17 Groundwater and geology

This chapter outlines the potential groundwater and geology impacts associated with the project. A detailed groundwater assessment has been undertaken for the project and is included in **Appendix K** (Groundwater technical report). A qualitative subsidence assessment is included in this chapter.

Table 17-1 sets out the SEARs relevant to groundwater and geology and identifies where the requirements have been addressed in this EIS.

Table 17-1 SEARs – Groundwater and geology

SEARs	Where addressed in this EIS
Health and safety	
The assessment must: 2 (f) assess the likely risks of the project to public safety, paying particular attention to pedestrian safety, subsidence risks, bushfire risks and the handling and use of dangerous goods	Section 17.3.3 and section 17.4.3
Socio-economic, Land Use and Property	
4. The Proponent must assess potential impacts on the Muddy Creek constructed channel such as damage due to subsidence.	Section 17.4.10
Water - Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users e.g. bore water for domestic use and irrigation, and for ecological purposes and groundwater dependent ecosystems) likely to be impacted by the project, including rivers, streams, wetlands and estuaries as described in Appendix 2 of the Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014).	Section 17.2, Chapter 12 (Biodiversity) and Chapter 18 (Surface water and flooding)
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations (including mapping of these locations), volume, frequency and duration for both the construction and operational phases of the project.	Section 17.3.8, section 17.4.9 and Chapter 18 (Surface water and flooding)
3. The Proponent must assess and model the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	Refer below
(a) natural processes within rivers, wetlands, estuaries, and floodplains that affect the health of the fluvial, riparian, estuarine systems and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity, water dependent fauna and flora and access to habitat for spawning and refuge;	Chapter 12 (Biodiversity) and Chapter 18 (Surface water and flooding)
(b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, change in groundwater levels, barriers to flows, implications for groundwater dependent on surface flows, ecosystems and species, groundwater users and the potential for settlement	Section 17.3 and section 17.4
(c) changes to environmental water availability and flows;	Section 17.3 and section 17.4
(f) measures to mitigate the impacts of the proposal and manage the disposal of produced and incidental water	Chapter 18 (Surface water and flooding)
4. The assessment must provide details of the landform (following completion) of the sites to be excavated or modified (e.g. portals and cut and cover works), including void management and rehabilitation measures.	Section 17.4.7
5. The Proponent must identify any requirements for baseline monitoring of hydrological attributes	Section 17.1.3

SEARs	Where addressed in this EIS
6. The assessment must include details of proposed surface and groundwater monitoring	Section 17.3.5 and section 17.4.8
7. Proposed tunnels must be designed to minimise impacts on aquifers, groundwater flows and groundwater dependent ecosystems	Section 17.2.1, section 17.2.4, section 17.2.8 and section 17.3.3.
Water - Quality	
1. The Proponent must: (a) describe the background conditions for any surface or groundwater resource likely to be affected by the development	Section 17.2.
(j) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality	Section 17.4.8
Soils	
5. The Proponent must assess whether salinity is likely to be an issue and if so, determine the presence, extent and severity of soil salinity within the project area	Section 17.2.4 and section 17.3.4
6. The Proponent must assess the impacts of the project on soil salinity and how it may affect groundwater resources, hydrology and vegetation	Section 17.3.3 and section 17.4.3
8. The Proponent must assess the impact of any disturbance of contaminated groundwater and the tunnels should be carefully designed so as to not exacerbate mobilisation of contaminated groundwater and/or prevent contaminated groundwater flow	Section 17.2.5, section 17.3.4 and section 17.4.4

17.1 Assessment approach

A groundwater assessment has been undertaken to address the relevant SEARs outlined in **Table 17-1**. The groundwater assessment has been reviewed by an independent technical peer reviewer in accordance with the *Australian Groundwater Modelling Guidelines*[1]. The assessment describes the existing groundwater environment and determines the potential impacts of the construction and operational of the project on groundwater flows, groundwater levels and water quality. A summary of the groundwater assessment for the project is provided in this chapter. The full assessment is included in **Appendix K** (Groundwater technical report) and 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 tunnels on groundwater dependant ecosystems (GDEs) and surrounding environment using numerical modelling techniques to quantify impacts
- Groundwater management and monitoring measures required to manage potential impacts on the groundwater regime.

The assessment has been undertaken with consideration of relevant legislation, policies, guidelines and water sharing plans listed below and in **Table 17-2**.

[1] Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A (2012); Australian Groundwater Modelling Guidelines, Waterlines Report Series No 82, National Water Commission, Canberra, 191 pp. June.

Table 17-2 Overview of relevant groundwater legislation and policy

Legislation or policy	Relevance
Water Management Act 2000 (NSW) (WM Act)	• Section 5.23(1)(g) of the EP&A Act provides for the exemption of state significant infrastructure projects from requiring a water use approval, a water management approval or an activity approval (other than an aquifer interference approval) • Provides for the administration of water sharing plans • It should be noted that aquifer interference activity approval provisions have not yet commenced, but are administered under the WM Act.
Water Act 1912 (NSW)	• Provides for the administration of water access licenses and the trade of water licences and allocations.
NSW Aquifer Interference Policy	• Manages the impacts of aquifer interference activities in accordance with the WM Act and water sharing plans • The policy prescribes that aquifer interference activities must address minimal impact considerations • The policy prescribes that in the event that actual impacts are greater than predicted there should be sufficient monitoring in place.
Water Sharing Plan, Greater Metropolitan Region, Groundwater Sources	• Water sharing plans manage the long term surface and groundwater resources of a defined area • The Water Sharing Plan, Greater Metropolitan Region, Groundwater Sources outlines rules for the sharing and sustainability of water between various uses such as town water supply, stock and domestic, industry and irrigation.

The compliance of the project with the legislation and guidelines outlined in **Table 17-2** is demonstrated in detail in **Appendix K** (Groundwater technical report).

This report has been prepared with reference to the following documents:

- *NSW State Groundwater Policy Framework Document* (NSW Department of Land and Water Conservation (DLWC) 1998)
- *NSW Groundwater Quality Protection Policy* (DLWC 1998)
- *NSW Groundwater Dependent Ecosystems Policy* (DLWC 2002)
- *NSW Groundwater Quantity Management Policy* (DLWC undated)
- *Risk assessment guidelines for groundwater dependent ecosystems* (NSW Office of Water (NoW) 2013a)
- Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) *National Water Quality Management Strategy Australian Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000)
- *NSW Water Extraction Monitoring Policy* (NSW Department of Water and Energy (DWE) 2007)
- *NSW Aquifer Interference Policy* (NoW 2012)
- *Guidelines for riparian corridors on waterfront land* (DPI 2012)
- *Acid Sulfate Soils Assessment Guidelines* (NSW Department of Planning (DoP) 2008)
- *Acid Sulfate Soils Manual* (Acid Sulfate Soils Management Advisory Committee 1998)
- *Framework for Biodiversity Assessment – Appendix 2* (NSW Office of Environment and Heritage (OEH) 2014)

- Managing Urban Stormwater: Soils and Construction Volume 1 (Landcom 2004) and Volume 2 (NSW Department of Environment, Climate Change (DECC) 2008)
- *NSW Sustainable Design Guidelines Version 4.0* (Transport for NSW 2017)
- *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (NoW 2012)
- *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (NSW Department of Environment and Conservation (DEC) 2006)
- *Approved Methods for sampling and Analysis of Water Pollutants in NSW* (DECC 2008)
- *Overview of the Australian Guidelines for Water Recycling: Managing Health and the Environmental Risks. National Resource Management Ministerial Council Environmental Protection and Heritage Council* (Australian Health Ministers Conference, 2006).

