appropriate, modifications, compensation, redrilling or provision of an alternative water supply.	As the proposed management measures contain contingency procedures, the potential for unforeseen residual risks is considered to be low.	**Section 19.3**
Operational risks					
Tunnel groundwater inflows		Groundwater inflow into tunnels exceeding project requirements.	A tunnelling procedure detailing when and what type of waterproofing is required to be installed during construction would be implemented during construction.	With mitigation, residual impacts are expected to be low.	**Section 19.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Sandstone slaking		Build-up of precipitated iron (slimes) and silt and sand due to slaking of the sandstone.	The drainage system would be regularly maintained in accordance with the Operational Environmental Management Plan.	With mitigation, residual impacts are expected to be low.	**Section 19.3**
Groundwater quality		Impact on surface and groundwater quality, resources and wetlands as a result of operation.	A groundwater quality monitoring program would be prepared and implemented to monitor groundwater impacts during tunnel operations.	With mitigation, residual impacts are expected to be low.	**Section 19.3**
Non-Aboriginal heritage	**Yes**				
Construction risks					
Unexpected finds		Impacts to items of non-Aboriginal heritage which are discovered during demolition or earthworks.	Protocols would be developed for anticipated categories of unexpected non-Aboriginal heritage finds, In the event of an unexpected cultural heritage find outside of these specific protocols, in line with the Roads and Maritime *Standard Management Procedure – Unexpected Archaeological Finds*.	The purpose of these management measures is to mitigate residual impacts, and as such, the risk of further unforeseen residual impacts occurring is low.	**Section 20.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Direct impacts to heritage structures		Removal of heritage listed structures.	Prior to demolition consideration would be given as to whether elements of the buildings could be salvaged and used to maintain or restore other properties of similar type within the area. Consideration would also be given as to whether the portion of the Bond Store not within the direct footprint of the St Peters, could be preserved *in situ* as mitigation. In the event that neither of these options is feasible, other management measures to record the historical and archaeological significance of the building would be considered. Prior to the commencement of construction works, full archival recordings would be undertaken following the NSW Heritage Division guidelines *How to Prepare an Archival Recording* (NSW Heritage Office, 2003) and *Photographic recording of heritage items using film or digital capture* (NSW Heritage Office, 2006).	Residual impacts would be high, and could not be effectively mitigated.	**Section 20.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Construction of stormwater discharge points		Impacts to the heritage values of the Alexandra Canal due to construction of stormwater discharge points.	The detailed design of discharge locations would incorporate appropriate mitigation and management measures to minimise potential impacts.	Where the application of management measures would mitigate impacts to heritage values, residual impacts would occur as mitigation measures would not be able to replicate any impacted heritage values to the same state they were in prior to construction works.	**Section 20.3**
Heritage listed vegetation		Construction works may require the removal of heritage listed vegetation.	The removal of heritage listed vegetation would be avoided. Where it is not practical to do so, vegetation removal would be minimised and feasible and reasonable options for vegetation relocation would be investigated where appropriate.	Where removal of heritage listed vegetation is necessitated, high residual impacts would occur despite the application of mitigation measures, as mitigation measures would not be able to replicate the heritage values of the heritage listed vegetation which is removed.	**Section 20.3**
Impact to geological and palaeontological values		Earthworks and the placement of new infrastructure have the potential to impact on existing geological and palaeontological values.	An archival recording of the St Peters brickpit geological site would be undertaken prior to the commencement of works. A palaeontologist would be engaged to assess the potential for further specimens of scientific interest at the site, and to provide further management measures if required.	Where the impacts to areas of existing geological and palaeontological values are anticipated, residual impacts would occur despite the undertaking of archival recordings, as such measures would not completely replicate the geological or palaeontological values of sites prior to their disturbance.	**Section 20.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Heritage conservation areas		Impacts to the heritage values of heritage conservation areas.	Landscaping of ancillary infrastructure sites would be undertaken with consideration of the heritage values of the heritage conservation areas within the project area.	The proposed management measures are considered sufficient to mitigate the impacts to heritage values of heritage conservation areas to an acceptable level. Residual impacts are considered to be negligible.	**Section 20.3**
Operational risks					
Changes in operational views		Impacts to heritage values due to changes in operational views.	The heritage values of items (including views and vistas from the items) would be considered during the detailed design of built elements of the project and the development of a landscaping plan.	With mitigation, residual adverse impacts are expected to be low and beneficial impacts could be achieved through appropriate development and landscaping.	**Section 20.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Aboriginal heritage	**Yes**				
Construction risks					
Disturbance or potential destruction of Aboriginal objects and places		Potential impacts to or destruction of Aboriginal objects and places. Seven previously recorded AHIMS sites are within the project corridor, focused along riparian corridors of Wolli Creek, Alexandra Canal and the Cooks River.	Vibration generating activities, including blasting, are to be conducted in a manner that would not result in vibration levels greater than three millimetres per second at potential Aboriginal heritage site SR-OVH-1. A baseline condition assessment would be completed by a qualified structural engineer for Aboriginal site SR-OVR-1 prior to construction commencing. At the completion of construction a condition assessment would be completed with recommendations for remediation measures if required.	Unforeseen impacts associated with unexpected discoveries are likely to be manageable to an acceptable level of impact in consultation with the Registered Aboriginal Parties and the OEH. Residual impacts are therefore expected to be low.	**Section 23.3**
		Potential for disturbance or destruction of previously unidentified objects and/or places.	If an Aboriginal object(s) or human remains are discovered during construction, this would be managed in line with the Roads and Maritime *Standard Management Procedure – Unexpected Archaeological Finds*.		**Section 23.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Greenhouse gas	**No**				
Construction risks					
Emissions		Increase in greenhouse gas emissions from construction fuel use and energy embodied in construction materials.	Reuse and recycling would be maximised throughout the construction period. Energy efficiency measures would be implemented and materials would be sourced locally where possible to reduce transport emissions. The project aims to source six per cent of energy from renewable energy sources.	Despite considering measures to reduce construction greenhouse gas generation, the construction of the project would nevertheless generate greenhouse gas emissions.	**Section 22.3**
Operational risks					
Emissions		Increased emission of greenhouse gases from the operation of road infrastructure.	Low carbon energy generation options would be investigated as part of the design process in order to reduce the demand on mains electricity and generate renewable energy onsite, where feasible. The project aims to source six per cent of power from renewable sources.	Despite considering measures to reduce operational greenhouse gas generation, the operation of the project would nevertheless generate greenhouse gas emissions.	**Section 22.3**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Construction resource use and waste minimisation	**No**				
Construction risks					
Generating spoil		Generation of large quantities of excess spoil due to tunnelling that cannot be reused in the project or adjacent projects.	A Spoil Management Strategy would be developed prior to the commencement of construction and implemented during construction. The strategy would identify spoil disposal sites and describe the management of spoil on-site and during off-site transport. Where possible and fit for purpose, spoil would be beneficially reused within the project before off-site reuse or disposal options are pursued.	Residual waste would be disposed of to a suitably licensed landfill or waste management facility where there are no other feasible and reasonable options for waste avoidance, reuse or recycling. Waste materials requiring removal from the site would be classified, handled and stored in accordance with the *Waste Classification Guidelines: Part 1 Classifying Waste* (EPA, 2014a) until collection by a contractor for disposal.	**Section 24.1**
Use of general building materials including concrete, steel, asphalt, fill and other miscellaneous materials.		Use of resources and the generation of waste.	A waste management plan would be prepared for the construction phase of the project, detailing appropriate procedures for waste management and pre-construction surveys (ie asbestos). Residual waste would be classified, handled, stored on site and disposed of, in accordance with the *Waste Classification Guidelines: Part 1 Classifying Waste* (EPA, 2014a), State legislation and government policies.	It may not be possible to source all construction resources and reuse / recycle all of the identified materials as part of the project. While construction resource requirements for the project are typical for a tunnelling project of this scale, they may have an impact on resource availability within the local area over the construction period. The impact would be limited to the construction period.	**Section 24.1**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Water extraction/supply		The use of water during construction activities would be required.	Feasible and reasonable opportunities for wastewater reuse on-site or for construction purposes would be pursued (such as dust suppression both in the tunnels and for surface works). Wastewater not used on-site would be discharged into the local stormwater system in accordance with the requirements of an environment protection licence issued for the project.	The project is not anticipated to have any unforeseen impacts relating to the use of water resources during construction. Residual impacts are therefore considered to be low.	**Section 24.1**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Power supply		Around 130,000 Megawatt hours of electricity and up to around 30,500 kilolitres of fuel (diesel and petrol) would be used to construct the project.	At least six per cent of construction energy would be sourced where possible from an accredited GreenPower energy supplier. Around two per cent of construction phase power requirements would be offset according to the Commonwealth Government's National Carbon Offset Standard. This and other offset options would be reviewed during detailed design. Further construction energy consumption initiatives such as sourcing local materials, selection of energy efficient plant, use of recycled materials, and efficient site practices would also reduce a portion of the construction energy requirements.	Despite considering offset measures to reduce the impacts of construction power usage, the project would nevertheless require the use of electricity and fuels.	**Section 24.1**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Operational risks					
Operational water requirements		Around four mega litres of water per annum would be required for the operation of the project. The primary source of water during operation would be potable water.	Rainwater harvesting would be explored as an alternative resource during detailed design. In order to reduce demand on local water supplies, options would be investigated for providing water required for operation of the deluge system from wastewater produced through the tunnel drainage system where it meets appropriate quality parameters.	With mitigation, residual impacts are expected to be low.	**Section 24.1**
Operational power requirements		During operation, the project would consume around 30,000 megawatt hours of electricity per year.	The vertical alignment of the main alignment tunnels would be designed to allow consistent vehicle speeds to be maintained, thereby minimising fuel use. Low carbon energy generation options would be investigated as part of the design process in order to reduce the demand on mains electricity where feasible.	Despite considering operational management measures to reduce operational power requirements, the operation of the project would nevertheless require the consistent use of electricity.	**Section 24.1**
Operational waste generation		Wastes generated by the operation of the project would be limited. Routine maintenance, repair activities, and operation of the motorway control centre would contribute to the majority of operational waste for the project.	No additional measures would be required to accommodate operational waste as it would be managed by standard work practices and existing metropolitan waste management facilities.	Waste generation and management during operation of the project would be minimal.	**Section 24.1**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Hazard and risk	**No**				
Construction risk					
Storage of dangerous goods and hazardous substances		Inappropriate storage of dangerous goods and hazardous substances could result in a workplace safety or environmental incident, with potential offsite implications.	Storage of dangerous goods and hazardous materials, including adequate bunding, would occur in accordance with applicable legislation, Australian standards and guidelines Material Safety Data Sheets would be obtained for dangerous goods and hazardous substances stored onsite prior to their arrival.	With the appropriate mitigation measures in place, the risk of residual impacts occurring through dangerous and hazardous goods storage is considered to be low.	**Section 26.1**
Transportation of dangerous goods		Releases of hazardous substances from vehicles transporting dangerous goods and hazardous substances to and from the construction sites in the event of an accident.	Transport of dangerous goods and hazardous substances would be conducted in accordance with relevant legislation and codes, including the *Road and Rail Transport (Dangerous Goods) (Road) Regulation 1998* and the Australian Code for the Transport of Dangerous Goods by Road and Rail (National Transport Commission, 2008).	With the appropriate transport strategies in place, the risk of residual impacts occurring through dangerous and hazardous goods storage is considered to be low.	**Section 26.1**
Aviation hazards		Cranes and lighting during construction.	The project would be constructed in line with CASA requirements, to the satisfaction of the Secretary of the Commonwealth Department of Infrastructure and Regional Development.	If the project is constructed in accordance with the relevant CASA requirements, residual impacts are expected to be negligible.	**Section 26.1**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Operational risk					
Fire and life safety		Potential risks to the safety of users, and structural integrity of the project in the event of an accident or spill that results in fire or other hazardous releases.	The fire and safety systems and measures adopted for the project would be equivalent to or exceed the fire safety measures recommended by NFPA502 (American), PIARC (European), AS4825 (Australian) and Roads and Maritime standards.	With the appropriate fire systems and measures in place, the risk of residual impacts occurring as a result of fire safety is considered to be low.	**Section 26.1**
Accident, spill, fire or other incident within the tunnel		Crashes and incidents within the mainline tunnels, on- and off-ramps, and surface roads.	The project would be designed to provide efficient, free flowing traffic with physical capacity to accommodate predicted traffic volumes. An incident response plan would also be developed and implemented in the event of an accident or incident. The design of the project includes a motorway control centre and emergency response. Emergency access is provided via cross passages and longitudinal passages to allow egress from the tunnels during an emergency.	With the appropriate incident response strategies in place, the risk of residual impacts occurring through inadequate response to incidents is considered to be low.	**Section 26.1**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Storage of dangerous goods and hazardous substances		Inappropriate storage of dangerous goods and hazardous substances could result in a workplace safety or environmental incident, with potential offsite implications.	Storage of dangerous goods and hazardous materials, including adequate bunding, would occur in accordance with applicable legislation, Australian standards and guidelines Material Safety Data Sheets would be obtained for dangerous goods and hazardous substances stored onsite prior to their arrival.	With the appropriate mitigation measures in place, the risk of residual impacts occurring through dangerous and hazardous goods storage is considered to be low.	**Section 26.1**
Electric and magnetic fields		Receiver exposure to electric and magnetic fields from operational project substations.	The detailed design of the project substations would ensure that the exposure limits for the general public suggested by the *Draft Radiation Standard* (Australian Radiation Protection and Nuclear Safety Agency, 2006) would not be exceeded at the boundary of the substation sites.	With the appropriate mitigation measures in place, the risk of residual impacts occurring through exposure to electric and magnetic fields is considered to be low.	**Section 26.1**
Aviation hazards		Impacts of the velocity of emissions on Sydney Airport flight paths.	The project would be operated in line with CASA requirements, to the satisfaction of the Secretary of the Commonwealth Department of Infrastructure and Regional Development.	If the project is constructed in accordance with the relevant CASA requirements, residual impacts are expected to be negligible.	**Section 26.1**

Issue	SEAR Key Issue?	Potential impacts	Proposed mitigation measures	Potential residual impacts	Where discussed
Cumulative impacts	**No**				
Construction risk					
Cumulative construction impacts associated with the total WestConnex program of works		Construction related impacts, depending on interfaces of construction activities with King Georges Road interchange and M4-M5 Link, (noise, traffic, groundwater, air, visual, noise heritage, ecology, socio-economic and human health including construction fatigue).	Project Managers of other WestConnex projects would be consulted during the preparation of the construction traffic management plan and other environmental management documentation.	Cumulative impacts during construction would potentially occur, however the level of impacts to environmental values is considered to be low. Beneficial impacts to traffic including freight, and businesses would occur along the alignment of WestConnex.	**Section 27.4**
Cumulative impacts associated with other projects in the project corridor		Construction related impacts associated with construction of the project concurrent**l**y/consecutively with other proposed projects in the vicinity of the New M5.	Proponents of other projects would be consulted during the preparation of the construction traffic management plan and other environmental management documentation.	With mitigation, residual cumulative impacts resulting from other known projects are expected to be low. Beneficial impacts to traffic including freight, and businesses would occur along the alignment of WestConnex.	**Section 27.5**

30 Summary of environmental management measures

This chapter collates the environmental management measures for the project that were identified through the impact assessment process in **Chapter 9** to **Chapter 26**. All measures listed in **Table 30-1** would be incorporated into the Construction Environmental Management Plan (CEMP) and / or the operational framework for the project.

Table 30-1 Summary of environmental management measures

Impact	No.	Environmental management measure	Timing
Traffic and transport			
Construction			
General	TT01	A Construction Traffic Management and Safety Plan (CTMSP) would be prepared as part of the CEMP. The CTMSP would include the guidelines, general requirements and principles of traffic management to be implemented during construction, including: • Signage requirements (eg temporary speed restrictions, changes to the road environment, traffic management controls) • Lane possession and approval process during periods of online construction (eg line marking and temporary barriers) • Traffic control devices such as traffic signals • A local and regional communications strategy, including methods to provide advanced notice of any major or prolonged impacts (eg leaflets and local media), and real-time information regarding current impacts (eg variable message signs, radio traffic news) • Details of both the general approach to be used for access and egress to construction compounds and the specific controls required at specific locations • Any specific provisions required to manage potential impacts to sensitive users, such as schools, child care centres and health facilities. The CTMSP would be prepared in accordance with Austroads *Guide to Road Design* (with appropriate Roads and Maritime supplements), the RTA *Traffic Control at Work Sites* manual and AS1742.3: *Manual of uniform traffic control devices – Part 3:Traffic control for works on roads*, and any other relevant standard, guide or manual.	Pre-construction
Impacts to road network performance	TT02	Construction methods and staging would be designed to minimise road closures, subject to other project constraints, and ensure that disruptions to existing traffic are minimised as much as feasible and reasonable.	Construction

Impact	No.	Environmental management measure	Timing
(delays) and safety	TT03	Construction works would be carried out offline, where possible. Where offline construction is not practical, and for tie-ins between online and offline sections of the project, construction sequencing and any temporary works identified would aim to minimise user delay while providing sufficient flexibility for the selected contractor to safely and efficiently construct the project	Construction
	TT04	Works that would significantly reduce the performance of the road network would be scheduled for periods of typically lower traffic volumes where feasible and reasonable.	Construction
	TT05	Work areas would be isolated from general traffic using temporary safety barriers where possible.	Construction
	TT06	Temporary closed-circuit television (CCTV) and Variable Message Signs (VMS) would be provided at the outset of construction to link with the existing Transport Management Centre (TMC) network to facilitate monitoring and management of traffic impacts	Construction
	TT07	Traffic volume data would be analysed to identify capacity requirements, assess the potential impact of lane occupancies on traffic flows, plan lane occupancies to minimise the work area, and identify the best time to minimise inconvenience to road users. Restrictions and obstructions would be limited, road capacities maximised and peak traffic periods avoided where possible	Construction
	TT08	Impacts on pedestrian paths and cycle lanes would be minimised, and alternatives provided during construction where practical and safe to do so	Construction
	TT09	Impacts to bus stops would be identified and alternative locations and access would be provided. This would be undertaken in consultation with Transport for NSW and the relevant bus service provider	Construction
	TT10	Local road closures would be managed and adequate property access maintained. This would be undertaken in consultation with Roads and Maritime, local councils and property owners likely to be impacted	Construction
	TT11	A spoil management plan would be prepared with subsequent monitoring of heavy vehicle and haulage routes to ensure compliance and minimise impact on local roads off the arterial road network	Construction
	TT12	A road dilapidation report(s) would be prepared identifying existing conditions of local roads and mechanisms to repair damage to the road network caused by heavy vehicle movements associated with the project.	Construction
	TT13	Road occupancy licences would be obtained where required.	Construction
Impacts to emergency services	TT14	The CTSMP would be developed in consultation with local emergency services and procedures would be implemented to maintain priority access and a safe environment for emergency vehicles to travel through construction areas. The CTSMP would include measures to keep emergency services informed of the staging and progress of construction works.	Construction

Impact	No.	Environmental management measure	Timing
Operation			
Impacts to road safety	OpTT01	A road safety audit would be undertaken by a qualified auditor(s) as part of the detailed design, and again immediately prior to project opening, to examine the design from a road safety perspective and identify potential safety issues. This process would be undertaken in accordance with the Roads and Maritime Accident Reduction Guide Part 2: Road Safety Audits (RTA, 2005a).	Detailed design and prior to operation
Impacts to road network performance	OpTT02	An operational traffic review would be conducted 12 months following the commencement of operation to confirm the operational traffic impacts of the project on surrounding arterial roads and major intersections. The operational traffic review would be undertaken by a suitably qualified traffic specialist that is independent of the design and traffic studies undertaken as part of the environmental impact statement. The operational traffic review would include an assessment of the level of service at major intersections on local roads around the St Peters interchange, the King Georges Road interchange and changes in traffic levels on parallel arterial roads, such as Stoney Creek Road.	Operation
Air quality			
Construction			
General	AQ01	Develop and implement a Construction Air Quality Management Plan in consultation with the NSW EPA. Any measures that are required will differ depending on the activities occurring, and so will need to be tailored for each individual site.	Pre-construction
	AQ02	Carry out regular site inspections to monitor compliance with the Construction Air Quality Management Plan, record inspection results.	Construction
	AQ03	Develop and implement a stakeholder communications plan that includes community engagement before work commences on site.	Pre-construction
	AQ04	Display the name and contact details of person(s) accountable for air quality and dust issues at the boundaries of each construction area. This may be the environment manager/engineer or the site manager. Display the head or regional office contact information.	Construction
Dust management	AQ05	Plan site layout so that machinery and dust causing activities are located away from receivers, as far as is possible.	Construction
	AQ06	Erect solid screens or barriers around dusty activities or the site boundary.	Construction
	AQ07	Ensure, where reasonable and feasible, that appropriate control methods are implemented to minimise dust emissions from the project site.	Construction
	AQ08	Remove materials that have a potential to produce dust from site as soon as possible, unless being re-used on site. If they are being re-used on-site, cover as soon as practicable.	Construction
	AQ09	Impose and signpost a maximum-speed-limit of 20 km/h on surfaced and unsurfaced haul roads and in work areas.	Construction

Impact	No.	Environmental management measure	Timing
	AQ11	Where practicable, only use cutting, grinding or sawing equipment fitted or in conjunction with suitable dust suppression techniques such as water sprays or local extraction, (e.g. suitable local exhaust ventilation systems).	Construction
	AQ12	Ensure an adequate water supply on the site for effective dust/particulate matter suppression/mitigation, using non-potable water where possible and appropriate.	Construction
	AQ13	Where possible, use enclosed chutes and conveyors and covered skips.	Construction
	AQ14	Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate.	Construction
	AQ15	Ensure equipment is readily available on site to clean any dry spillages, and clean up spillages as soon as reasonably practicable after the event using appropriate cleaning methods.	Construction
	AQ16	Avoid scabbling (roughening of concrete surfaces) if possible.	Construction
Stockpile management	AQ17	Stockpiles would be located outside overland flowpaths, and where left exposed and undisturbed for longer than 28 days, would be finished and contoured to minimise loss of material in flood or rainfall events. Materials which require stockpiling for longer than 28 days would be stabilised by compaction, covering with anchored fabrics, or seeded with sterile grass where appropriate.	Construction
	AQ18	Where a stockpile, eg sand or fine aggregate, has the potential to generate dust, control measures would be implemented. These would include wetting the stockpile, covering the stockpile or contouring the stockpile.	Construction
	AQ19	Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery.	Construction
	AQ20	For smaller supplies of fine powder materials ensure bags are sealed after use and stored appropriately to prevent dust.	Construction
Tracking of material on roads	AQ21	Use water-assisted dust sweeper(s) on the access and local roads, to remove, as necessary, any material tracked out of the site.	Construction
	AQ22	Avoid dry sweeping of large areas.	Construction
	AQ23	Ensure vehicles entering and leaving sites are covered to prevent escape of materials during transport.	Construction
	AQ24	Inspect on-site haul routes for integrity and instigate necessary repairs to the surface as soon as reasonably practicable.	Construction
	AQ25	Record all inspections of haul routes and any subsequent action in a site log book.	Construction
	AQ26	Where reasonable and feasible, haul roads will be maintained with water carts and graders, and the condition of the roads will be monitored.	Construction
	AQ27	Implement site exit controls (e.g. wheel washing system and rumble grids) to dislodge accumulated dust and mud prior to leaving the site where reasonably practicable.	Construction

Impact	No.	Environmental management measure	Timing
	AQ28	Ensure there is an adequate area of hard surfaced road between the wheel wash facility and the site exit, wherever site size and layout permits.	Construction
	AQ29	Access gates to be located at least 10 metres from receivers where possible.	Construction
Emissions management	AQ30	Ensure all construction vehicles comply with their relevant emission standards.	Construction
	AQ31	Ensure that, where practicable, engine idling is minimised when stationary.	Construction
	AQ32	Avoid the use of diesel or petrol powered generators and use mains electricity or battery powered equipment where practicable.	Construction
	AQ33	Promote and encourage sustainable travel (public transport, cycling, walking, and car-sharing).	Construction
	AQ34	No bonfires and burning of waste materials.	Construction
Demolition	AQ35	Soft strip inside buildings before demolition (retaining walls and windows in the rest of the building where possible, to provide a screen against dust).	Construction
	AQ36	Ensure effective water suppression is used during demolition operations. Hand held sprays are more effective than hoses attached to equipment as the water can be directed to where it is needed. In addition high volume water suppression systems, manually controlled, can produce fine water droplets that effectively bring the dust particles to the ground and may be more useful for covering larger areas.	Construction
	AQ37	Minimise explosive blasting where possible during demolition, using appropriate manual or mechanical alternatives.	Construction
	AQ38	Bag and remove any biological debris or other hazardous materials such as asbestos, damp down such material before demolition.	Construction
Earthworks	AQ39	Re-vegetate earthworks and exposed areas/soil stockpiles to stabilise surfaces as soon as practicable.	Construction
	AQ40	Use hessian, mulches or tackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable.	Construction
	AQ41	Where possible, only remove any cover for exposed areas in small areas during work and not all at once.	Construction
Cumulative impacts	AQ42	Regular communication with other high risk construction ancillary facilities within 500 metres of the site boundary, to ensure plans are co-ordinated and dust and particulate matter emissions are minimised. It is important to understand the interactions of the off-site transport/deliveries which might be using the same strategic road network routes.	Construction
	AQ43	Undertake regular on-site and off-site inspection, where receivers are nearby, to monitor dust, record inspection results.	Construction
Complaints management	AQ44	Record all dust and air quality complaints, identify cause(s), take appropriate measures to reduce emissions in a timely manner, and record the measures taken.	Construction
	AQ45	Make complaints available to the Secretary upon request.	Construction

Impact	No.	Environmental management measure	Timing
	AQ46	Record any exceptional incidents that cause dust and/or air emissions, either on- or offsite, and the action taken to resolve the situation in the log book.	Construction
Operation			
Air Quality	N / A	Environmental management measures that are available for improving tunnel-related air quality are categorised as follows: • Tunnel design • Ventilation design and control • Air treatment systems • Emission controls and other measures • Monitoring. Refer to **Section 10.10.2** for detailed discussion of these categories.	Operation
Human health			
Construction			
Moving house as a result of property acquisition	HH1	Affected households would be provided access to a free counselling service; WestConnex Assist, to support them in the land acquisition process and relocation.	Pre-construction
Noise and vibration			
Construction			
General	NV1	A construction noise and vibration management plan(s) will be prepared and implemented consistent with the requirements of the *Interim Construction Noise Guideline* (DECC, 2009), and will include the following: • Identification of nearby residences and other sensitive land uses • Description of approved hours of work • Description and identification of construction activities, including work areas, equipment and duration • Description of what work practices (generic and specific) will be applied to minimise noise and vibration • A complaints handling process • Noise and vibration monitoring procedures • Overview of community consultation required for identified high impact works.	Pre-construction
Construction noise	NV2	Induction and training will be provided to relevant staff and subcontractors outlining their responsibilities with regard to noise.	Construction
	NV3	Noisy activities that cannot be undertaken during standard construction hours will be scheduled as early as possible during the evening and/or night time periods.	Construction

Impact	No.	Environmental management measure	Timing
	NV4	Permanent noise barriers will be scheduled for completion as early as possible in order to minimise construction noise.	Construction
	NV5	Property treatments identified for the operational phase of the project will be considered for installation before or early in the construction period, where they would improve noise levels.	Construction
	NV6	Acoustic sheds will be erected at the Kingsgrove North (C1), Bexley Road North (C4) and Bexley Road South (C5) construction compounds, to mitigate noise generated by tunnelling support activities. The noise attenuation requirements for these acoustic sheds will be reviewed and confirmed during detailed design.	Pre-construction
	NV7	Temporary acoustic hoardings will be installed at the Kingsgrove North (C1), Commercial Road (C3), Bexley Road North (C4), Bexley Road South (C5), Bexley Road East (C6), Arncliffe (C7), Canal Road (C8) and Campbell Road (C9) construction compounds. The design and location of acoustic hoardings will be confirmed during detailed design.	Pre-construction
	NV8	When working adjacent to schools, particularly noisy activities will be scheduled outside normal school hours, where practicable.	Construction
	NV9	Where feasible and reasonable, equipment with directional noise emissions will be oriented away from sensitive receivers.	Construction
	NV10	Verification checks on the noise emissions of plant and machinery will be conducted.	Construction
	NV11	Ongoing noise monitoring will be undertaken during construction at sensitive receivers during critical periods to identify and assist in managing high risk noise events.	Construction
	NV12	Reversing of equipment will be minimised to prevent nuisance caused by reversing alarms. Use of non-tonal reversing alarms ('quackers') will be implemented to further reduce the nuisance caused by reversing alarms.	Construction
	NV13	Loading and unloading will be carried out away from sensitive receivers, where practicable.	Construction
	NV14	Deliveries will be carried out during standard construction hours where feasible and reasonable.	Construction
	NV15	Additional noise mitigation measures during out of hours works will be determined on a case-by-case basis using individual receiver predictions, and may consist of offers of alternative accommodation, monitoring, individual briefings, letter box drops, project specific respite offers, phone calls and specific notifications.	Construction
	NV16	Respite periods (eg one hour respite for every three hours of continuous construction activity) will be scheduled for high noise impact works where appropriate.	Construction
Construction traffic noise	NV17	Truck drivers will be advised of designated vehicle routes, parking and queuing locations, acceptable delivery hours and other relevant practices (ie minimising the use of engine brakes, and no extended periods of engine idling).	Construction
	NV18	Deliveries and spoil removal will be planned to avoid queuing of trucks around construction compounds.	Construction