A qualitative assessment of the potential for the project to create ground movements and settlement was also undertaken.

17.1.1 Study area

A three-dimensional numerical groundwater model was developed to predict future groundwater conditions and potential impacts related to the project (refer to **section 17.1.5**).

For the purposes of the groundwater impact assessment, the study area is the domain considered by the groundwater model. The model domain (study area) includes the operational infrastructure of the project, extending outwards into areas where potential groundwater impacts could occur as a result of construction or operation of the project. The study area is shown in **Figure 17-1** and covers an area of around 90 square kilometre area bounded by:

- Botany Bay, Botany, Eastlakes, Roseberry and Zetland to the east
- Ashbury, Dulwich Hill, Enmore and Erskineville to the north
- Hurlstone Park, Earlwood, Bardwell Park, Bexley, Carlton, Carss Park and Blakehurst to the west and
- Sans Souci to the south.

The study area partially includes the M4 East, the New M5 Motorway and the M4 M5 Link motorways to predict cumulative drawdown impacts.

For the purposes of assessing the potential for ground movements, the area of potential impact was identified by adopting an angle of draw of 15 degrees from the depth of the tunnel. This is the zone of expected ground movements relating to the project, although the range of movement is related to the tunnel depth at each location.

17.1.2 Desktop study

The following database searches were conducted to summarise the existing environment:

- *Australian Soils Resource Information System acid sulfate soils*, accessed December 2017
- Bureau of Meteorology *Australian Groundwater Explorer*, (formerly DPI-Water groundwater database) accessed December 2017
- *Greater Metropolitan Regional Groundwater Sources Water Sharing Plan*, Appendix 4
- Bureau of Meteorology Atlas of Groundwater Dependent Ecosystems, accessed January 2018
- Bureau of Meteorology online climate data, accessed January 2018
- NSW Environment Protection Authority (NSW EPA) Contaminated Land Record, accessed January 2018.

17.1.3 Field investigation

Groundwater field investigations, including drilling boreholes, monitoring well installation, water pressure testing, groundwater gauging, groundwater sampling and hydrogeochemical analysis, were undertaken across the study area as part of the F6 Extension geotechnical drilling program initially between October 2014 and March 2015 and later between July 2016 and February 2018. Groundwater monitoring has been undertaken at 20 monitoring well locations which are shown in **Figure 17-2** and this monitoring is ongoing.

Groundwater data collected included:

- Hydraulic conductivity (i.e. the rate at which groundwater naturally moves through the rock or sediments)
- Groundwater levels (including fluctuations), determined through groundwater gauging (i.e. monitoring levels in groundwater wells) and data loggers
- Groundwater quality, determined through hydrogeochemical sampling and analysis.

Hydraulic conductivity

Hydraulic conductivity assists in the understanding of tunnel water inflows or the local drawdown (i.e. the reduction in the water level) 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).

Packer tests (or water pressure tests) were conducted to measure the hydraulic conductivity of selected rock mass intervals. Packer tests involve injecting water under pressure into a 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. Site specific hydraulic conductivity tests by slug testing was conducted by SMEC, 2018 (refer to section 4 of **Appendix K** (Groundwater technical report) for further information).

Groundwater levels

Groundwater gauging was conducted throughout the field programs, measuring standing water levels manually with an electronic dipper. The data loggers were then installed to measure groundwater level fluctuations automatically at one hourly intervals. The loggers were suspended in each monitoring well at a depth of about five metres below the standing water level.

Groundwater quality

Groundwater samples were collected from the monitoring well network for laboratory analysis. Groundwater was sampled and analysed to characterise the local groundwater quality of each of the main hydrogeological units; specifically to identify any spatial and temporal variability, and to identify potential groundwater contamination.

Groundwater quality samples were tested for the following components:

- Heavy metals and metalloids (including arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel and zinc)
- Nutrients (nitrate, nitrite, ammonia and reactive phosphorous)
- Benzene, toluene, ethylbenzene, xylene and naphthalene (BTEXN)
- Total recoverable hydrocarbons (TRHs)
- Polycyclic aromatic hydrocarbons (PAHs)
- Inorganics and field parameters (including major anions and cations, alkalinity, ammonia, temperature, 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)

- Polyfluoroalkyl Substances (PFAS) (tested at one location in the alluvium).

Groundwater aggressivity was also assessed, to gauge the extent to which the natural groundwater may corrode or degrade materials such as steel and concrete, which may be used in the construction of tunnel infrastructure.