Impact	No.	Environmental management measure	Timing
Construction vibration	NV19	Before the start of tunnelling or other vibration intensive works at each site, condition surveys will be undertaken on properties and structures within the preferred project corridor (the zone on the surface equal to 50 metres from the outer edge of the tunnels) and within 50 metres of surface works.	Construction
	NV20	The safe working distances will be complied with where feasible and reasonable. This will include the consideration of smaller equipment when working close to existing structures.	Construction
	NV21	If vibration intensive works are required within the safe working distances, vibration monitoring or attended vibration trials will be undertaken at the outset of these works to ensure that levels are within relevant criteria.	Construction
	NV22	Building condition surveys of potentially affected structures will be completed both before and after the works to identify existing damage and any damage due to the works.	Pre-construction and post construction
Ground borne noise	NV23	Vibration intensive construction works will be confined to the less sensitive daytime period (9.00 am to 12.00 pm and 2.00 pm to 5.00 pm) as far as reasonably practicable.	Construction
	NV24	A detailed ground-borne noise assessment will be undertaken following further geotechnical investigations. This will include developing the vibration site law for the project.	Construction
Blasting	NV25	Noise and vibration mitigation methods specific to blasting will be incorporated into the construction noise and vibration management plans where required.	Construction
	NV26	Blasting with the potential to generate an impact at the surface will be restricted to standard daytime hours (except where approved by the relevant authority). Blasting would occur between 9:00am and 5:00pm, up to five days per week (Monday to Friday) and on Saturdays (9:00 am to 1:00pm). Blasts would be limited to one single detonation in any one day per receiver group, unless otherwise agreed by the NSW EPA through consultation on the Construction Noise and Vibration Management Plan.	Construction
	NV27	Site investigations will be conducted prior to production blasting to define suitable blast sizes to comply with project blasting noise and vibration criteria.	Construction
	NV28	Dilapidation studies of nearby receiver buildings will be undertaken where the potential for exceedances of the blasting criteria is identified.	Pre-construction
	NV29	Where the predicted levels exceed the noise or vibration criteria for blasting, alternative construction methods, such as penetrating cone fracture, will be utilised.	Construction
Consultation with impacted receivers	NV30	Community consultation protocols for sensitive receivers likely to be impacted by construction activities such as blasting, vibration and noise will be prepared and implemented.	Pre-construction and construction
Operation			
Road traffic noise	OpNV01	At locations where residual impacts remain after all feasible and reasonable approaches have been exhausted, noise mitigation in the form of acoustic treatment of existing individual dwellings will be considered.	Operation

Impact	No.	Environmental management measure	Timing
	OpNV02	Operational traffic noise will be monitored at sensitive receivers between six months and one year after opening. If the traffic noise levels are above the predicted levels, consideration of additional feasible and reasonable mitigation measures will be undertaken.	Operation
Operational fixed facilities	OpNV03	Operational fixed facilities will be designed to meet project specific noise criteria derived in accordance with the *NSW Industrial Noise Policy*.	Pre-construction
Land use and property			
Construction			
Temporary acquisition	LP01	The relevant property owners would be consulted in relation to the acquisition of properties required to facilitate construction of the project. Acquisition would be undertaken consistently with the principles in the Land Acquisition Information Guide (Roads and Maritime, 2014b) and the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW).	Construction
Property access	LP02	Prior to any impact to access, alternative arrangements would be negotiated with the affected parties in order to enable continued access and to minimise disruption as much as reasonably possible.	Pre-construction and construction
	LP03	Affected property owners and community facilities would be provided with advanced notification of relevant project schedules, construction works and changes to access arrangements.	Construction
	LP04	Community updates would be provided on changes to the local road network within the project area during construction.	Construction
	LP05	Appropriate signage would be provided advising of walking track closures and alternative walking routes.	Construction
Settlement	LP06	A Settlement Monitoring Plan would be prepared that would provide details on: • Location of monitoring points • Duration of monitoring • Data collection and review • Roles and responsibilities for review of data • Triggers and actions for corrective actions.	Construction
	LP07	Building condition surveys would be undertaken on properties and structures within the preferred project corridor (the zone on the surface equal to 50 metres from the outer edge of the tunnels) and within 50 metres of surface.	Construction
	LP08	Services in locations where differential / angular settlement is anticipated would be identified. A monitoring plan, triggers and actions would be agreed with the utilities owner prior to potential impacts occurring.	Construction
	LP09	A monitoring program, undertaken as part of the Settlement Management Plan, would be undertaken to ensure that settlement has stabilised before monitoring is completed.	Construction

Impact	No.	Environmental management measure	Timing
Operation			
Permanent acquisition	OpLP01	Land acquisition for the project would be undertaken consistently with the principles in the Land Acquisition Information Guide (Roads and Maritime, 2014b) and the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW).	Detailed design / preconstruction
Loss of land use and property access	OpLP02	Property accesses that are affected as a result of the project would be reinstated in consultation with the affected landowners including relocation if required.	Detailed design / construction
Visual impacts and urban design			
Construction			
Landscaping	V01	Existing vegetation around the perimeter of the construction compounds would be retained where feasible and reasonable, particularly: • Vegetation surrounding the Bexley Road East construction compound, particularly along the boundary between residential properties and the compound along the northern and eastern boundaries • Mature trees along the north-west (Marsh Street) and south-west boundaries of the Arncliffe construction compound site • Mature trees and vegetation along the boundary of Sydney Park along Campbell Road and Barwon Park Road.	Pre- construction
	V02	Landscape planting would use fast growing species where reasonable and feasible. This would soften views of construction sites, particularly for compounds located within public recreational spaces.	Construction
	V03	Revegetation and landscaping would be undertaken progressively.	Construction
Visual amenity	V04	Temporary noise barriers would be erected early within the site establishment phase where required to minimise noise impacts and provide visual screening.	Pre-construction / construction
	V05	Temporary noise barriers would be designed to include painted surface and project information / logo to deter graffiti and reduce the scale of noise barriers, particularly adjacent to residential areas or public open space.	Detailed design
	V06	Site hoardings and fencing would be regularly maintained, including the prompt removal of graffiti.	Construction
	V07	Acoustic sheds would be designed to minimise noise impacts and provide visual screening to be visually recessive, such as the use of mid toned colours and materials to minimise the intrusiveness and potential glare of the sheds.	Detailed design
Sydney Airport lighting	V08	During detailed design, the Roads and Maritime would liaise with the Civil Aviation Safety Authority to assess the potential for impacts of night lighting from the construction of the project on Sydney Airport operations. Mitigation measures would then be developed as required.	Detailed design

Impact	No.	Environmental management measure	Timing
Lighting	V09	Cut-off or and directed lighting would be used within and outside of construction compounds with lighting location and direction considered to ensure glare and light spill are minimised.	Detailed design
	V10	The lighting design for shared paths located within the M5 Linear Park impacted by the project or located adjacent to compounds would be designed to minimise light spill to adjoining residential properties while maintaining a safe night time environment for path users (eg lighting position below the height of the fence line).	Detailed design
	V11	A signage strategy would be developed during detailed design for temporary wayfinding and safety. Potentially affected receivers would be consulted on the final signage in relation to the location and associated impacts.	Detailed design
Signage	V12	Elements within construction sites would be located to minimise visual impacts as far as feasible and reasonable, for example, locating equipment back from site boundaries.	Detailed design / construction
Visual amenity	V13	Opportunities would be investigated to maximise the separation distances as far as reasonable and feasible: • Between the Kingsgrove North construction compound to the adjoining residential areas to reduce shading and visual impacts • Between the Bexley Road North and Bexley Road East construction compounds and adjoining residential areas to reduce sharing and visual impacts.	Detailed design
	V14	Opportunities would be investigated to provide an alternative southern cycle route for the length of the existing shared path impacted by the western surface works.	Detailed design
Operation			
Visual amenity	OpV01	Vegetated batters would be limited to 1:3 and 1:4 where possible in order to maximise the impact of vegetation on these batters and minimise maintenance.	Detailed design
	OpV02	Chain link fencing for sites would only be used where these would not be viewed by sensitive receivers, such as residents and users of recreational space. At these locations, high quality fencing suitable for parks and public spaces would be considered.	Detailed design
	OpV03	Where large areas of hardstand are or structures are designed, such as carparks, consideration of shade trees within these spaces would be considered where reasonable and feasible to soften views and provide shade and visual amenity.	Detailed design / post construction
	OpV04	Pedestrian and shared paths would be aligned away from residential property boundaries where public open space adjoins residential boundaries.	Detailed design
Landscaping	OpV05	Planting areas would be maximised, where feasible, between public open space and infrastructure, and would include taller screening vegetation (at the Bexley Road South motorway operations complex (MOC2) between the built form and the M5 Linear Park shared path for example).	Detailed design

Impact	No.	Environmental management measure	Timing
Landscape and urban design (general)	OpV06	A final urban design and landscape plan would be prepared in consultation with the New M5 Urban Design Review Panel, local councils within the project corridor and the local community. The Plan shall include (but not limited to): • The architectural treatment of the ventilation facilities, which would be informed by the functional requirements and the design principles detailed in the New M5 Urban Design Report. • Landscape plans and final plant species for the western surface works, Bexley Road motorway operations complex, Arncliffe motorway operations complex, the St Peters interchange and local road upgrades • The artwork strategy for the Kindilan underpass • Consideration of the outcomes of the Safety in Design review of the project.	Detailed design
Landscape and urban design at Kingsgrove	OpV07	The design of the noise attenuation at the western surface works would be confirmed during detailed design and in consultation with the local community. This may consist of noise mounds and barriers (or a combination of both) and with consideration to the provision of accessible open space at Beverly Grove Park and a landscaped outlook.	Detailed design
Landscape and urban design at Bexley	OpV08	Landscaping at the Bexley Road motorway operations complex would consider opportunities to complement the existing topography of the built site as well as the adjacent Wolli Creek bushland.	Detailed design
Landscape and urban design at Arncliffe	OpV09	Reasonable and feasible measures to use landscaping to screen or filter views of the Arncliffe motorway operations complex from residential areas to the west would be implemented.	Detailed design
Landscape and urban design at St Peters	OpV10	Opportunities to maximise the green canopy throughout the local road upgrades at Peters with tree planting in medians where safety barriers and / or speed limits permit would be explored during detailed design, and implemented where reasonable and feasible.	Detailed design
Sydney Airport lighting	OpV11	During detailed design, the Roads and Maritime would liaise with the Civil Aviation Safety Authority to assess the potential for impacts of night lighting from the operation of the project on Sydney Airport operations. Mitigation measures would then be developed as required.	Detailed design
Lighting	OpV12	Lighting design within motorway operations complexes, roadways, and on elevated pedestrian bridges would minimise the impacts of lighting to surrounding areas (particularly residential areas), for example through the use of cut-off, directed lighting and landscaping to minimise light spill and glare. This includes consideration of residences along Campbell Road.	Detailed design

Impact	No.	Environmental management measure	Timing
Social and economic			
Construction			
Accessibility	SEO1	A community involvement plan would be implemented to provide timely, regular and transparent information about changes to access and traffic conditions, details of future work programs and general construction progress throughout the construction phase of the project. Information would be provided in a variety of ways including letter box drops, media releases, internet site, signage and a hotline.	Construction
Property acquisition	SEO2	Acquisition would be undertaken consistently with the principles in the Land Acquisition Information Guide (Roads and Maritime, 2014b) and the *Land Acquisition (Just Terms Compensation) Act 1991* (NSW).	Pre-construction and construction
Business impacts	SEO3	A toll free number and website would be maintained to enable business owners and/or operators to receive prompt responses to their concerns, access information and view assistance measures in place during construction related work.	Construction
	SEO4	A business impact risk register would be maintained to identify and manage the specific impacts associated with construction related works for individual businesses.	Construction
	SEO5	The business stakeholder forum would be continued during detailed design and throughout construction to address business concerns. Further information about consultation can be found in **Chapter 7** (Consultation)	Construction
Soils and water quality			
Construction			
Water quality	SW01	The control and mitigation of potential surface water quality impacts during construction would be defined in a Soil and Water Management Plan prepared as part of the overall CEMP.	Pre-construction/ construction
	SW02	The Soil and Water Management Plan would be developed to incorporate controls and measures in accordance with The Blue Book. The plan would be continually updated to suit the changing needs as the project works progress. The plan would be developed in consultation with the Environment Protection Authority and DPI - Water and document the types of measures that would be put in place to minimise the risk of soil erosion or polluted discharges reaching the receiving environments.	Pre-construction/ construction
	SW03	An Erosion and Sedimentation Management Plan would be prepared as outlined in the Erosion and Sedimentation Risk Assessment Procedure (RTA, 2004).	Pre-construction/ construction

Impact	No.	Environmental management measure	Timing
	SW04	The Soil and Water Management Plan would include: • Construction traffic restricted to delineated access tracks, and maintained until construction complete • Appropriate sediment and erosion controls to be implemented prior to soil disturbance • Stormwater management to avoid flow over exposed soils which may result in erosion and impacts to water quality • Stockpiles located outside the 20 year ARI flood extent where feasible. Otherwise, appropriate management control measures such as bunding would be implemented • Staging of surface works to minimise area of exposed surfaces, with re-vegetation and / or stabilisation of disturbed areas to occur as soon as feasible • Site compounds sealed or hard stand to minimise erosion where possible • Wheel wash or rumble grid systems installed at exit points to minimise dirt on roads • A soil conservation specialist would be contracted to supervise construction in high risk areas in accordance with the Erosion and Sedimentation Management Procedure (RTA, 2008c) • All water generated during construction would be captured, tested (and treated if required) prior to reuse or discharge under a site specific arrangement, depending on the quality of water generated. This would target compliance with the Water Quality Reference Criteria. At the St Peters interchange site this would include transfer of some water to the leachate treatment plant. Varying levels of groundwater quality would also require a variation to treatment approaches • Contaminated sediments and potential acid sulfate soils would be segregated and disposed of (with or without prior treatment as appropriate) at a licensed facility or treated onsite • Stockpiles would be located outside of riparian corridors.	Pre-construction/ construction
	SW05	The water quality and outflow velocities of the water treatment plants at the following compounds would be in accordance with the project's Water Quality Reference Criteria and the project's Environment Protection Licence: Kingsgrove North construction compound (C1), Commercial Road construction compound (C3), Bexley Road South construction compound (C5), Arncliffe construction compound (C7), Canal Road construction compound (C8).	Construction

Impact	No.	Environmental management measure	Timing
	SW06	The project specific water quality monitoring program would continue to collect to at least 12 months of data or to the commencement of construction (whichever is sooner) to represent pre-construction conditions for the project. Monitoring would continue during construction of the project as identified in Appendix A of the Technical working paper: Surface water (**Appendix N**). The details of this monitoring program would be contained in the Soil and Water Management Plan, and would include the following: • Sampling locations to include upstream (control) and downstream measurement locations • Samples taken twice a month, once in dry conditions and once in wet conditions where possible • In-situ monitoring of: – pH – Reduction Oxidation Potential – Dissolved Oxygen – Temperature – Conductivity – Turbidity – Colour – Odour • Analytical sampling of the following potential constituents of concern: – Total Recoverable Hydrocarbons – Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene – Nutrients including: Total Nitrogen, Total Kjeldahl Nitrogen, Nitrogen Oxide, Nitrite, Nitrate, Total Phosphorous and Reactive Phosphorous – Heavy metals (Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel, Zinc) – Manganese – Ferrous Iron and Total Iron.	Pre-construction/ construction
	SW07	Water quality monitoring of the breeding ponds for Green and Golden Bell Frog near Marsh Street, Arncliffe would occur during construction by a suitably qualified scientist as part of the Green and Golden Bell Frog Plan of Management.	Construction
Water reuse	SW08	Opportunities for reuse of treated water generated at the Arncliffe motorway operations complex would be considered during detailed design.	Detailed design
Acid sulfate soils	SW09	An Acid Sulfate Soil Management Plan would be prepared as a sub-plan to the Construction Environment Management Plan to outline the requirements for the management of potential acid sulfate soils.	Pre-construction/ construction

Impact	No.	Environmental management measure	Timing
	SW10	Further contamination investigation would be conducted in areas with medium or high acid sulfate soils potential during the detailed design stage as part of early works. Management of acid sulphate soils during the project would be undertaken as per the management measures outlined in **Section 17.4**.	Detailed design / pre-construction
Contamination	SW11	During landfill closure activities, surface water management measures would be implemented in accordance with The Blue Book to isolate and capture potentially contaminated water. Any such water would be transferred to the leachate treatment plant for treatment prior to discharge to sewer under a trade waste agreement with Sydney Water.	Construction
Contaminated runoff and spills	SW12	The following measures would be in place to manage spills of contaminated fluids: • Areas would be allocated for the storage of fuels, chemicals and other hazardous materials • Facilities would be secured and bunded to levels dictated by Environment Protection Authority guidelines • Spills or contaminated runoff would be captured and treated and / or disposed of at a licensed facility • Re-fuelling, wash down and preparation of construction materials would be undertaken in bunded areas to mitigate risks in relation to spills or leaks of fuels / oils or other hazardous onsite construction material • The application of good practice in the storage and handling of dangerous and hazardous goods would provide appropriate practical responses to manage impacts on occupational health and safety and minimise the risk of a spill occurring • Potential discharges from construction sites would be managed through the installation of basins (primarily designed for sediment capture but with capacity to contain the nominated spill volume) constructed in accordance with The Blue Book • Captured contaminants resulting from spills or leaks would be treated and disposed of at a licensed facility • Any soil which has been contaminated with fuel, oils or other chemicals would be disposed as contaminated soil by a waste subcontractor.	Construction
Geomorphology	SW13	Construction work activities within and / or adjacent to waterways would be minimised as much as feasibly possible to minimise disturbance to those waterways and waterfront land.	Construction
	SW14	Alignment of drainage and discharge outlet infrastructure would direct flows downstream to minimise alterations and erosion of the channel beds and banks.	Detailed design/ construction
	SW15	Drainage and discharge outlet infrastructure would include energy dissipation and erosion scour protection as appropriate.	Detailed design/ construction
	SW16	Disturbed floodplain environments adjacent to watercourses (including waterfront land) and / or along overland drainage lines would be stabilised and vegetation managed in accordance with the *Guidelines for Controlled Activities on Waterfront Land* (DPI, 2012a).	Construction

Impact	No.	Environmental management measure	Timing
Operation			
Surface runoff Surface runoff	OpSW01	Suitable stormwater treatment devices would be identified during detailed design, including an operational water treatment plant, with the aim of meeting the targets of the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011). Where space is available, water quality basins would be installed. In the case where space is unavailable, treatment would include the use of proprietary stormwater treatment devices. The design of treatment trains would be informed by an assessment of the sensitivity of the receiving environments and supported by MUSIC modelling.	Detailed design/ operation
	OpSW02	The treatment capacity lost in decommissioning pond WQP – 3 would be provided by new or upgraded stormwater treatment devices.	Detailed design/ operation
Water quality monitoring	OpSW03	Operational water quality monitoring would be conducted for 12 months post-construction or as otherwise required by the conditions of approval. This would include upstream (control) and downstream monitoring locations. The details of this monitoring program would be contained in the Soil and Water Management Plan, and would include the following: • Sampling locations to include upstream (control) and downstream measurement locations • Samples taken twice a month, once in dry conditions and once in wet conditions where possible • In-situ monitoring of: – pH – Reduction Oxidation Potential – Dissolved Oxygen – Temperature – Conductivity – Turbidity – Colour – Odour • Analytical sampling of the following potential constituents of concern: – Total Recoverable Hydrocarbons – Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene – Nutrients including: Total Nitrogen, Total Kjeldahl Nitrogen, Nitrogen Oxide, Nitrite, Nitrate, Total Phosphorous and Reactive Phosphorous – Heavy metals (Arsenic, Cadmium, Copper, Chromium, Lead, Mercury, Nickel, Zinc) – Manganese – Ferrous Iron and Total Iron.	Operation
New discharge outlets	OpSW04	New discharge outlets into Alexandra Canal would be designed with sufficient energy dissipation or scour protection to limit the impact on contaminated sediments and reduce the possibilities of contaminated sediments being subject to scour or resuspension.	Detailed design/ operation

Impact	No.	Environmental management measure	Timing
Existing drainage outlets	OpSW05	Where existing drainage lines are to be subject to increased inflow, an assessment of their discharge characteristics would be made. If necessary, energy dissipation or scour protection would be added to prevent contaminated sediments from being subject to scour or resuspended. This would be undertaken during detailed design.	Detailed design/ operation
Mitigation for spills	OpSW06	The assessment of risk of spills on the motorway would be undertaken during detailed design. If warranted, spill containment would be provided.	Detailed design/ operation
Operational water treatment plant	OpSW07	The operational water treatment plant would be designed to meet the Water Quality Reference Criteria outlined in Appendix A of the Technical working paper: Surface water (**Appendix N**). Monitoring of the Cooks River would be undertaken during initial operation of the project to ensure discharge meets these criteria.	Detailed design/ operation
Geomorphology Geomorphology	OpSW08	Suitably designed scour and erosion control measures would be included in the detailed design.	Detailed design/ operation
	OpSW09	Drainage and discharge infrastructure where space is available would incorporate measures, as appropriate, to trap and remove sediments in line with the outcomes of the stormwater pollution reduction targets from the Botany Bay and Catchment Water Quality Improvement Plan (SMCMA, 2011). This would reduce the risk of any impacts to the geomorphic condition of receiving waters.	Detailed design/ operation
Contamination			
Construction			
Landfill closure	CM01	The closure and ongoing management of the Alexandria Landfill would be undertaken in line with the LCMP (see **Section 17.3.4** and **Section 5.9.1**) and remedial action plan. This includes a landfill closure, environmental management and monitoring framework.	Pre-construction and construction
Landfill closure	CM02	A site specific management plan would be prepared for the Alexandria Landfill to manage the excavation of parts of the landfill during construction. The management plans, amongst other requirements would detail mitigation measures to: • Contain and treat landfill gas emissions from excavations • Treat offensive odours produced by leachate and landfill gas • Contain, extract and treat leachate within excavations • Protect workers and off-site receptors from exposure to potential biological, chemical and physical hazards encountered during the exhumation of landfill waste. • Manage asbestos contaminated wastes	Pre-construction
Disturbance and mobilisation of contaminated material	CM03	Potentially contaminated areas directly affected by the project would be investigated and managed in accordance with the requirements of guidance endorsed under section 105 of the CLM Act. This includes further investigations in areas of potential contamination identified in the construction footprint.	Pre-construction

Impact	No.	Environmental management measure	Timing
General	CM04	An unexpected finds and hazardous materials procedure would be implemented to manage any potentially contaminated materials that may be encountered during site preparation and / or construction works.	Pre-construction
General	CM05	Waste management plans, as part of the CEMP, would include procedures for handling and storing potentially contaminated spoil and undertaking waste assessment and classification for off-site disposal to appropriately licenced waste facilities. See **Chapter 24** (Resource use and waste minimisation) for more information.	Pre-construction
Asbestos	CM06	Site specific asbestos management plans would be developed where relevant. Refer to **Chapter 24** (Resource use and waste minimisation) for further information on asbestos management.	Pre-construction
Hazardous materials	CM07	A hazardous materials assessment would be carried out prior to and during the demolition of buildings. Demolition works would be undertaken in accordance with the relevant Australian Standards and relevant NSW WorkCover Codes of Practice, including the *Work Health and Safety Regulation 2011.*	Pre-construction, construction
Dangerous goods	CM08	A dangerous goods search of the WorkCover NSW records for licenced dangerous good would be undertaken prior to construction.	Pre-construction
Explosive ordnance	CM09	An explosive ordnance due diligence assessment would be completed at the identified former ammunition site (Project area 3), located between Flatrock Road, Bexley Road and Wolli Creek.	Pre-construction
General	CM10	In the event of encountering unexpected finds of contamination (i.e. the observation of offensive odours, soil discoloration, buried waste or potential asbestos containing materials) during construction, work in the area would cease until an appropriately qualified environmental consultant can advise on the need for further assessment, remediation or other action, as deemed appropriate. Further assessment and management of contamination, if required, would be undertaken in accordance with section 105 of the CLM Act.	Construction
Contamination	CM11	Appropriate mitigation measures to minimise sediment mobilisation as a result of construction activities at the location of the new stormwater infrastructure at Alexandra Canal would be detailed in the CEMP in accordance with the requirements of the Remediation Order in consultation with NSW EPA and Sydney Water.	Pre-construction and construction
Contamination	CM12	Appropriate mitigation measures including stockpiling and management of potentially contaminated material would be undertaken at construction compounds to prevent movement of material into receiving waters.	Construction
General	CM13	Plant, equipment and supplies would be managed to prevent spills and leaks. See **Chapter 26** (Hazard and risk) for more information.	Construction
General	CM14	Tunnel washing water and waste would be appropriately contained, treated and disposed of. Refer to **Chapter 24** (Resource use and waste minimisation) for more information.	Construction
Contamination	CM15	Further *in situ* testing of soils in areas of known potential contamination to determine waste classification.	Construction

Impact	No.	Environmental management measure	Timing
Operation			
General	OpCM1	The ongoing management of the Alexandria Landfill will be undertaken in line with the LCMP (see **Section 17.3.4** and **Section 5.9.1**)	Pre-construction, construction and post construction
Contamination	OpCM2	Procedures to address spills, leaks and tunnel washing would be developed and implemented during operation of the project	Operation
Scour protection	OpCM3	Measures to minimise sediment mobilisation during operation would be incorporated into the design of stormwater outlets at the location of the new stormwater infrastructure at Alexandra Canal. The design of the outlets, including discharge velocities and scour protection measures, would be confirmed during detailed design and supported by appropriate drainage modelling. The detailed design of the outlets would be provided to Sydney Water and NSW EPA for approval in accordance with the requirements of the Remediation Order.	Detailed design
Flooding and drainage			
Construction			
Flood Management Strategy	FD01	A Flood Management Strategy would be prepared by a suitable qualified and experienced person in consultation with directly affected landowners, DPI-Water, OEH and the relevant local councils. It would include but not be limited to: • Identification of flood risks to the project and adjoining areas, including consideration of local drainage catchment assessments and climate change implications on rainfall, drainage and tidal characteristics • Design and mitigation measures to protect proposed operations and not worsen existing flooding characteristics during construction and operation, including soil erosion and scouring • Drainage system upgrades • Preparation of a flood / emergency management plan.	Pre-construction
Flood Management Strategy	FD02	The Flood Management Strategy would be peer reviewed and confirmed as meeting the requirements of this management measure by a suitably qualified and experienced independent hydrological engineer. It would be submitted to the Secretary of DP&E and the relevant local councils prior to construction works commencing in the vicinity of flood prone land and overland flow paths for the waterways and catchments in the vicinity of the project area, or as otherwise agreed by the Secretary of DP&E.	Pre-construction
Flooding design	FD03	The 100 year ARI flood level is to be adopted in the assessment of measures which are required to mitigate any adverse impacts attributable to the project. Changes in flood behaviour under PMF conditions would also be assessed in order to identify impacts on critical infrastructure and significant changes in flood hazards as a result of the project.	Detailed design
Hydraulic assessment	FD04	A detailed hydraulic assessment into the impacts the project would have on flooding behaviour and relevant mitigation measures would be undertaken.	Detailed design

Impact	No.	Environmental management measure	Timing
Flooding design	FD05	Works within the floodplain would be designed to minimise adverse impacts on surrounding developments for flooding up to the 100 year ARI flood. Assessment would also be undertaken of the impacts during flooding in excess of the 100 year ARI flood up to the PMF in the context of impacts to critical infrastructure and flood hazards.	Detailed design
Survey	FD06	A floor level survey would be undertaken in affected areas to determine whether the project would increase floor damages in adjacent developments (ie in properties where there is a potential for increases in peak flood levels for events up to the 100 year ARI flood).	Detailed design
Flood management	FD07	Flood management plans would be developed as part of the CEMP prior to construction to guide the detailed design of temporary ancillary facilities, including construction compounds, to minimise the potential impacts of flooding on the project.	Pre-construction
Flooding in existing residential development	FD08	Around 8,000 cubic metres of the projected 12,000 cubic metres of lost floodplain storage due to the operation of the Arncliffe motorway operations complex (MOC3) would be required to be recaptured. Floor level surveys would be undertaken to determine whether the project would result in the above-floor inundation of the following potentially affected properties. Further design development would be undertaken during detailed design to confirm the extent of works required to mitigate the impact of the project on flooding conditions at these existing residential developments.	Detailed design / construction
Flooding in existing commercial / industrial development	FD09	Detailed design would aim to reduce the impact of the project on flooding conditions for the following two potentially affected properties. This would include consideration of whether the project would result in above-floor inundation of these properties.	Detailed design / construction
Flooding in existing commercial / industrial development	FD10	The potential to reduce impacts of the project on flooding for the properties located on the western overbank of the Alexandra Canal would be considered during detailed design. This would also include consideration of whether the project would result in above-floor inundation of these properties.	Detailed design / construction
Flooding in TransGrid's Beaconsfield West substation	FD11	Further design development would be undertaken to mitigate the impact of the project on flooding conditions in the TransGrid site. This would include further refinement of design of the relief drain, as well as the western approach to the Campbell Road bridge.	Detailed design / construction
Hydrology and flooding	FD12	Existing transverse drainage structures would be left in place during construction where transverse drainage structures are to be upgraded or replaced. If this is not feasible, temporary drainage would be adopted.	Detailed design / pre-construction

Impact	No.	Environmental management measure	Timing
Hydrology and flooding	FD13	Detailed flood modelling to understand the effects of likely rainfall events would be undertaken. Construction layouts would be finalised accordingly.	Pre-construction
Hydrology and flooding	FD14	Tunnel dive shafts would be protected against flooding either through locating openings outside of flood prone areas or constructing temporary bunding and / or appropriate temporary drainage. Stockpiles would be located outside the 20 year ARI flood extent where possible. Where construction compounds are located in the 20 year ARI flood extent, a contingency plan to manage flooding would be prepared and implemented.	Detailed design / pre-construction
Hydrology and flooding	FD15	Further detailed assessment of flooding impacts for proposed construction compounds and relevant management measures would be undertaken during detailed design. Contingency plans to manage flooding would be prepared and implemented for high risk temporary facilities proposed including fuel storages, water treatment plants and substations, as well as for the following construction compounds (located either wholly or partially within the 20 year ARI flood extent): • Kingsgrove South construction compound (C2) • Commercial Road construction compound (C3) • Bexley Road North construction compound (C4) • Bexley Road South construction compound (C5) • Arncliffe construction compound (C7) • Alexandra Canal bridge construction compound (C12) • Gardeners Road bridge construction compound (C13). For these sites, suitable procedures for flood warning, emergency management, site evacuation and planning would be developed.	Detailed design / pre-construction
Hydrology and flooding	FD16	The following measures would be implemented to manage flooding risks on construction sites: • Temporary bunding around parts of the site that would be adversely affected by floodwaters • Temporary drains / detention areas within the site • Use of carparks to provide detention • Elevation of site buildings where necessary to get floor levels above expected flood levels • Use of erosion and sediment fences around noise barriers to provide bunding to some parts of the sites while directing overland flows through less sensitive parts of sites, particularly at Kingsgrove and Arncliffe.	Detailed design / pre-construction
Hydrology and flooding	FD17	A drainage strategy would be determined during detailed design to manage the increased runoff within the catchment draining into Camdenville Park. This drainage strategy would be based on not increasing flows into the Eastern Channel for all events up to and including the 100 year ARI flood.	Detailed design / construction