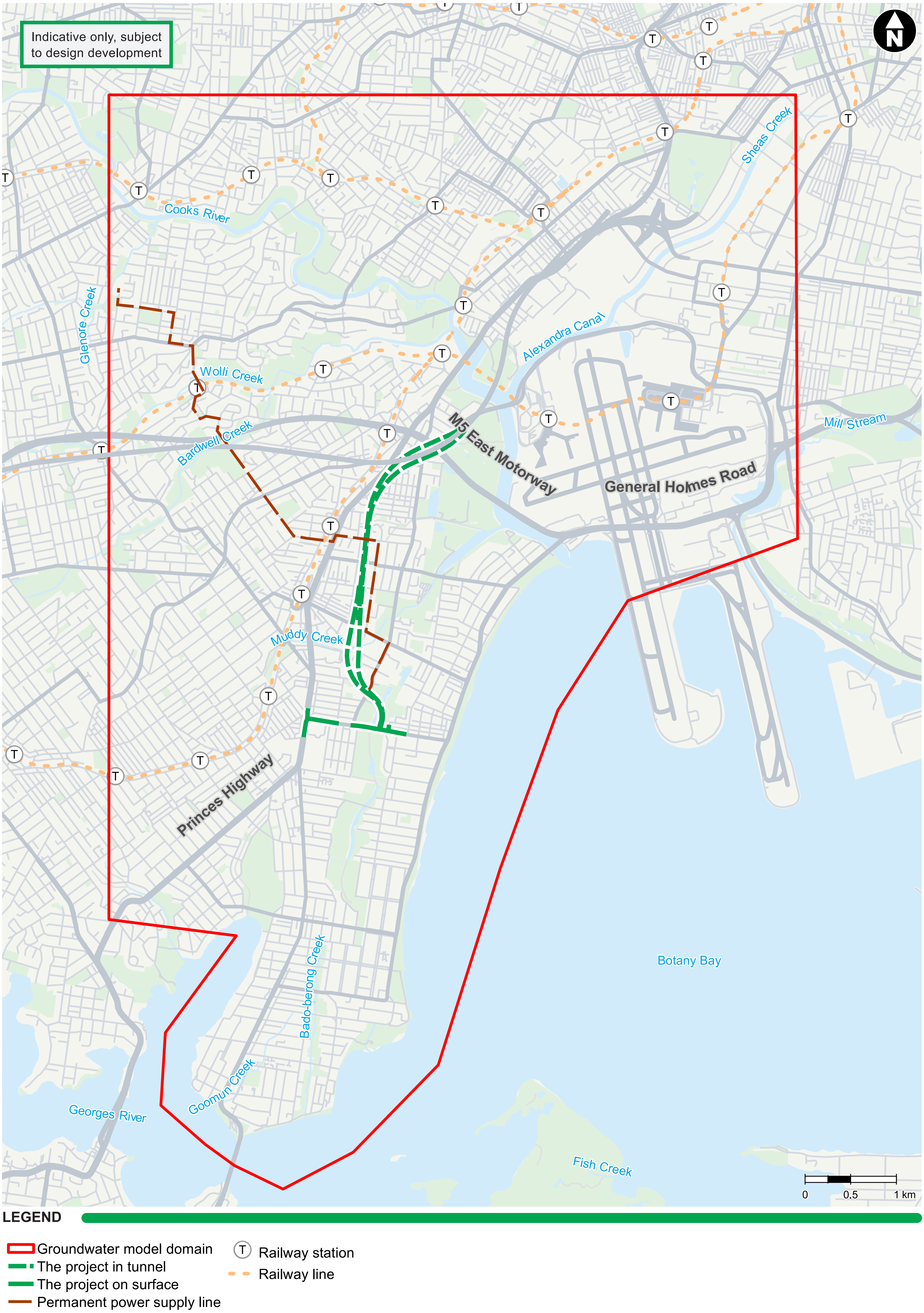


Figure 17-1 Groundwater assessment study area

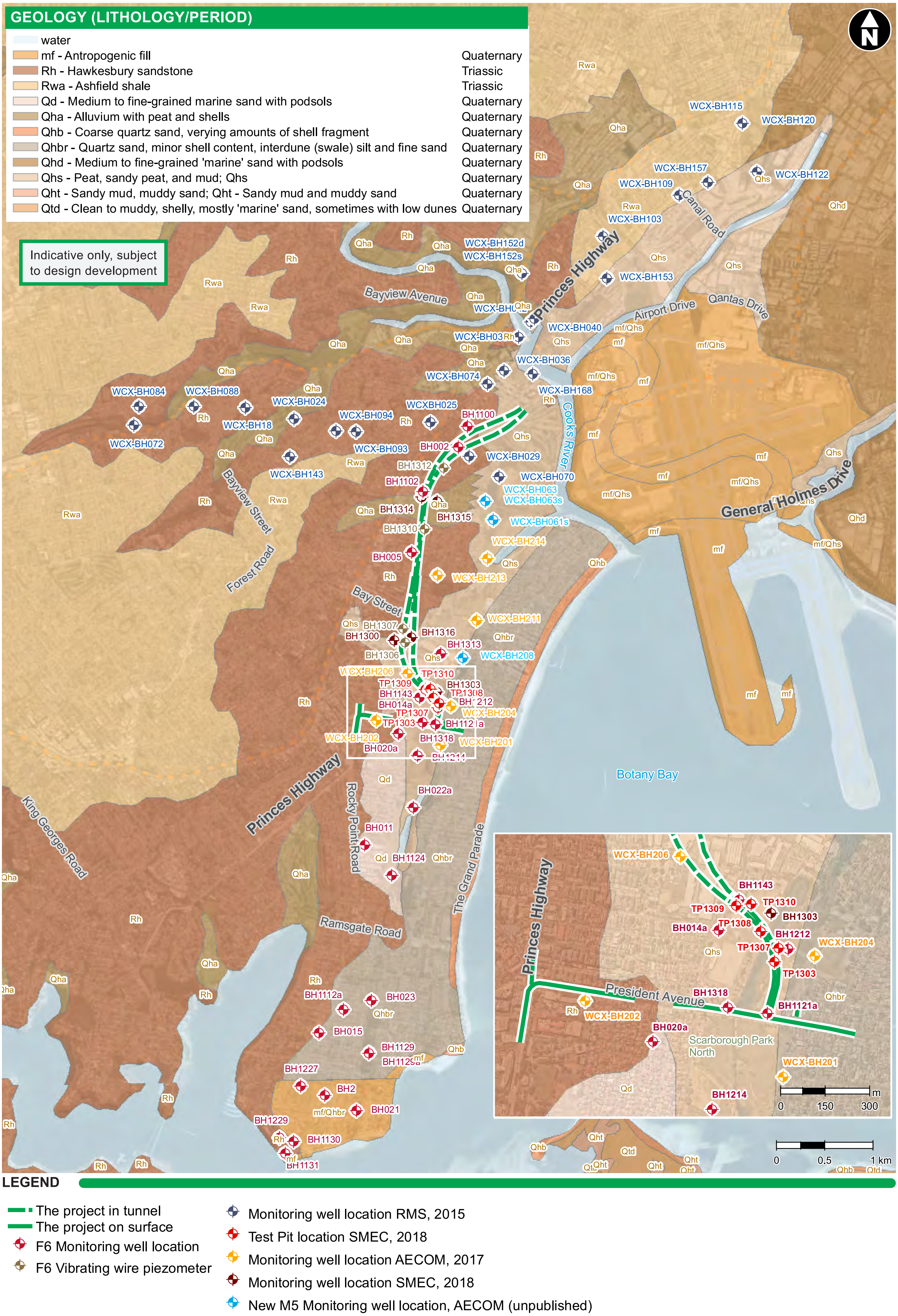


Figure 17-2 Groundwater monitoring locations

17.1.4 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. Priority GDEs are ecosystems with a high ecological value which are considered high priority for management action as defined in the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources* (2011). Sources reviewed to understand potential GDEs that may be affected by the project include:

- *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*. Schedule 4 of the Plan identifies high priority GDEs and Appendix 2 identifies GDEs
- Atlas of Groundwater Dependent Ecosystems
- The Biodiversity Assessment Report for the project as contained in **Appendix H** (Biodiversity development assessment report).

17.1.5 Groundwater modelling

A three-dimensional numerical groundwater model was developed in accordance with the Australian Groundwater Modelling Guidelines[2] to simulate existing groundwater conditions, project infrastructure, caverns and associated subsurface ancillary infrastructure including ventilation shafts. The active model domain extends over a 7.5 x 12 kilometre area centred on the project alignment as shown in **Figure 17-1**. The model domain partially includes the New M5 Motorway and the M4-M5 Link motorways to predict cumulative drawdown impacts. The model also allows for future stages of the F6 Extension (subject to separate assessment and planning approval).

The groundwater model was used to predict future groundwater conditions and potential impacts related to the project during the construction and operational phases. Both steady state (where the magnitude and direction of flow is constant across the whole model domain) and transient (where the magnitude and direction of flow is changing across the model domain) models were developed and calibrated.

Three predictive model scenarios were run to replicate the construction and long term operational groundwater impacts of the project as follows:

- Scenario 1: A 'Null' run (as per Barnett *et al* 2012), which does not include current approved WestConnex tunnel projects (M4 East, New M5 Motorway and M4-M5 Link) projects but does include the existing drained M5 tunnels
- Scenario 2: Scenario 1 plus the current approved WestConnex tunnel projects (M4 East, New M5 Motorway and M4-M5 Link)
- Scenario 3: Scenario 2 plus the project.

Impacts associated with Scenario 3 minus the impacts associated with Scenario 2 represent project specific impacts.

The groundwater model was prepared by RPS Group Australia[3]. Further information regarding the groundwater model is provided in section 3.3.3 of **Appendix K** (Groundwater technical report) and a description of the models design, parameters, grid, hydraulic boundaries and assumptions, is provided in Annexure G of **Appendix K** (Groundwater technical report).

17.1.6 Cumulative impact assessment

Cumulative impacts are determined by considering project specific impacts combining with other impacts to affect the same resources or receptors in a way where the sum of the impacts is greater than the individual. Cumulative groundwater impacts can be related to groundwater extraction (active and passive), groundwater drawdown, and groundwater quality.

---

[2] Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A (2012); Australian Groundwater Modelling Guidelines, Waterlines Report Series No 82, National Water Commission, Canberra, 191 pp. June.