Impact	No.	Environmental management measure	Timing
Potential impacts of future climate change on flooding	FD18	A more detailed assessment would be undertaken during detailed design to determine the climate change related flood risks to the project and to scope requirements for any management measures. The assessment would be undertaken in accordance with the *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC, 2007)	Detailed design
Operation			
Bridges	OpFD01	Bridge crossings over the Alexandra canal would incorporate a suitable freeboard between the underside of the bridge structure and the peak 100 year ARI flood level.	Detailed design / operation
Flooding design	OPFD02	The project and associated arrangements would be designed to limit increases in peak discharges into the downstream drainage systems in accordance with local council requirements.	Detailed design
Drainage and localised flooding	OpFD03	The control and mitigation of potential localised flooding and drainage impacts during operation would include: • Drainage systems that are of insufficient capacity would be modified or upgraded to cater for increased flows • Where new drains connect with existing drainage networks a survey and condition assessment would be undertaken to inform detailed design • The efficiency of transverse drainage upgrades would be taken into account during detailed design • The effects a partial blockage of major hydraulic structures on flooding behaviour would be considered when determining finished road level and flood wall heights.	Detailed design / operation
Tunnel portals and ancillary facilities	OpFD04	Tunnel entries and associated flood protection barriers would be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater). The same hydrological standard would be applied to tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwaters would also have the potential to flood the tunnels.	Detailed design / operations
Tunnel design	OpFD05	A suitable freeboard would be incorporated into the design of openings into the new road tunnels (eg at the location of the tunnel portals and ventilation shafts). These designs would take into account the impacts of a partial blockage of major hydraulic structures as well as climate change induced sea level rise on PMF event levels.	Detailed design / operation
Emergency response facilities	OpFD06	Emergency response facilities, including the motorway control centre, tunnel fire water tank and pump buildings and associated electrical substations would be locate above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).	Detailed design / operations
Groundwater			
Construction			
Disturbance of acid sulfate soils during excavation	GW01	An Acid Sulfate Soil Management Plan (ASSMP) would be prepared including the measures and monitoring to be undertaken where potential acid sulfate soils are expected. The plan would outline the type of treatment required for acid sulfate soils, bunding and requirement for treatment ponds.	Pre-Construction

Impact	No.	Environmental management measure	Timing
Intersection of saline soils and groundwater	GW02	A groundwater and soil salinity report would be prepared prior to the commencement of earthworks to assess the potential impacts to the local hydrogeological regime.	Pre-Construction
Failure of the leachate pumping system	GW03	Contingency measures to address leachate management at the Alexandria Landfill during construction and prior to the commissioning of the new leachate treatment plant would be explored during detailed design. Identified measures would be detailed in the CEMP and implemented during construction.	Construction
Migration of contaminated groundwater into the tunnels.	GW04	The tunnel construction program would be constructed in accordance with an overarching CEMP for the project which would include measures to manage contaminated groundwater issues. This may include removal of the source of the contamination by excavation and remediation of shallow impacted soils or engineering a solution to prevent the migration of contaminated groundwater into the tunnels.	Construction
Intersection of shallow perched groundwater within Alexandria Landfill or Botany Sands	GW05	Intersected shallow contaminated groundwater would be directed to the construction water treatment plant prior to discharge. Elsewhere, collection and treatment options would be considered and releases made under relevant discharge criteria.	Construction
Intersection of shallow contaminated groundwater during construction activities at Arncliffe	GW06	The intersection of shallow groundwater at the Arncliffe construction compound (C7) would be managed under CEMP(s) for the project. In the event that contaminated groundwater is intersected the approach would be to either remove the source of the contamination by excavation and remediation of shallow impacted soils or engineering a solution to prevent the migration of contaminated groundwater into the project tunnels.	Construction
Unsustainable release of groundwater resources	GW07	Treated waste water would be stored and re-used for project purposes wherever possible. Groundwater reuse would be in accordance with the policies of sustainable water use of the NSW Office of Water, such as dust suppression and earthworks	Construction
Excessive inflows during construction that may exceed the design inflow criterion of 1L/sec/km	GW08	Where saturated faults and fractures are intersected additional rock support would be installed in order to ensure tunnel stability. Appropriate waterproofing measure to reduce the inflow to an acceptable quantity will be applied as required. Measures can range from a spray- on membrane to grouting or installation of a sheet membrane	Construction

Impact	No.	Environmental management measure	Timing
Possible high groundwater inflows and sustained pressure heads (no drawdown) beneath the Cooks River and higher fracture permeability	GW09	Where higher than expected inflows are experienced as beneath the Cooks River and under other major surface water features, appropriate waterproofing measure to permanently reduce the inflow to an acceptable quantity will be applied as required. Measures can range from a spray- on membrane to grouting or installation of a sheet membrane depending on the inflow volume	Construction
Aggressive groundwater chemistry such as elevated sodium, chloride, ammonia, low pH conditions that are aggressive to concrete and steel	GW10	Building materials that are resistant to aggressive groundwater conditions would be selected.	Detailed design

Impact	No.	Environmental management measure	Timing
Spills and incidents relating to fuels, oils, lubricants and refuelling	GW11	The project works would be undertaken in accordance with a CEMP(s) for the project which would include the following management measures: • Stockpiles of fuels, hazardous liquids and chemicals would be stored in an impervious bunded area in accordance with Australian Standards and EPA guidelines • The storage of fuels and chemicals would be limited to locations more than 40 metres from any water course • Refuelling of vehicles and machinery would occur off-site where possible or in a designated re-fuelling area • Vehicles would be properly maintained to minimise the risk of fuel/oil leaks and routine inspections of construction equipment would be undertaken to identify any fuel/oil leaks • Emergency spill kits would be kept on-site and project personnel would be aware of the location of spill kits and trained in their use • Hazardous materials handling procedures would be documented and implemented • In the event of an incident resulting in impacts to human health or the environment, works would cease immediately and the EPA would be notified (if required) • Erosion and sediment control measures would be regularly inspected, and particularly following rainfall events. The controls would remain in place until construction works are completed and areas are stabilised.	Construction
Groundwater inflow into tunnels exceeding project requirements	GW12	A tunnelling procedure that details a methodology to determine when and what type of waterproofing is required to be installed during construction would be implemented during construction. Pre-excavation pressure grouting may also be used in locations identified that could produce substantial inflows to reduce groundwater inflows to an acceptable level. Post grouting (ie grouting undertaken post excavation) may also be required to further reduce groundwater inflows. Post grouting would occur within one month post excavation.	Construction
Construction of the tunnels could adversely impact surface and groundwater quality, resources and wetlands.	GW13	A groundwater monitoring program would be prepared and implemented to monitor groundwater impacts during construction. The program would be developed in consultation with the EPA, DPI (Fisheries), NSW DPI Water and relevant councils.	Construction

Impact	No.	Environmental management measure	Timing
Cracking creek beds, localised elevated inflows to tunnels from fractured rock beneath the creeks and potential surface environmental consequences from the increased flows	GW14	Where the project alignment passes close to watercourses and inflows are elevated, appropriate waterproofing measures to permanently reduce the inflow to an acceptable quantity would be applied as required	Construction
Impact to existing registered bores.	GW15	In the event that the drawdown in a water supply bore or irrigation bore exceeds two metres (in accordance with the Aquifer Interference Policy) measures would be taken to 'make good' the impact by restoring the water supply to pre-development levels. The measures taken would be dependent upon the location of the impacted bore and would 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.	Construction Operation
Ground settlement	GW16	A Settlement Monitoring Plan would be prepared that would provide details on: • Location of monitoring points • Duration of monitoring • Data collection and review • Roles and responsibilities for review of data • Triggers and actions for corrective actions.	Construction
	GW17	Building conditions surveys would be undertaken in the zone of influence of the tunnel settlement where the settlement is expected to have a potential impact. In the unlikely event that any damage occurs to a property, appropriate rectifications would be carried out.	Construction
	GW18	Services in locations where differential/ angular settlement is anticipated would be identified. A monitoring plan, triggers and actions would be agreed with the relevant utility owner prior to potential impacts occurring.	Construction
	GW19	A monitoring program, undertaken as part of the Settlement Management Plan, would be carried out prior to excavation until all relevant settlement has stabilised. Monitoring would be for a period of not less than six months after settlement has stabilised.	Construction

Impact	No.	Environmental management measure	Timing
Operation			
On-going groundwater extraction and treatment during operation	OpGW01	An OEMP would be prepared and implemented to outline management measures for groundwater inflows, treatment and discharge and protocols for spillages or incidents. Monitoring parameters may include groundwater levels, groundwater quality including field parameters, laboratory analytes and sample frequency.	Operation
Build-up of precipitated iron (slimes) and silt and sand due to slaking of the sandstone.	OpGW02	The drainage system would be regularly maintained in accordance with the Operational Environmental Management Plan.	Operation
Impact on surface and groundwater quality, resources and wetlands as a result of operation	OpGW03	A groundwater quality monitoring program would be prepared and implemented to monitor groundwater impacts during tunnel operations. The program would be developed in consultation with the EPA, DPI (Fisheries), NSW DPI Water and relevant councils.	Operation
Failure of the leachate pumping system	OpGW04	Contingency measures to address leachate management in the event of pump failure would be explored during detailed design and implemented in the Landfill Closure Plan.	Operation
Non-Aboriginal heritage			
Construction			
General	NAH01	Protocols would be developed for anticipated categories of unexpected non-Aboriginal heritage finds, such as tram infrastructure, late 19th to early 20th refuse, and brick works. In the event of an unexpected cultural heritage find outside of these specific protocols, the *Standard Management Procedure – Unexpected Archaeological Finds* (Roads and Maritime, 2015a) would be followed. This would include notification to the NSW Heritage Division of OEH (highly effective).	Pre-construction and construction
	NAH02	Construction personnel would be made aware of non-Aboriginal heritage sites as part of the site induction. These sites would be identified on sensitive area plans and in the CEMP (highly effective).	Pre-construction and construction
	NAH03	As part pf the construction heritage management plan, an overarching historical archaeological research design would be prepared prior to commencement of construction in consultation with the NSW Heritage Division of OEH. It would describe clear significance thresholds to possible archaeological items that may be uncovered during works and designate when monitoring, testing and / or salvage and excavation should occur in relation to the project works and timing. Post-excavation reporting, including artefact analysis and additional historical research (where necessary), would be required for any historical archaeological investigations undertaken (moderately effective).	Detailed design

Impact	No.	Environmental management measure	Timing
	NAH04	A construction heritage management plan would be prepared prior to construction in consultation with the NSW Heritage Division of OEH. The plan would detail how construction impacts on heritage would be minimised and managed including training and induction processes for construction personnel. Inductions are to cover built heritage, landscape and historical archaeological sites and their management, and provide heritage guidance on how to avoid / manage impacts. The induction would be prepared in consultation with a suitably qualified heritage specialist and historical archaeologist. As a minimum, the plan would include the following: • Induction protocols for staff and project personnel to undertake a cultural heritage induction, to assist them in understanding and complying with their legal obligations under the *Heritage Act 1977* • A list, plan and GIS layer showing the location of identified heritage items • A significance assessment and statement of significance for each item • Detail the mitigation measures identified and when the measures are to be implemented • Provide protocols and procedures to be enacted during construction to ensure the protection of items of heritage significance • An unexpected finds procedure in the event that further sites are identified during works • The separate procedure for the discovery of skeletal remains (highly effective).	Pre-construction
	NAH05	Impacts to built heritage, heritage landscapes and historical archaeological sites, will to the greatest extent practicable, be avoided and minimised. Where impacts are unavoidable, works shall be undertaken in accordance with the strategy outlined in the construction heritage management plan (moderately effective).	Pre-construction and construction
Removal of heritage listed structures	NAH06	In relation to the house at 82 Campbell Street and terrace group at 28-44 Campbell Street the following would be undertaken: • The buildings would be subject to a full archival recording following the *NSW Heritage Division guidelines How to Prepare an Archival Recording* (NSW Heritage Office, 2003) and *Photographic recording of heritage items using film or digital capture* (NSW Heritage Office, 2006) • Consideration should be given as to whether elements of the houses could be salvaged and used to maintain or restore other properties managed by Roads and Maritime (somewhat effective).	Detailed design

Impact	No.	Environmental management measure	Timing
	NAH07	In relation to Rudders Bond Store, the following would be undertaken: • The bond store would be subject to a full archival recording following the *NSW Heritage Division guidelines How to Prepare an Archival Recording* (NSW Heritage Office, 2003) and *Photographic recording of heritage items using film or digital capture* (NSW Heritage Office, 2006) • Consideration would be given as to whether the laminated timber columns could be salvaged and re-erected and clad elsewhere within the St Peters interchange or the local area. The cladding and brick walls are not considered to be of heritage significance and are not included within the reuse proposal • Investigate options for documenting the history of the Ralph Symonds company and presenting it to a national audience, in partnership with stakeholders such as the City of Sydney and Powerhouse Museum. The focus would be on their development of innovative timber construction methods during and after World War II (somewhat effective).	Detailed design / pre-construction
Change of use	NAH08	In relation to the Service Garage at 316 Princes Highway, the following would be undertaken: • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to the heritage item • A photographic archival recording is undertaken prior to the current use ceasing. The archival recording should conform to the guidelines provided in *How to prepare archival records* (NSW Heritage Office, 2003) and *Photographic recording of heritage items using film or digital capture* (NSW Heritage Office, 2006). The archival recording should be lodged with the relevant local libraries and the State Library of NSW. • The oral history should be prepared, which seeks to contact past and present employees as well as others with memories of the service station. The oral history should be lodged with the relevant local libraries and the State Library of NSW (somewhat effective).	Pre-construction
Potential for direct impacts due to vibration associated with surface construction	NAH09	Detailed mitigation and management measures would be developed for each heritage item directly impacted by the project with regard to vibration (surface and tunnelling) and settlement once final disturbance areas have been identified through detailed design. These mitigation and management measures would be included in the CEMP(s) for the project (highly effective).	Detailed design

Impact	No.	Environmental management measure	Timing
Potential for direct impacts due to vibration associated with surface construction	NAH10	Surface works would adhere to safe working distances, and an existing condition survey report and program of monitoring would be undertaken to identify early potential risks at the following non-Aboriginal heritage items: • Wolli Creek Culvert • St Peters Public School, including interiors • Terrace housing, including interiors (I273) • Waugh and Josephson industrial buildings, former, showroom, offices and workshops, including interiors • Town and Country Hotel, including interiors • Group of Victorian Filigree and Victorian Italianate terrace houses – Narara, including interiors • Terrace group I12 • Water Board pump house, including Interior and substructure • Industrial Building, 'Frank G Spurway' • Former Alexandria Spinning Mills (highly effective).	
Visual impacts, as well as vibration impacts to the Macdonaldtown Stormwater Channel #3	NAH11	An existing condition survey report and program of monitoring would be undertaken to identify early potential risks at the Macdonaldtown Stormwater Channel #3 (highly effective).	Pre-construction and construction
Acoustic impacts to non-Aboriginal heritage items	NAH12	The following non-Aboriginal heritage properties would be considered for at property acoustic treatment: • St Peters Public School, including interiors • Terrace group I12 (highly effective). Acoustic treatments would be confirmed during detailed design, and would consider the principles of *The Burra Charter (the Australia ICOMOS charter for places of Cultural Significance)* (ICOMOS (Australia), 2013).	Detailed design