[3] RPS (2018); F6 Extension. Groundwater Model report. RPS Group Australia. Report Number HS2017/01. Prepared for AECOM, June.

A cumulative impact assessment has been conducted as part of the groundwater modelling on the local hydrogeological regime taking into account other relevant infrastructure including the New M5 Motorway, M4 East tunnels, M4-M5 Link and the existing M5 East tunnels. The proposed future Sydney Gateway project has not been included in the groundwater cumulative impact assessment, as the updated road infrastructure is to be constructed along the ground surface and is unlikely to substantially impact groundwater.

The groundwater model has been used to quantify cumulative impacts of nearby tunnelling projects on the hydrogeological regime. Impacts associated with groundwater model Scenario 3 (see above) represent cumulative impacts.

17.1.7 Ground movement assessment

Background

Ground movement is an expected outcome of tunnelling projects. The ground movement anticipated is predominantly settlement (also termed subsidence). Upward ground movement (also termed heave) may also occur.

The causes of ground movement due to tunnelling can be classified as:

- Consolidation of the soil profile - due to water inflow in to the tunnel resulting in groundwater drawdown in the overlying soil profile. This results in an increase in stress in the soil matrix as water is lost from the soil pores (settlement only)
- Tunnel induced movement - due to the change in stresses in the surrounding rock mass and ground loss caused by the tunnel excavation (settlement or upward heave).

Consolidation is significant only where water seepage into the tunnel results in the drainage of a thick layer of compressible water saturated soils. Along the F6 Stage 1 alignment, these conditions are only encountered where the alignment crosses several palaeochannels that are infilled with compressible water saturated soil.

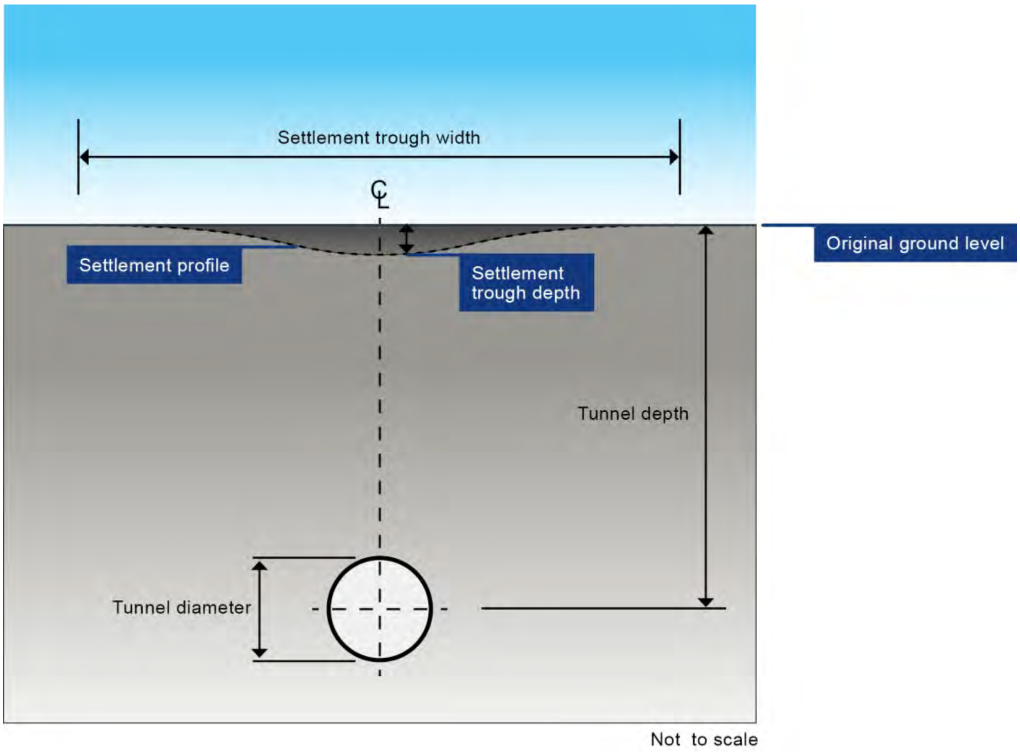
Tunnel induced movement is anticipated to be the prevalent mechanism causing ground settlement, given the tunnel profile is primarily located within competent bedrock overlain by thin residual soils that are not compressible or continually water saturated.

Both vertical and lateral ground movement would be associated with a settlement trough. The ground settlement profile generated is typically concave in shape and termed a settlement trough as shown in **Figure 17-3**. Damage to structures and services damage associated with settlement can occur where the structure or service is subjected to tensile strains. Tensile strain can depend on where the structure or service is located with respect to the settlement curve and the shape of the curve itself.

When the tunnel is sufficiently deep or the ground is sufficiently stiff, the surface movements can be negligible. It is also possible that upward movement (heave) can be induced by the release of high in-situ stresses in the rock mass. In the Sydney Basin substantial horizontal in situ stresses are present at shallow depths, exceeding the vertical stress due to gravity (Chesnut, 1983 and Enever et al., 1984). This can cause the sides of a tunnel excavation to move inwards (converge), bringing the tunnel walls together and causing the crown to move upwards.

The shape, width and magnitude of the tunnel excavation induced settlement trough is dependent on a number of factors including:

- The depth and size (span) of the tunnel
- The distance between tunnels where multiple tunnels are proposed
- The geotechnical conditions, particularly the stiffness of the rock mass
- The excavation methodology, sequence and allowable advance before the installation of tunnel support
- The tunnel support design and actual performance
- The permeability of the soil and rock and the degree of hydraulic connection between the various soil and rock strata.



Note - CL refers to centre line

Figure 17-3 Typical settlement profile[4]

Relevant criteria

Settlement criteria have been specified in the conditions of approval for recent tunnelling projects in Sydney including the WestConnex M4 East and New M5 projects and the NorthConnex project. These criteria are summarised in **Table 14-3** and it is expected that they would be adopted for this project. The additional criterion of tensile strain is included, which addresses the cause of potential building damage.

Settlement criteria for individual utilities and infrastructure would be determined in consultation with the relevant authorities prior to the commencement of any construction potentially affecting the individual utilities or infrastructure.

Further investigations to support the detailed design of the project would confirm predicted ground movements.

Table 17-3 Settlement criteria

Beneath structure/facility	Maximum settlement (mm)	Maximum angular distortion (probability)	Limiting tensile strain (per cent)
Buildings – Low or non-sensitive properties (i.e. less than or equal to two levels and carparks)	30	1 in 350	0.1
Buildings – High or sensitive properties (i.e. greater than or equal to 3 levels and carparks)	20	1 in 500	0.1
Roads and parking areas	40	1 in 250	N/A
Parks	50	1 in 250	N/A

[4] C. Jeremy Hung, PE, James Monsees, PhD, PE, Nasri Munfah, PE, and John Wisniewski, PE (2009)Technical Manual for Design and Construction of Road Tunnels – Civil Elements

17.2 Existing Environment

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

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

17.2.1 Existing and proposed infrastructure

Existing infrastructure

The project alignment, including the permanent power supply corridor, transects an urban environment that consists of established industrial, commercial, recreational and residential areas. In some areas, there is major existing or proposed infrastructure that has deep foundations that may influence the project or the local hydrogeological regime. Major existing infrastructure is listed below:

- Kogarah Golf Course and reserves
- Bardwell Valley Golf Club
- Surface roads such as the M5 East Motorway and the Princes Highway
- Sydney Airport
- Industrial and commercial areas around Bay Street and President Avenue at Kogarah
- Existing tunnels including
  - The M5 East Motorway tunnels which are a pair of undrained (tanked) twin road tunnels around five kilometres in length located in Arncliffe

The Airport Link rail tunnel which consists of around 10 kilometres of undrained (tanked) tunnel. The tunnel extends from Green Square Station in the north, and passes beneath the domestic and international terminals at Sydney Airport, beneath the Cooks River and eventually joining the above ground rail system near Wolli Creek Station.