Impact	No.	Environmental management measure	Timing
Impacts to the Goodsell Estate Heritage Conservation Area as a result of vibration, acquisition and modification, as well as visual impacts and impacts conservation area values.	NAH13	Management measures for the Goodsell Estate Heritage Conservation Area would include: • Landscaping, to mitigate the impacts of realigning and widening roads, as well as alterations to the existing stormwater detention basin • Surface works would adhere to safe working distances • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conversation area and within 50 metres of the main alignment tunnels (highly effective).	Pre-construction, construction and post-construction
Impacts to the Clemton Park Urban Conservation Area as a result of vibration, changes in heritage area conservation values, and visual impacts.	NAH14	Management measures for the Clemton Park Urban Conservation Area would include: • Surface works would adhere to safe working distances • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conservation area • Landscaping would provide screening of the Bexley Road South motorway operations complex from the Clemton Park Urban Conservation Area, once established (highly effective).	Pre-construction, construction and post-construction
Impacts to the Pallamanna Parade urban Conservation Area as a result of vibration, changes in heritage area conservation values, and visual impacts.	NAH15	Management measures for the Pallamanna Parade Urban Conservation Area would include: • Surface works would adhere to safe working distances • An existing condition survey report and program of monitoring would be undertaken to identify early potential risks to relevant structures within the conservation area • Landscaping would provide screening of the project from the Pallamanna Parade Urban Conservation Area, once established (highly effective).	Pre-construction, construction and post-construction

Impact	No.	Environmental management measure	Timing
Impacts to heritage values due to construction of stormwater discharge points	NAH16	The following management measures would be implemented with respect to Alexandra Canal: • Monitoring during works to ensure vibration is not impacting the Alexandra Canal walls • Preparation of an archival recording of the Canal, involving both scale drawings and photography, prior to the removal of sandstone blocks • Numbering of sandstone blocks so that those displaced by the discharge points can be replaced in their previous locations • Stockpiling displaced sandstone blocks for use in repairs of other sections of the Alexandra Canal • Installation of heritage interpretation regarding the Canal in accordance with an interpretation plan (moderately effective).	Detailed design and construction
Heritage interpretation	NAH17	An interpretation plan would be prepared and implemented for: • Alexandra Canal and the industrial heritage of the area. This shall include installation of a heritage interpretation regarding the Canal in accordance with an interpretation plan • The St Peters Brickpit geological site, including: – Integrate the geological interpretation into the Sydney Park brickworks in consultation with City of Sydney, as the industrial counterpart to the geological history to tell a more complete story of historical land use in the area – Integrate the geological / palaeontological discovery of the *Paraclytosaurus davdi* – Retain an exposed section of the fresh shales and siltstones, including features associated with deposition of the sedimentary rocks, and later formed fractures such as joints and faults, if safe to do so for both landform stability and ongoing access for interpretation (moderately effective).	Detailed design and construction
Impact to geological and palaeontological values	NAH18	An archival recording of the St Peters brickpit geological site would be undertaken prior to and during the construction (highly effective).	Pre-construction
	NAH19	An assessment and / or consultation with a palaeontologist to determine whether the project impact area has potential to contain further specimens of scientific interest (highly effective).	Pre-construction
Visual	NAH20	Approaches to appropriately manage impacts of the project to the individual contribution of views into and out from heritage properties and the long-term impact of construction would be detailed in a CEMP (highly effective). Individually tailored landscape treatments would be developed during detailed design to mitigate visual impacts at 2-34 Campbell Road, St Peters.	Pre-construction Detailed design
Impacts on archaeology	NAH21	The construction heritage management plan would include detailed procedures / strategies for the conservation and curation of any historical artefacts recovered during works (moderately effective).	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
Urban design and landscaping	NAH22	Urban design and landscaping would be undertaken to manage visual impacts to the following additional non-Aboriginal heritage items: • Terrace housing (I273) • Southern Cross Hotel (I277) • Water Board pump house (I18) (highly effective).	Construction and post-construction
Biodiversity			
Construction			
General construction impacts	B01	A Flora and Fauna Management Plan will be developed before construction. The Plan will identify potential impacts to biodiversity and describe mitigation measures and environmental controls to be implemented during construction, including measures to protect biodiversity features which will be retained.	Construction
Vegetation clearance	B02	The removal of established vegetation will be minimised, where possible.	Construction
	B03	Pre-clearance activities will be carried out in accordance with *Guide 1 Pre-clearing process* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011). Pre-clearing surveys will be undertaken by a suitably qualified ecologist to identify the presence of: • Hollow-bearing trees • Threatened flora and fauna.	Construction
	B04	Trees will be removed in accordance with *Guide 4 – Clearing of Vegetation and Removal of Bushrock* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011).	Construction
	B05	Where vegetation clearance is required, exclusion zones will be established in accordance with *Guide 2 Exclusion Zones* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011).	Construction
	B06	Where reasonable and feasible, mature and hollow-bearing trees will be retained. Where this is not reasonable and feasible, nest boxes will be installed to mitigate the impacts of removing hollow bearing trees in accordance with Table 8.1 of *Guide 8 – Nest boxes* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011) at least one month prior to the commencement of construction	Construction
	B07	Locally indigenous species will be included as part of landscaping and rehabilitation works to promote native fauna habitat.	Construction
Impacts to native flora and fauna	B08	Should unexpected threatened flora or fauna be located at any time during construction, relevant works will cease in the area to prevent further harm to the individual. Should this occur, a suitably qualified ecologist will be engaged to advise on appropriate mitigation and management measures.	Construction
	B09	Any fauna handling would be undertaken by an appropriately licenced ecologist in accordance with *Guide 9 – Fauna handling* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011).	Construction

Impact	No.	Environmental management measure	Timing
Impacts to the Green and Golden Bell Frog	B10	The Green and Golden Bell Frog Plan of Management Plan will be finalised and implemented to minimise and manage impacts to the Arncliffe key population. The Green and Golden Bell Frog Plan of Management Plan would be approved by the Commonwealth Department of the Environment and OEH, and would include: • Management measures to be implemented at the Arncliffe construction compound (C7) and RTA Ponds to minimise and manage impacts to the Green and Golden Bell Frog habitat and key population during construction. • Management measures relating to the enhancement of existing habitat at the Marsh Street Wetland • Supplementary management measures for consideration to mitigate and minimise impacts to the Green and Golden Bell Frog.	Construction
Impacts to hydrology and aquatic biodiversity	B11	Measures to mitigate potential water quality impacts during construction are outlined in **Section 16.4** and **Section 18.4**.	Construction
	B12	Works within or near aquatic habitats and riparian areas will be managed in accordance with *Roads and Maritime's Guide 10 – Aquatic habitats and riparian zones*.	Construction
	B13	Works within aquatic habitats or riparian zones would be undertaken to limit impacts on aquatic flora and fauna, and their habitats, and impacts on riparian areas. This would be undertaken in accordance with Guide 10 of the *Biodiversity Guidelines*.	Construction
	B14	Where possible, construction activities would minimise disturbance to waterways and riparian land	Construction
	B15	Stockpiles would be located outside riparian corridors.	Construction
Spread of weeds	B16	Weeds within the construction footprint will be actively managed prior to the clearance of vegetation. All weed material cleared from within the construction footprint of the project will be disposed of at a facility licensed to receive green waste.	Construction
	B17	Vegetation within the road reserve adjacent to areas to be cleared will be managed in accordance with *Guide 6 – Weed Management and Guide 10 – Aquatic Habitats and Riparian Zones* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011) to reduce the introduction and spread of noxious weed species.	Construction
	B18	Landscaping and revegetation works will be undertaken using weed-free topsoil in accordance with the project's urban design concept plan.	Construction
Introduction and spread of pathogens	B19	A hygiene protocol will be implemented as part of the CEMP(s) for the project to prevent the spread and exacerbation of the Chytrid Fungus in accordance with *Guide 7 – Pathogen Management* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011).	Construction
	B20	A risk assessment process will be used for each construction compound to determine the need to clean machinery prior to entering	Construction

Impact	No.	Environmental management measure	Timing
	B21	Pathogens will be identified as part of pre-clearing inspections. In the event that pathogens are identified within the construction footprint, appropriate mitigation measures will be identified by an ecologist and implemented as part of the CEMP(s) in accordance with *Guide 7 – Pathogen Management* of Roads and Maritime's *Biodiversity Guidelines* (RTA, 2011).	Construction
Operation			
General	OpB01	A management plan will be developed and implemented to identify and mitigate potential ongoing impacts to biodiversity, including procedures for: • Management of weeds • Management, maintenance and rehabilitation of riparian land disturbed by the project and riparian areas associated with the discharge of treated water • Maintenance of nest boxes	Operation
Greenhouse gas			
Construction			
Emission of greenhouse gases during construction	GHG1	Prepare a Greenhouse Gas Emissions Strategy and Management Plan for the project.	Detailed design
	GHG2	Undertake an updated greenhouse gas assessment based on detailed design.	Detailed design
	GHG3	The emissions intensity of significant construction materials specified in the design of the project would be assessed and, where feasible and in compliance with technical specifications, low emission construction materials would be used.	Detailed design
	GHG4	Where feasible, recycled content road construction materials such as recycled aggregates in road pavement and surfacing, or similar, would be used.	Detailed design
	GHG5	The fuel efficiency of construction plant and equipment would be assessed before selection and, where feasible and reasonable, equipment with the highest fuel efficiency or equipment that uses lower greenhouse gas intensive fuel such as biofuels (eg biodiesel, ethanol) would be used.	Pre-construction and construction
	GHG6	Project planning would be undertaken to ensure that the site vehicle movements and construction activities are efficient, to avoid double handling of materials and unnecessary fuel use where possible.	Detailed design
	GHG7	Locally produced goods and services would be procured where feasible and cost effective to reduce transport fuel emissions.	Detailed design and construction
	GHG8	At least six per cent of construction energy required for the project would be sourced where possible from an accredited GreenPower energy supplier	Pre-construction and construction
	GHG9	Where possible, and fit for purpose, spoil would be beneficially re-used within the project before off-site re-use or disposal options are investigated. A spoil management strategy would be developed for the project prior to the commencement of construction and would identify spoil disposal sites and the management of excess spoil.	Pre-construction and construction

Impact	No.	Environmental management measure	Timing
	GHG10	Waste would be diverted from landfill, including diversion of spoil, construction and demolition waste, and commercial and industrial waste, where reasonable and feasible. The management of waste would be considered as part of the preparation of the CEMP for the project, detailing the appropriate procedures for waste management.	Detailed design and construction
Operation			
Emission of greenhouse gases during operation	OpGHG 1	The main alignment tunnels would be designed to minimise fuel consumed by vehicles using the road, for example through the provision of a vertical alignment that allows consistent vehicle speeds to be maintained.	Detailed design
	OpGHG 2	A life cycle assessment would be undertaken as part of the detailed design in order to select mechanical and electrical systems with increased energy efficiencies, where reasonable and feasible, such as the tunnel ventilation system, tunnel lighting, water treatment systems and electronic toll and surveillance systems.	Detailed design
	OpGHG 3	Low carbon energy generation options would be investigated as part of the detailed design process in order to reduce the demand on mains electricity and generate renewable energy onsite, where feasible. At least six per cent of energy required for the project would be sourced from an accredited GreenPower energy supplier, where possible.	Detailed design
Aboriginal heritage			
Construction			
Impacts on culturally sensitive Aboriginal sites	AH 1	Vibration generating activities, including blasting would be conducted in a manner to ensure vibration levels do not exceed three millimetres per second at potential Aboriginal heritage site SR-OVRH-1.	Construction
Indirect impacts on sandstone rock overhang site Impacts on culturally sensitive Aboriginal sites	AH 2	Vibration monitoring would be carried out during vibration intensive works within 50 metres of SR-OVRH-1. The need for vibration monitoring would be informed by a preliminary screening of activities at this location to identify what activities have the potential for vibration at this location. The preliminary screening and works requiring monitoring would be contained within the CEMP.	Pre-construction and construction
	AH 3	A baseline condition assessment would be completed by a qualified structural engineer for Aboriginal site SR-OVR-1 before construction commences, followed by a condition assessment immediately following significant vibration and with recommendations for remediation measures if required.	Pre- construction and construction

Impact	No.	Environmental management measure	Timing
Unexpected discovery of Aboriginal objects (Project wide)	AH 4	If an Aboriginal object(s) is discovered during construction it would be managed in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime Services, 2015), including: • Ceasing works in the vicinity of the object(s), where there is the potential to directly or indirectly impact on the object(s) • Notifying the construction Environmental Representative and OEH of the discovery • Engaging a qualified archaeologist to determine the nature, extent and scientific significance of the object(s) • Developing management recommendations in consultation with the qualified archaeologist, OEH and RAPs.	Construction
Unexpected discovery of Aboriginal objects (Alexandra Canal)	AH 5	In order to manage the potential discovery of an Aboriginal object(s) during pile installation adjacent to Alexandra Canal the following strategy would be implemented: • Geotechnical coring at each pile location by a geotechnical engineer to obtain intact sediment samples to a depth of around seven metres • Inspection of obtained sediment samples by a qualified archaeologist in consultation with the geotechnical engineer in order to characterise the soil profile and identify any Aboriginal archaeological materials Should Aboriginal archaeological material be present within one or more core samples, management would occur in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime, 2015).	
Unexpected discovery of human remains	AH 6	If human remains are discovered during construction would be managed in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime Services, 2015), including: • Ceasing works in the vicinity of the remains, with the potential to directly or indirectly impact on the remains • Notifying the construction Environmental Representative, OEH and NSW Police of the discovery • Following directions from the NSW Police and / or OEH, as relevant, depending on the nature of the remains and the outcomes of forensic investigations.	Construction

Impact	No.	Environmental management measure	Timing
Resource use and waste minimisation			
Construction			
Resource consumption	WM01	Construction energy consumption would be reduced through initiatives such as: • Use of roadheaders, which can excavate a more efficient shape for the road tunnel than tunnel boring machines, resulting in less spoil generation and less energy consumption for handling, management and transport of spoil • Local materials procurement where feasible and cost effective to reduce fuel consumption for transport • Selection of efficient construction plant and equipment where possible • Use of recycled materials where feasible • Efficient practices on site (for example, switching off engines when not in use) • Use of energy efficient or solar powered lighting for temporary construction facilities • Investigating the use of biofuel for construction vehicles.	Construction
	WM02	Where feasible and reasonable, construction material would be sourced from within the Sydney region.	Pre-construction and construction
	WM03	Unnecessary resource consumption would be avoided by making realistic predictions of the required quantities of resources such as construction materials	Construction
	WM04	Resource recovery would be applied to the management of construction waste and would include: • Recovery of resources for reuse-reusable materials generated by the project would be segregated for reuse either on-site or off-site where possible, including the reuse of the major waste streams (VENM and ENM) • Recovery of resources for recycling - recyclable resources (such as metals, plastics and other recyclable materials) generated during construction and demolition • Resources would be segregated for recycling • These materials would then be sent to an appropriate recycling facility for processing. • Recovery of resources for reprocessing -cleared vegetation would be mulched or chipped on-site and used for landscaping, in the absence of a higher beneficial use being identified.	Construction
	WM05	Where reasonable and feasible, Packaging Take Back arrangements would be implemented with suppliers.	Construction