Proposed project infrastructure

The mainline tunnels for the project have been designed to minimise the intersection of highly permeable material (e.g. alluvium or deeply weathered sandstone) that could result in high groundwater inflows into the tunnels. The tunnel alignment avoids the underlying palaeochannels and unsuitable geology that lies to the east of the project alignment.

The project tunnels would operate predominately as drained (i.e. not tanked) tunnels. Drained tunnels are typically constructed in structurally competent rock such as the Hawkesbury Sandstone with some waterproofing to reduce groundwater inflows along particular tunnel sections. Allowing groundwater flow into the tunnel reduces an external hydrostatic pressure (pressure exerted by water due to the force of gravity) building up behind tunnel lining (which would be included in an undrained scenario), placing less stress on the underground infrastructure.

Where the tunnels intersect alluvium, or deeply weathered sandstone, groundwater inflows are likely to exceed the project design criterion of one litre per second per kilometre of tunnel and cause excessive drawdown within the alluvium or sandstone. To restrict groundwater inflow into the project tunnels, driven tunnel and cut-and-cover sections located within alluvium and deeply weathered sandstone would be constructed with an impermeable lining. The undrained (tanked), sections of the tunnels would be constructed with a full perimeter waterproofing membrane to prevent groundwater flow into the tunnels.

Where cut and cover structures pass through alluvium, such as for the entry and exit ramp tunnels that would pass through alluvium beneath Rockdale Bicentennial Park, they would be constructed with impermeable diaphragm walls. Diaphragm walls are constructed by excavating a trench to bedrock and filling the trench with a cement slurry and reinforcing to form a barrier wall.

Throughout the operational phase of the project, groundwater and surface water entering the tunnels would be captured and treated separately. The primary features of the drainage design for the collection of groundwater during operation of the tunnels include:

- Provision for the collection of sub-surface water seepage
- Collection of water from ventilation shafts and tunnels
- Allowance for cleaning and maintenance of the drainage system.

The operational tunnel design would incorporate a permanent drainage system and sumps at low points to capture groundwater ingress. Groundwater is to be treated at the water treatment plant at the Arncliffe Motorway Operations Complex (MOC1).

Other proposed and approved infrastructure projects

A number of other proposed and approved infrastructure projects in the vicinity of the project have the potential to cause cumulative impacts on the local environment, including:

- New M5 Motorway, which would consist of about nine kilometres of twin motorway drained tunnels between the existing M5 East Motorway (between King Georges Road and Bexley Road) and St Peters
- M4 East, which would extend from the widened M4 Motorway at Homebush to Haberfield consisting of 5.5 kilometres of three lane twin drained tunnel
- M4-M5 Link, which would extend from the M4 East at Haberfield to the New M5 Motorway at St Peters with about eight kilometres of twin motorway tunnels consisting of drained and tanked sections of tunnel
- Proposed future Sydney Gateway, which consists of new road infrastructure linking the New M5 Motorway at St Peters interchange with Sydney Airport and the Port Botany precincts. Sydney Gateway is subject to a separate environmental impact assessment and approval process
- Sydney Metro a rail alignment linking the north-west region to the Sydney CBD and further south to Bankstown. The Chatswood to Sydenham portion of the project was approved in early January 2017. The alignment would consist of 15.5 kilometres twin railway tunnels extending from Chatswood, beneath Sydney Harbour to Sydenham.

17.2.2 Topography and drainage

The project is located within the Cooks River catchment, which covers an area of about 10,200 hectares. Wolli Creek is a major waterway located to the immediate north of the project. Wolli Creek is tidal in its lower reaches and is a tributary of the Cooks River. The main surface water features in the vicinity of the project are the Cooks River and its tributaries; the Marsh Street, Eve Street Wetlands and Landing Lights Wetland at Arncliffe; and Kings Wetland and Rockdale Wetlands at Kogarah. The Towra Point Wetlands, which are Ramsar listed, are located outside of the study area, around seven kilometres to the south east.

The project extends across low lying and elevated areas from the New M5 Motorway at Arncliffe to President Avenue, Kogarah.

Wolli Creek and its southern tributary, Bardwell Creek have incised gullies through a subterranean (under the surface) sandstone (Hawkesbury Sandstone) plateau, which is higher in elevation than in other parts of the Sydney basin. Wolli Creek flows to the east to join the Cooks River which is to the north of the project. 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 flat alluvial plains.

Elevated ground (considered to be about relative level (RL) +10 metres Australian Height Datum (AHD) to RL+30 metres AHD) is generally underlain by shallow Hawkesbury Sandstone. Low areas (about RL+3 metres AHD to RL+10 metres AHD) generally cross Quaternary Alluvium. The geological setting of the project is described further in **section 17.2.3**.

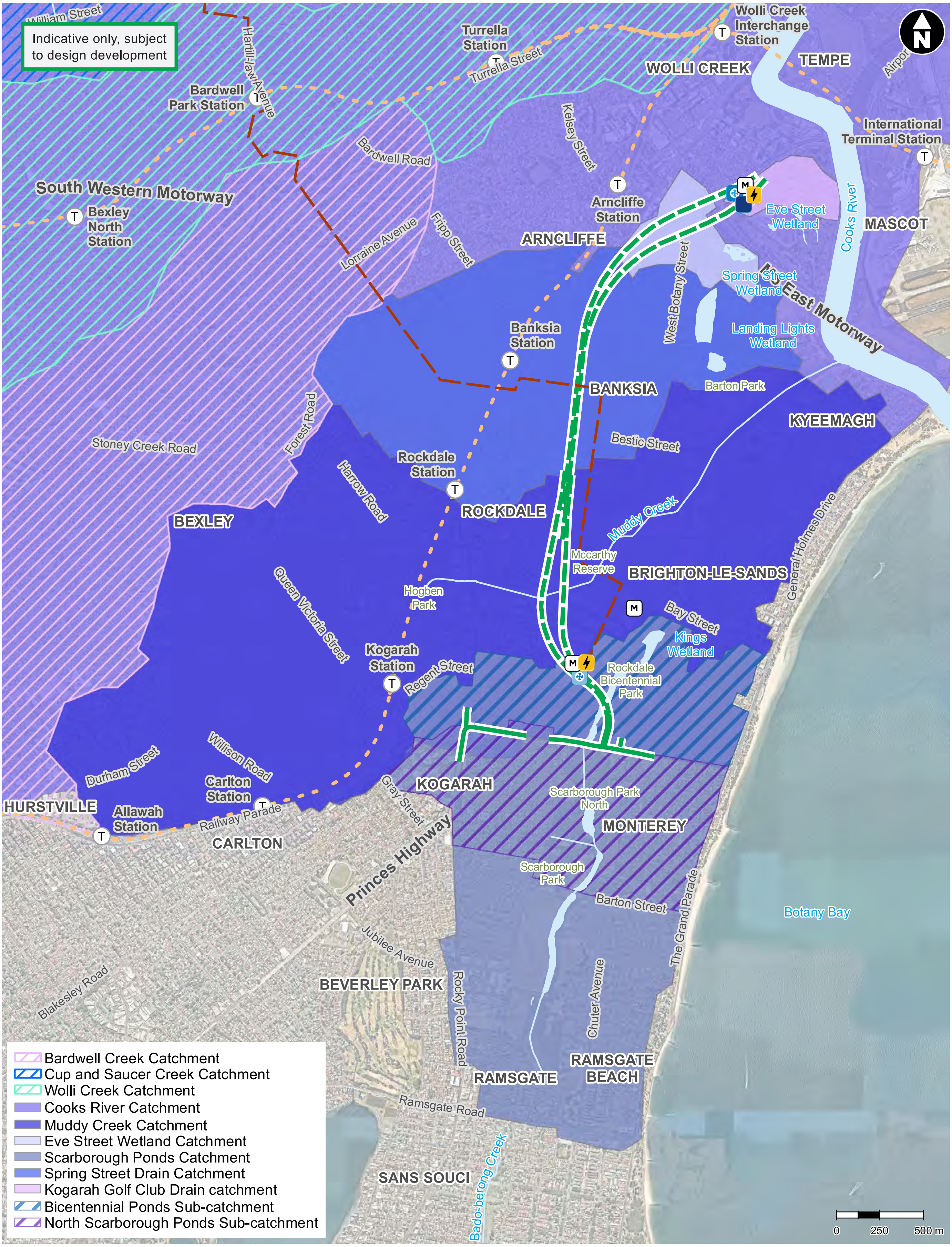
Low lying areas are located:

- At the intersection of the project with New M5 Motorway at Arncliffe
- South of Rockdale

Elevated areas are located from:

- Wickham Street to Spring Street at Arncliffe
- Tabrett Street, Banksia to around Bay Street, Brighton-Le-Sands.

Catchments and watercourses within the study area are shown in **Figure 17-4**.



LEGEND

- The project in tunnel
- The project on surface
- Permanent power supply line
- Substation
- Water treatment facility
- Rockdale ventilation facility
- Motorway operations complex
- Arncliffe ventilation facility*
- * Under construction as part of the New M5 Motorway project
- Waterway
- Waterbody
- Railway line
- Railway station

Figure 17-4 Catchments and watercourses in the study area

17.2.3 Geological setting

Regionally, the study area is located within the Permo-Triassic Sydney Basin that is mainly characterised by sandstone and areas of alternating layers of sandstone and shale. The project is underlain primarily by the Hawkesbury Sandstone and some complex quaternary sediments. The main stratigraphic units that have been encountered within the study area, from youngest to oldest, are:

- Anthropogenic fill
- Quaternary alluvium (generally beneath rivers, palaeochannels and Botany Sands)
- Jurassic intrusions (e.g. dykes, which are younger vertical rock layers between older layers of rock)
- Triassic Hawkesbury Sandstone Formation.

Areas of higher elevation and westerly sections along the tunnel alignment consist of Triassic aged Hawkesbury Sandstone. The Hawkesbury Sandstone is the dominant lithology across the project and is present beneath the entire length of the project alignment and at depth where the Cooks River palaeochannel is incised. The formation extends across the whole Sydney Basin and is up to 290 metres thick.

The low elevation areas along the tunnel alignment consist of Quaternary alluvium with areas of former swamps consisting of man-made fill. The man-made fill often contains dredged estuarine sand and mud, demolition rubble and industrial and domestic waste.

The alluvium extends further west in the location of a drainage line that runs east to Muddy Creek from the western side of Banksia and also west of Rockdale Industrial area along Muddy Creek, where it extends west of the Princes Highway in Kogarah. The alluvium usually consists of a mixture of peat, sandy peat, and mud; coarse quartz sand with varying amounts of shell fragments; and medium to fine grained marine sand with podsols.

The geology of the study area is shown in **Figure 17-5**. Further detail on the stratigraphic units is provided in **Appendix K** (Groundwater technical report).

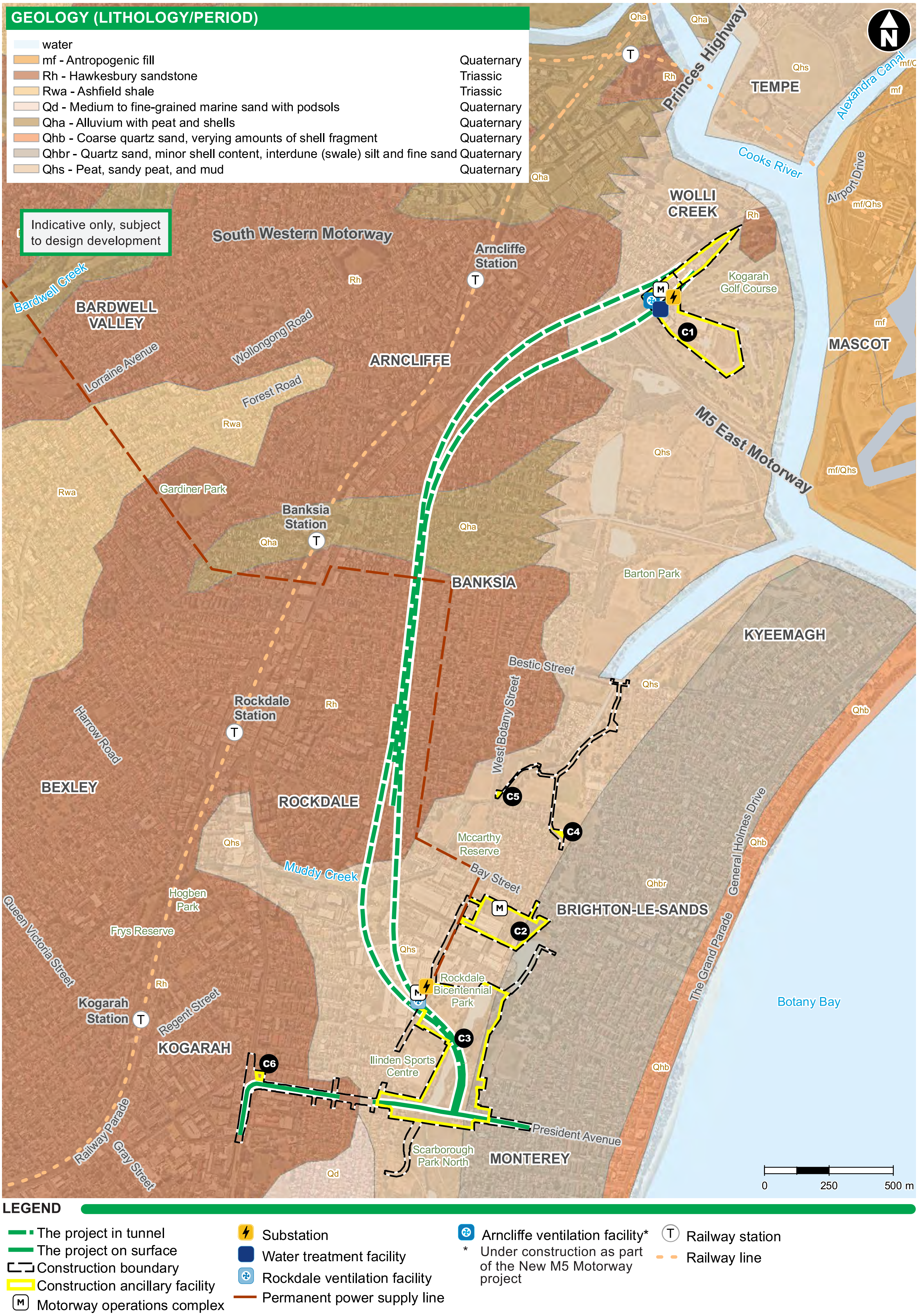


Figure 17-5 Project geological setting

17.2.4 Hydrogeological setting

Across the study area, the groundwater levels are typically deeper beneath hills and shallowest beneath creeks and gullies. Groundwater within the vicinity of the project is recharged by rainfall runoff and infiltration. Perched groundwater (i.e. groundwater at a level above the regional water table) may be encountered within fill and natural soils in more elevated areas. In lower lying areas tidal influences are typically experienced within close proximity to the foreshore. Seasonal variations in groundwater levels can be expected in response to natural climatic variation.