Impact	No.	Environmental management measure	Timing
Management of waste	WM06	Wastes would be managed (classified, handled and stored) and reused / recycled / disposed of in accordance with relevant State legislation and government policies including the POEO Act*, Waste Avoidance and Resource Recovery Act 2001, Waste Avoidance and Resource Recovery Strategy 2014-2021* (EPA, 2014b), and the sustainable procurement objective of the *WestConnex sustainability strategy* (WestConnex Delivery Authority, 2015).	Construction
	WM07	A Construction Waste Reuse Recycling and Energy plan (CWRREMP) would be prepared as part of the CEMP detailing appropriate procedures for waste management. The Construction Waste Recycling Reuse Environment Management Plan would ensure waste disposal and energy use is minimised by tracking and reporting performance and applying corrective action as required.	Construction
	WM08	Wastes would be managed using the waste hierarchy principles of: • Avoidance of unnecessary resource consumption to reduce the quantity of waste being generated. • Recover resources for reuse on-site or off-site for the same or similar use, without reprocessing. • Recover resources through recycling and reprocessing so that waste can be processed into a similar non-waste product and reused. • Disposal of residual waste.	Construction
	WM09	Residual waste would be disposed of to a suitably licensed landfill or waste management facility where there are no other feasible and reasonable options for waste avoidance, reuse or recycling. Waste materials requiring removal from the site would be classified, handled and stored in accordance with the *Waste Classification Guidelines: Part 1 Classifying Waste* (EPA, 2014a) until collection by a contractor for disposal.	Pre-construction and construction
	WM10	Off-site reuse of waste would comply with relevant NSW Environment Protection Authority resource recovery exemptions and requirements.	Construction
	WM11	Asbestos handling and management would be undertaken in accordance with the project's Asbestos Management Plan and relevant legislation, policies and standards: • *Work Health and Safety Act 2011* • *Code of Practice for the Safe Removal of Asbestos 2nd Edition (NOHSC, 2005a).* • *Code of Practice for the Management and Control of Asbestos in Workplaces (NOHSC, 2005b).* • *Protection of the Environment Operations (Waste) Regulation 2014* – Part 7 Transportation and management of asbestos waste. • Australian Standard AS2601:1991 Demolition of Structures.	Pre-construction
	WM12	Measures would be implemented to manage stockpiles such as potentially locating stockpiles outside of overland flowpaths, riparian corridors and finished and contoured so as to minimise loss of material in flood or rainfall events. Stockpiles left exposed and undisturbed for longer than 28 days would be stabilised by compaction then either sprayed with suitable tackifier, covered with anchored fabrics, or seeded with sterile grass.	

Impact	No.	Environmental management measure	Timing
Excess spoil	WM13	A Spoil Management Strategy would be developed prior to the commencement of construction and implemented during construction. The strategy would identify spoil disposal sites and describe the management of spoil on-site and during off-site transport.	Pre-construction
	WM14	Where possible and fit for purpose, spoil would be beneficially reused within the project before off-site reuse or disposal options are pursued.	Construction
	WM15	Before being transported from construction sites, excavated spoil would be classified in accordance with the *Waste Classification Guidelines: Part 1 Classifying Waste* (EPA, 2014a) to ensure appropriate reuse or disposal.	Construction
Wastewater	WM16	Feasible and reasonable opportunities for wastewater reuse on-site or for construction purposes would be pursued (such as dust suppression both in the tunnels and for surface works).	Construction
	WM17	Wastewater not used on-site would be discharged into the local stormwater system in accordance with the requirements of an environment protection licence issued for the project.	Construction
Contaminated soil	WM18	An Unexpected Finds Protocol would be implemented in the event of encountering previously unidentified area(s) or types of contaminated material. Where this happens, all relevant work would cease in the vicinity of the discovery in accordance with a unsuitable spoil management contingency procedure which would be included as part of the Spoil Management Strategy for the project. Relevant works would not recommence until the need for and scope of remedial action(s), if required, is identified in accordance with the requirements of the *Contaminated Land Management Act 1997*.	Construction
Operation			
Management of waste	OPWM01	Wastes would be managed and disposed of in accordance with relevant State legislation and government policies including the POEO Act, *Waste Avoidance and Resource Recovery Act 2001*, *Waste Avoidance and Resource Recovery Strategy 2014-2021* (EPA, 2014b), and the sustainable procurement objective of the *WestConnex sustainability strategy* (WestConnex Delivery Authority, 2015).	Operation
Operational water requirements	OPWM02	Opportunities for reuse of wastewater would be considered in preference to discharge to the local stormwater system.	Detailed design and operation
	OPWM03	In order to reduce demand on local water supplies, options would be investigated for providing water required for operation of the deluge system from wastewater produced through the tunnel drainage system where it meets appropriate quality parameters.	Detailed design and operation

Impact	No.	Environmental management measure	Timing
Climate change and risk adaptation			
Operation			
Climate change impacts	CC01	The risk associated with future climate change on the project would be further considered during detailed design.	Pre-construction
	CC02	Implement adaptation measures to address high and extreme rated risks identified in the subsequent detailed climate change risk assessment.	Pre-construction
	CC03	Where extreme, high or medium risks have been identified in this assessment or subsequent climate change risk assessments, a review of the existing design policies, specifications or practices would be undertaken to consider the impacts of climate change.	Pre-construction
Hazard and risks			
Construction			
General	HR01	Site-specific hazard and risk management measures would be included within the CEMP, which may include items such as: • Details of the hazards and risk associated with construction activities for both surface and subsurface works • Procedures to comply with legislative and industry standard requirements • Contingency plans, as required.	Pre-construction / construction
Storage of dangerous goods and hazardous substances	HR02	Storage of dangerous goods and hazardous materials would occur in accordance with suppliers' instructions and relevant Australian Standards and may include bulk storage tanks, chemical storage cabinets / containers or impervious bunds.	Construction
	HR03	Storage, handling and use of dangerous goods and hazardous substances would be in accordance with the *Work Health and Safety Act 2011* and the *Storage and Handling of Dangerous Goods Code of Practice* (WorkCover NSW, 2005).	Construction
	HR04	Secure, bunded areas would be provided around storage areas for oils, fuels and other hazardous liquids.	Construction
	HR05	Bunds would be provided around activities such as vehicle refuelling, servicing, maintenance or wash-down, where there is a potential for spills and contamination.	Construction
	HR06	Material Safety Data Sheets would be obtained for dangerous goods and hazardous substances stored onsite prior to their arrival.	Construction
Transportation of dangerous goods and hazardous substances	HR07	Transport of dangerous goods and hazardous substances would be conducted in accordance with relevant legislation and codes, including the Dangerous Goods (*Road and Rail Transport) Regulation 2014* and the Australian Code for the *Transport of Dangerous Goods by Road and Rail* (National Transport Commission, 2008).	Construction

Impact	No.	Environmental management measure	Timing
Aviation Measures	HR08	The project would be constructed in line with Civil Aviation Safety Authority requirements, to the satisfaction of the Secretary of the Commonwealth Department of Infrastructure and Regional Development.	Construction
Aviation Measures - lighting	HR09	The project would be constructed in in accordance with the requirements of the Civil Aviation Safety Authority and the *Sydney Airport Master Plan 2033*, with respect to lighting used during construction.	Construction
Operation			
Fire and life safety	OpHR01	The fire and safety systems and measures adopted for the project would be equivalent to or exceed the fire safety measures recommended by NFPA502 (American), PIARC (European), AS4825 (Australian) and Roads and Maritime standards.	Detailed Design
Storage of dangerous goods and hazardous substances	OpHR02	Storage of dangerous goods and hazardous materials would occur in accordance with supplier's instructions and relevant Australian standards and may include bulk storage tanks, chemical storage cabinets / containers or impervious bunds.	Operation
	OpHR03	Storage, handling and use of dangerous goods and hazardous substances would be in accordance with the *Work Health and Safety Act 2011* and the *Storage and Handling of Dangerous Goods Code of Practice* (WorkCover NSW, 2005).	Operation
	OpHR04	Secure, bunded areas would be provided around storage areas for oils, fuels and other hazardous liquids. Impervious bunds would be of sufficient capacity to contain at least 110 per cent of the volume of the largest stored container.	Operation
	OpHR05	Bunds would be provided around activities such as vehicle refuelling, servicing, maintenance or wash-down, where there is a potential for spills and contamination.	Operation
	OpHR06	Material Safety Data Sheets would be obtained for dangerous goods and hazardous substances stored onsite prior to their arrival.	Operation
Transportation of dangerous goods and hazardous substances	OpHR07	The transport of dangerous goods and hazardous substances would be prohibited through the main alignment tunnels and on and off-ramp tunnels.	Operation
Incident response	OpHR08	An Incident Response Plan would be developed and implemented in the event of an accident or incident.	Operation
	OpHR09	The response to incidents within the motorway would be managed in accordance with the memorandum of understanding between Roads and Maritime and the NSW Police Service, NSW Rural Fire Service, NSW Fire Brigade and other emergency services.	Operation
Electric and magnetic fields	OpHR10	The detailed design of the project substations would ensure that the exposure limits for the general public suggested by the Draft Radiation Standard (*Australian Radiation Protection and Nuclear Safety Agency*, *2006*) would not be exceeded at the boundary of the substation sites.	Detailed Design

Impact	No.	Environmental management measure	Timing
Aviation Measures	OpHR11	The project would be operated in line with Civil Aviation Safety Authority requirements, to the satisfaction of the Secretary of the Commonwealth Department of Infrastructure and Regional Development.	Detailed Design
Aviation Measures - lighting	OpHR12	Aviation hazard lighting, building lighting and surface road lighting would be designed and operated in accordance with the requirements of the Civil Aviation Safety Authority and the *Sydney Airport Master Plan 2033*.	Detailed Design and Operation
Cumulative impacts			
Cumulative impacts	CI01	Consultation would be undertaken with local communities potentially affected by the impacts of multiple projects in addition to the project.	Construction
	CI02	Where relevant, consultation would be undertaken with proponents of other nearby developments to increase the overall awareness of project timeframes and impacts.	Construction

31 Project justification and conclusion

This chapter presents a justification for the project and a conclusion to the environmental impact statement (EIS). The justification is based on the strategic need for the project and in particular, how the project would fulfil the objectives outlined in **Chapter 3** (Strategic context and project need). The justification also takes into consideration the objects of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

Table 31-1 sets out the Secretary's Environmental Assessment Requirements (SEARs), as they relate to the justification of the project, and where these have been addressed in the EIS.

Table 31-1 SEARs – project justification and conclusion

SEAR	Where addressed
An analysis of feasible alternatives to the carrying out of the proposal and proposal justification, including: • an analysis of alternatives/options considered, having regard to the proposal objectives (including an assessment of the environmental costs and benefits of the proposal relative to alternatives and the consequences of not carrying out the proposal), and whether or not the proposal is in the public interest, • justification for the preferred proposal taking into consideration the objects of the *Environmental Planning and Assessment Act 1979*.	An analysis of the alternatives and options considered for the project is presented in **Chapter 4** (Project development and alternatives). Strategic justification for the project, and consideration of relevant strategic planning policies, is provided in **Chapter 3** (Strategic context and project need) and summarised in **Section 31.1**. The way in which the project meets the objects of the EP&A Act is presented in **Section 31.1.3**.

31.1 Project justification

This section considers how the project delivers strategic and project needs, while protecting the environment and the health and amenity of local communities. The project is required to meet the strategic need for a new motorway within the project corridor, as outlined in **Section 31.1.1**, and to achieve the project objectives outlined in **Section 31.1.2**. Justification for the project has been considered within the framework of the objects of the EP&A Act in **Section 31.1.3**.

31.1.1 Summary of strategic need and justification

The New M5 is a key component of the WestConnex program of works. WestConnex is the largest integrated transport project in Australia. Once completed, WestConnex would cut 20 minutes off an average peak hour trip from Kingsgrove Road to the Sydney CBD and bypass 12 sets of traffic lights. It would provide a continuous, free flowing motorway with connections to the city, airport and port.

WestConnex would deliver significant long-term benefits to the economic growth and development of NSW and Australia. This strong economic benefit is supported by the economic analysis conducted for WestConnex, which identified benefits that would outweigh the initial upfront construction cost and ongoing operational costs.

The population of Sydney is set to increase by 1.3 million over the next 20 years, and the city's transport infrastructure needs to improve in order to cater for this growth. Currently, congestion costs the NSW economy an estimated $5.1 billion each year or nearly $1,100 for every person living in Sydney. By 2020 the cost of congestion is expected to rise to $8.8 billion as Sydney's population grows and travel demand increases. WestConnex will be a major driver in meeting these demographic challenges by easing congestion along the M5 East Motorway, connecting communities and creating jobs.

The New M5 would double the capacity of the M5 East Motorway, which is the main passenger, commercial and freight route between Sydney Airport, Port Botany and South West Sydney. The M5 East Motorway currently experiences heavy congestion, slow speeds and unreliable travel times especially in the morning and afternoon peak, and increasingly at other times of the day and on weekends.

Travel times and speeds would improve along the M5 East Motorway following the completion of the New M5. Between 2021 and 2031, average travel times on the M5 East Motorway would generally be halved and average travel speeds would double during the morning and afternoon peak.

If the New M5 is not built, congestion on the existing M5 East Motorway will continue to negatively impact on the NSW economy. Future growth in traffic volumes along the project corridor will worsen congestion problems, leading to further loss of productivity and increased economic impacts in the future.

Further, the M5 Motorway corridor is an important connection for road freight transport. The New M5 would provide additional capacity, improving freight transport efficiencies and reducing transport costs. In particular, the project would support more efficient connections between south-west Sydney and the Sydney CBD, Sydney Airport and Port Botany. Consequently, the project would result in economic benefits for the State.

The heavy congestion in the M5 East Motorway has reduced amenity and traffic safety. This is because congested traffic generates more vehicle emissions than free flowing traffic, and stop-start traffic has a greater crash risk.

If the New M5 is not built, there would be further deterioration of amenity and traffic safety along the M5 Motorway corridor, whereas the New M5 would reduce congestion along the M5 East Motorway. The project would also provide additional route options along the corridor and therefore increase network resilience in the event of incidents, especially in the M5 East Motorway tunnel. Some improvement along parallel arterial roads is forecast, with some increases in volumes along other parallel routes.

Construction of the New M5 would also result in the closure and rehabilitation of the Alexandria Landfill, generating a beneficial end land use for this site. The strategic use of this parcel of land as the St Peters interchange will result in enhanced motorway, cycle path and pedestrian connections for the community.

31.1.2 Achieving project objectives

Project alternatives were considered as part of the design process for the project (refer **Chapter 4** (Project development and alternatives)). The project, as described in **Chapter 5** (Project description), was selected as the preferred option to best achieve the project objectives.