Groundwater within the vicinity of the project is present in the following hydrogeological units:

- Quaternary alluvium around the edges of Muddy Creek, Cooks River and the Rockdale Wetlands
- Botany Sands Aquifer
- Hawkesbury Sandstone
- Geological structural features (such as dykes, fault zones and palaeochannels).

The hydrogeological characteristics of the hydrogeological units outlined above are described in detail in the sections below.

The hydrogeological setting of the project has also been characterised by:

- The development of hydrogeological cross-sections extending from St Peters to Sans Souci and Botany Bay to the south
- A review of groundwater inflow in existing Sydney tunnels within Hawkesbury Sandstone.

The hydrogeological cross sections and review of groundwater inflow in existing Sydney tunnels are provided in the sections below.

Quaternary alluvium

Modern alluvium outcrops around the flanks of Cooks River and Muddy Creek form an unconfined aquifer which is generally of high permeability. Groundwater flow within the shallow alluvium associated with the Rockdale Wetlands is to the south, discharging into the Georges River. Typical hydraulic conductivity values are between 0.01 and 1 metre per day. Groundwater within the alluvium can be a source of either recharge or discharge to the Cooks River and Muddy Creek depending on whether upward or downward hydraulic gradients are present. Recharge to the alluvium is via direct rainfall recharge and runoff or surface water inflow. Groundwater baseflow (the groundwater that discharges to a creek or river) is restricted where the natural system has been modified and the creeks concrete lined.

The palaeochannels (ancient river systems eroded deeply into the landscape and subsequently infilled with saturated alluvial sediments) of the Cooks River and Georges River and the palaeochannel under what is now Towra Point, extend to depths of up to 25 metres and are saturated with groundwater.[5] In contrast to the surficial alluvium groundwater flow within the deeper palaeochannels is eastward discharging into Botany Bay. Groundwater quality within the palaeochannels is expected to be saline due to leakage from tidally flushed rivers and tributaries. The alluvium infilling the palaeochannels is highly transmissive (i.e. groundwater can easily flow through the alluvium) given the coarse sands and gravels present and a low clay content in this area.

[5] Albani, A.D., Rickwood, P.C.,Quilty, P.G. and Tayton J.W.; (2015); The morphology and late Quaternary paleogeomorphology of the continental shelf off Sydney NSW, Australian Journal of Earth Sciences, 62 681-694, 2015.

Botany Sands aquifer

Groundwater is present within the Botany Sands as a shallow unconfined aquifer (where water is able to seep from the ground surface directly to the aquifer because no impermeable layer is present). Groundwater levels are variable but are typically within five metres of the ground surface when not influenced by localised pumping. Regional groundwater flow is eastward discharging into Botany Bay. The Botany Sands aquifer naturally contains moderately low salinity groundwater (generally less than 2000 milligrams per litre) and is moderately acidic but is vulnerable to contamination because of the unconfined nature of the aquifer and the urban environment. This vulnerability is evident to the north where the aquifer near the Botany Industrial Park has been embargoed for groundwater use due to contamination.

Recharge to the Botany Sands aquifer is via direct rainfall, locally enhanced by rainfall runoff and by rainfall infiltration in green spaces such as parks, gardens and golf courses. Groundwater recharge has typically decreased with increased urbanisation due to enhanced runoff from hardstand areas directing stormwater directly into Botany Bay. Groundwater discharge is via localised pumping or natural discharge to Botany Bay.

Groundwater from the Botany Sands aquifer has historically been used beneficially for a number of purposes including irrigation, watering market gardens and domestic use. Groundwater is typically extracted from shallow areas via vacuum extraction systems at groundwater yields typically up to two litres per second. The NSW Department of Primary Industries – Water (DPI – Water) advises that the whole Botany Sands hydrogeological unit is over allocated and to extract groundwater, a water allocation license must be bought on the open market.

The project alignment intersects the Botany Sands to the south near President Avenue, Kogarah, however in this area the tunnels for the project would be constructed as undrained (tanked) or as cut and cover structures with secant pile walls constructed to bedrock to prevent groundwater ingress. While the tunnels are designed to not receive any direct inflow from the Botany Sands, groundwater from the Botany Sands may be hydraulically linked with the drained tunnels. The residual alluvial clay that separates the sands from the underlying bedrock forms a hydraulic seal that would reduce vertical leakage restricting groundwater drawdown due to the project.

Hawkesbury Sandstone

The tunnel alignment is designed to allow the majority of the tunnels to be excavated from within Hawkesbury Sandstone as the engineering properties of the sandstone are suited to tunnelling. The Hawkesbury Sandstone is characterised as a 'dual porosity aquifer', which means that groundwater is transmitted by both the primary porosity – or interconnected void space between grains of the rock matrix – and the secondary porosity, which is due to secondary structural features such as joints, fractures, faults, shear zones and bedding planes.

The Hawkesbury Sandstone is not one aquifer but several 'stacked aquifers', given the heterogeneous and layered nature of the unit. Interbedded shale lenses can provide local or extensive confining layers, creating separate aquifers with different hydraulic properties including hydraulic heads (i.e. the elevation of groundwater in a monitoring well that the column of water would naturally attain).

The hydraulic conductivity of the Hawkesbury Sandstone is low, which means the groundwater flow through the sandstone is in the order of millimetres to centimetres per year. High groundwater yields can sometimes be pumped from the Hawkesbury Sandstone, particularly when saturated fractures are intersected. Increased groundwater flow to tunnels is typically associated with the intersection of such major joints or fractures.

Groundwater flow within the Hawkesbury Sandstone is dominated by secondary fracture flow. Regionally, groundwater flow is eastward, discharging into the Tasman Sea. Discharge is also via seepage from outcrops in topographically elevated areas, and evapotranspiration. Recharge is via rainfall infiltration on fractured outcrop and through leakage from the soil profile and alluvium.

Groundwater within the Hawkesbury Sandstone is generally acidic but of low salinity. A basin wide salinity map[6] indicates that groundwater within the Hawkesbury Sandstone in the study area is of much poorer quality water than in other areas of the basin. Elevated concentrations of dissolved iron and manganese naturally occur within the Hawkesbury Sandstone which can cause staining when discharged and oxidised. In tunnels groundwater ingress becomes oxidised and can cause the dissolved iron and manganese to precipitate forming sludge in drainage lines.

Geological structural features

The geology along the project alignment is expected to be cross-cut by geological structural features such as dykes and fault zones.

The intersection of dykes during tunnel construction can either increase or decrease groundwater ingress to the tunnel depending on the weathering of the dyke and what units or structures it cross-cuts. A fractured dyke cross-cutting water bearing structural features can provide a conduit for groundwater to flow directly into the tunnel.

Fault zones can have a significant impact on rock mass permeability and groundwater flow causing preferential flow paths, although not all structural features are saturated and hence transmissive. During construction, water-bearing fractures and faults can release groundwater initially when intersected, which would decline as the storage is depleted.