Eight project objectives were developed which:

- Respond to issues that underpin the strategic need for the project **Chapter 3** (Strategic context and project need).
- Are consistent with strategic objectives of State and national planning and policy documents, as discussed in **Section 3.5**.

Table 31-2 provides a summary of how the project would meet these objectives.

Table 31-2 Achieving the project objectives

Project objective	Comment
Support Sydney's long-term economic growth through improved motorway access and connections linking Sydney's international gateways and Western Sydney and places of business across the city.	The New M5 would improve the capacity of the NSW motorway network, particularly within the project corridor, and would support connections to Sydney Airport and Port Botany, assisting with growth in air travel and freight movements. The project would provide improved motorway access and efficiency within the project corridor by: • Improving the existing motorway capacity to reduce congestion and increase efficiency • Adding a motorway connection point immediately west of Sydney Airport, supplementing the existing motorway connection to the M5 East Motorway, east of Sydney Airport • Providing a future motorway connection point for the possible future M4-M5 Link • Safe guarding a potential future Southern extension link.
Relieve road congestion so as to improve the speed, reliability and safety of travel in the M4 and M5 Motorway corridor, including parallel arterial roads.	The project would reduce vehicle numbers and travel time along the M5 East Motorway, which would improve speed, journey reliability and safety in this corridor. The project would also provide additional route options along the corridor and therefore increase network resilience in the event of incidents, especially in the M5 East Motorway tunnel. Some improvement along parallel arterial roads is forecast, with some increases in volumes along other parallel routes.
Cater for the diverse travel demands along these corridors that are best met by road infrastructure.	The key customers who would benefit from the project include: • Highly dispersed and long distance passenger movements • Heavy and light freight and commercial services • Businesses whose travel patterns are highly dispersed and diverse. The transport demands of these customers are best served by an efficient motorway connection. The project would meet this project objective by relieving congestion within the project corridor and facilitating efficient passenger and freight movements through Sydney.
Enhance the productivity of commercial and freight generating land uses strategically located near transport infrastructure.	Commercial and freight generating land uses are located around Sydney Airport and Port Botany, in south-west Sydney and along the project corridor at Kingsgrove and St Peters. By providing a more efficient motorway between commercial and freight hubs, the project would enhance the commercial and freight generating land uses located within the Port Botany precinct, along the project corridor and towards south-west Sydney. The productivity of these land uses may be currently impeded by congestion. By providing additional capacity along the corridor, the project would improve transport efficiency, reducing costs to businesses. The project would also contribute to improved profitability for commercial and freight businesses through reduced transport costs, in terms of money and time lost to congestion and fuel consumption. It may also contribute to the desirability of services that rely on transport along the corridor.

Project objective	Comment
Fit within the financial capacity of the State and Federal Governments, in partnership with the private sector.	The project has been subject to a competitive tendering process and would fit within the financial capacity of the State and Federal Governments. The project would be funded by the NSW and Federal Governments. The government contributions would be supplemented by finance from the private sector, and a user-pays system, which would be introduced when the project opens.
Optimise user pays contributions to support funding in an affordable and equitable way.	The project would consist of a tolled motorway to facilitate user pays contributions and reduce the overall burden on the wider community in NSW. Inclusion of a toll makes construction of the project affordable and equitable, as the cost is shared between tax payers and individual users of the New M5.
Provide for integration with other WestConnex projects while not significantly impacting on the surrounding environment in the interim period.	The project has been designed to allow integration with other WestConnex projects, and would include tunnel stubs for connection with the future Southern extension and an interchange at St Peters for connection to the future M4-M5 Link. Notwithstanding these proposed connections, which would ultimately allow for through traffic, the project includes upgrades to local roads around St Peters interchange in order to avoid shifting congestion problems onto local roads. The project has been designed to minimise the project footprint and maximise the use of land already reserved for road infrastructure. Further, the project would involve the closure and rehabilitation of the Alexandria Landfill, for use as the St Peters interchange. This approach allows for integration with the future M4-M5 Link at St Peters, while realising an end land use for the Alexandria landfill that is beneficial to the wider community.

Project objective	Comment
Protect natural and cultural resources and enhance the environment.	The design of the project avoided or minimised potential environmental impacts. For example, the design has: avoided high value ecological areas such as the Wolli Creek Regional Valley, and minimised impacts to Cooks River Castlereagh Ironbark Forest Critically Endangered Ecological Community and the Green and Golden Bell Frogs key population of the lower Cooks River. Where potential adverse impacts were not able to be completely avoided through design, additional mitigation and management measures have been identified. The measures identified to minimise potential impacts are described in this EIS and summarised in **Chapter 30** (Summary of environmental management measures). The mitigation measures proposed would minimise adverse social and environmental impacts in the local area during construction and operation of the project as far as feasible and reasonable. The project would enhance the environment through: • Allowing for improved efficiency of the road network and predicted travel time savings, resulting in lower vehicle emissions and a long term reduction in greenhouse gas emissions. • The closure and remediation of the Alexandria Landfill, which would improve the environment at this location, resolving impacts of this contaminated land and allowing for a more beneficial end use of this site. • Enhancing cycling and pedestrian infrastructure around the St Peters interchange, improving social welfare by providing greater connectivity for cyclist and pedestrian journeys.

31.1.3 Objects of the Environmental Planning & Assessment Act

The objects of the EP&A Act provide a framework within which the justification of the project has been considered. A summary of this assessment is provided in **Table 31-3**.

Table 31-3 Objects of the EP&A Act

EP&A Act object	Comment
To encourage the proper management, development and conservation of natural and artificial resources, including agricultural land, natural areas, forests, minerals, waters, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment.	The project has been designed to achieve an Infrastructure Sustainability Council of Australia rating of excellent, demonstrating a commitment to conserve natural and artificial resources. Where reasonable and feasible, the project has been designed to avoid impacts on the surrounding natural environment and minimise the need for land acquisition, impacts on existing development and local communities. The improved efficiency of the road network and the predicted travel time savings would result in lower vehicle emissions and a reduction in fuel use in the future. Additionally, the project would result in a long-term reduction in greenhouse gas emissions. By reducing congestion and improving transport efficiency within the project corridor for both people and goods, the project would promote social and economic welfare. The closure and remediation of the Alexandria Landfill would: • Improve the environment at this location, resolving impacts of this contaminated land and allowing for a more beneficial end use of this site. • Reduce the requirement for residential and commercial property acquisition to enable the project. Further, the project would enhance the cycling and pedestrian infrastructure around the St Peters interchange, improving social welfare by providing greater connectivity for cyclist and pedestrian journeys.
To encourage the promotion and coordination of the orderly and economic use and development of land.	The project would relieve congestion along the M5 East Motorway, including an improvement in travel times and improvements in road safety. The improved efficiency of the road network and the predicted travel time savings would result in economic benefits for NSW. By minimising its surface footprint, the project has been designed to reduce impacts to the surrounding natural and built environments, and to minimise disruption to existing development patterns, and the economic value of these land uses. Parts of the Alexandria Landfill site have been subject to local environmental plan provisions which expressly contemplate a future road use. Use of the site for the St Peters Interchange is therefore consistent with the orderly use and development of the land for that purpose. Further, provision of a mostly underground motorway is an orderly and economic approach to delivery of the project in the context of avoiding substantial impacts to existing residential, industrial, and commercial land uses within the project corridor.

EP&A Act object	Comment
To encourage the protection, provision and co-ordination of communication and utility services.	Where practicable, the project has been designed to minimise impacts on communications and utility services. Utility services would be relocated, adjusted or protected where affected by the construction of the project. Communication and utility service providers would be consulted during detailed design and the implementation of relevant works to ensure coordination and delivery of new and / or modified communications and utility infrastructure.
To encourage the provision of land for public purposes	The project would facilitate the provision of land for public purposes through: • Utilising land within road reserves for additional transport infrastructure, allowing public use of the land in a way that enhances connectivity between the Sydney CBD and south-west Sydney • The closure and rehabilitation of the Alexandria Landfill, which would: – Resolve the impacts of this contaminated land – Allow the land to be used for transport infrastructure for use by the public – Create open space for public purposes around the completed St Peters interchange.
To encourage the provision and coordination of community services and facilities.	Provision of a mostly underground motorway would minimise direct impacts on community services and facilities during construction and operation. Further, the project would improve a transport corridor that currently experiences heavy congestion and on which the community relies. The project would also provide improved pedestrian and cycle path connections: • Through and around the St Peters interchange • Between Alexandria and Sydney Park • Between St Peters and Mascot, completing a regional cycle connection. The quality of the shared paths in Kingsgrove would also be improved at the completion of the project construction. Temporary construction compounds have been designed and located to minimise direct impacts to community facilities and services.

EP&A Act object	Comment
To encourage the protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats.	The design of the project, as a mostly underground motorway, has avoided impacts to areas of high ecological value within the Wolli Creek valley. Further, the design of the surface works of the project has minimised impacts to threatened species, populations and ecological communities and their habitats as follows: • The project footprint has been minimised to reduce direct impacts to the Green and Golden Bell Frog key population of the lower Cooks River (at Arncliffe) • The construction footprint has been minimised to reduce direct impacts to Cooks River Castlereagh Ironbark Forest at Beverly Grove • Groundwater modelling confirms that the project will not significantly impact on groundwater dependent ecosystems Potential impacts of the project on terrestrial and aquatic ecology and measures to avoid, mitigate and offset potential impacts on native plants and animals, and their habitats, have been identified and are summarised in **Chapter 21** (Biodiversity).
To encourage ecologically sustainable development.	The project has been designed to achieve an ISCA rating of excellent. Further, sustainability initiatives, described in **Chapter 28** (Sustainability) would be implemented during construction and operation. Ecologically sustainable development has been considered in the development of the project and is discussed in **Chapter 28** (Sustainability).
To encourage the provision and maintenance of affordable housing.	The project would encourage and support the NSW Government's goals for housing and land supply by providing improved access to new housing areas. The M5 Motorway corridor (comprising the M5 East Motorway and the M5 South West Motorway) is a well-established route serving suburbs and growth centres in south west Sydney and supports planned residential and employment growth in the south-west region. The New M5 would double the capacity of this corridor.
To promote the sharing of the responsibility for environmental planning between different levels of government in the State.	Consultation has been undertaken with the relevant local councils and government agencies throughout the development of the project and the preparation of this EIS. All levels of government have been encouraged to be actively involved in and to contribute, to the evolution of the project and this EIS. Further, a referral to the Commonwealth Government under the EPBC Act has been made for the project.
To provide increased opportunity for public involvement and participation in environmental planning and assessment.	The project development process has involved extensive consultation with the community and relevant stakeholders, as detailed in **Chapter 7** (Consultation).

31.2 Conclusion

This EIS addresses the key issues identified in the SEARs issued under Part 5.1 of the EP&A Act and the relevant provisions of Schedule 2 of the EP&A Regulation.

The project is a component of the WestConnex program of works, which is a proposal to provide a 33 kilometre motorway linking Sydney's west and south-west with Sydney Airport and the Port Botany precinct. The project is a key transport infrastructure project, required to improve connections for the growing economic growth areas in Sydney's south-west, address traffic congestion and provide additional capacity along the M5 East Motorway corridor in line with State and national planning strategies.

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

The following alternatives to the project were considered:

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

These options were considered and assessed against the project objectives and resulted in Alternative 5 - Construction of the New M5 as part of the WestConnex program of works being determined as the preferred strategic alternative.

The project is considered to be in the public interest by providing the following key benefits:

- Between 2021 and 2031, average travel times on the M5 East Motorway would generally be halved and average travel speeds would double during the morning and afternoon peak, improving the efficiencies of intrastate and interstate freight movements through travel time saving and reduced operating costs.
- Providing new connections for the residential, commercial and industrial growth in Sydney's south-west, including along the M5 corridor
- Doubling the capacity of the M5 corridor
- Providing a new and improved land use for the Alexandria Landfill site
- Improving pedestrian and cycle path connections:
  - Through and around the St Peters interchange
  - Between Alexandria and Sydney Park
  - Between St Peters and Mascot, completing a regional cycle connection.
- Improving shared facilities in Kingsgrove.

With the completion of the WestConnex program of works, average travel times and speeds would improve further. The project would have an average travel time of between nine and 10 minutes at a speed of 68 kilometres per hour in both directions during the morning and afternoon peak in 2021 and in 2031.

The project has been designed to minimise land acquisition and limit the impact on private properties. Some short-term property access impacts during construction may occur; however, these are not expected to be significant and alternative access would be provided at all times.

There are 30 properties that would be directly impacted by the temporary construction compounds and construction activities. Of these properties:

- Five are already owned by Roads and Maritime
- Four are owned by other NSW Government agencies
- Fifteen are owned by Local Government
- Six are privately owned.

In most cases, land that is occupied for construction compounds and construction activities would be rehabilitated at the end of the construction period and returned for potential development for permissible uses under land use zoning provisions.

There are 143 properties that would be directly impacted by operational infrastructure and would require permanent acquisition. Of these properties:

- Thirty-nine are already owned by Roads and Maritime
- Six are owned by other NSW Government agencies
- Seventeen are owned by Local Government
- Five properties are owned by utility providers
- Seventy-six are privately owned.

All acquisitions would be undertaken consistently with the principles in the *Land Acquisition (Just Terms Compensation) Act 1991* and the *Land Acquisition Information Guide* (Roads and Maritime, 2014b). The extent of property acquisition would be reviewed and confirmed during detailed design of the project.

The construction of the project would also result in short-term air quality and noise impacts. However, these impacts would be minimised through the development and implementation of construction environmental management plans and careful planning of the construction schedule and methodologies.

Impacts to biodiversity features have been minimised as far as reasonable and feasible during design, including minimising impacts to the Wolli Creek Regional Park and the Roads Transport Authority (RTA) Ponds, which are known to provide breeding habitat for the Green and Golden Bell Frog. Although impacts have been minimised, the project would still involve the clearance of about 20 per cent of available foraging, sheltering and dispersal habitat for the Green and Golden Bell Frog Key Population of the Lower Cooks River within the Kogarah Golf Course at Arncliffe. The project would also require the clearance of about 3.31 hectares of native vegetation, including 1.4 hectares of Cooks River Castlereagh Ironbark Forest.

Mitigation and management measures would be implemented during the construction phase to minimise impacts to biodiversity. Where direct impacts to threatened ecological communities and threatened fauna are unavoidable, offsets would be provided. Biodiversity offset calculations identified that 261 credits would be required for impacts to threatened ecological communities and impacts to the Green and Golden Bell Frog (*Litoria aurea*). Opportunities to minimise impacts to biodiversity would be considered further during detailed design of the project.

Operational impacts of the project such as noise and flooding would be further investigated during detailed design to confirm the need for appropriate mitigation measures or, where relevant, design refinements.

WestConnex would result in both positive and adverse cumulative impacts in relation to noise and traffic in particular. One key cumulative benefit of WestConnex would be the improved movement of freight around Sydney. The construction of WestConnex progressively would also result in prolonged impacts on some areas which are located in close proximity to multiple stages. Cumulative impacts from other projects are not considered to be significant.

This EIS includes a suite of management measures that aim to ensure the best possible environmental outcomes are achieved during its construction and operation.

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