Hydrogeological cross-sections

A north-south oriented hydrogeological cross-section extending from St Peters to Sans Souci and Botany Bay to the south is presented in **Figure 17-6**. The section is based on boreholes and monitoring wells constructed during the investigation and shows the monitoring wells, screen intervals and nine model layers. The cross-sections also present the simplified geology, the water table and tunnel alignment for the project and New M5 Motorway.

The cross section shows the Ashfield Shale to the north at St Peters which is underlain and flanked to the south by Hawkesbury Sandstone. The Hawkesbury Sandstone is overlain by alluvium and thick sequences of alluvium that represent palaeochannels beneath Cooks River, Muddy River and Sans Souci.

[6] Russell G. 2007. Hawkesbury Sandstone Groundwater Attributes and Geological Influences. UTS/UNSW 20th Anniversary Hydrogeology Symposium 20 July 2007, University of Technology, Sydney.

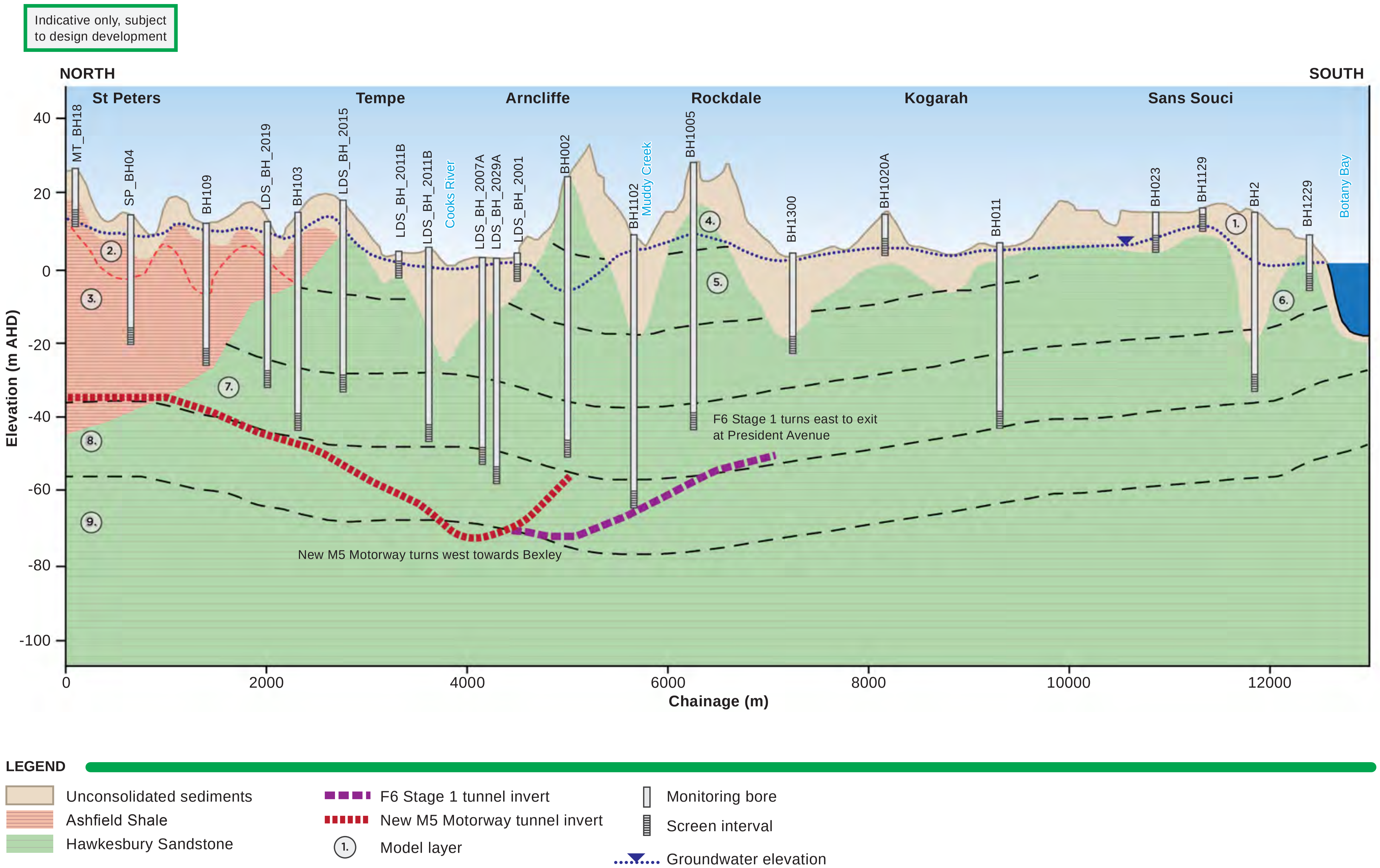


Figure 17-6 Hydrogeological cross section (extending from St Peters to Sans Souci and Botany Bay)

Groundwater inflow in existing Sydney tunnels within Hawkesbury Sandstone

Within the Hawkesbury Sandstone, water inflow is dependent upon the number and size of saturated secondary structural features intersected. Rates of water inflow have been monitored in recent years from several unlined tunnels in the Sydney area with similar geology, hydrogeology and construction to that proposed for the project. These inflow rates are considered long term flow rates throughout the operational life of the infrastructure, and are summarised in **Table 17-4**.

Drainage inflow as summarised in **Table 17-4** varies from 0.6 litres per second per kilometre to up to 1.7 litres per second per kilometre.

Table 17-4 Measured drainage inflow rates from other Sydney tunnels

Tunnel	Year opened	Type	Width (metres)	Length (kilometres)	Drainage inflow (litres per second per kilometre)	Reference
Eastern Distributor	1999	3 lane road (twin)	12 (Double deck)	1.7	1	Hewitt 2005
M5 East Motorway	2001	Twin 2 lane road	8 (twin)	3.8	0.9	Tammetta and Hewitt 2004
Epping to Chatswood	2009	Twin rail	7.2 (twin)	13	0.9	Best and Parker 2005
Lane Cove	2007	Twin 3 lane road	9 (twin)	3.6	0.6/1.71	Coffey 2012
Northside Storage	2000	Sewer storage	6	20	0.9	Coffey 2012
Cross City Tunnel	2005	Twin 2 lane road	8 (twin)	2.1	>3	Hewitt 2005

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

Predicted inflows to the proposed New M5 Motorway and M4 East tunnels have been calculated by numerical modelling published in the respective environmental impact statements. At the New M5 Motorway, groundwater modelling predicted an average inflow rate over the full length of the tunnel of 0.63 litres per second (L/sec) along the eastbound tunnel and 0.67 litres per second along the westbound tunnel.[7]

For the M4 East, groundwater modelling predicted inflows to the drained tunnels which extend over a combined length of 17 kilometres. Groundwater modelling predicted inflow rates between 0.3 and 0.9 litres per second per kilometre of tunnel[8].

Groundwater inflows to the M4-M5 Link tunnels were predicted to be below the 1 litre per second per kilometre of tunnel criteria for any kilometre of tunnel.

[7] CDM Smith, (2016). WestConnex Stage 2. New M5 Groundwater Modelling Report
[8] WestConnex Delivery Authority (2015); WestConnex M4 East EIS.

17.2.5 Groundwater quality

Table 17-5 provides a baseline for the existing groundwater quality within the study area. The groundwater quality criteria for the project have been developed in accordance with guidelines from ANZECC. For analytes not covered by the ANZECC guidelines the amended National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines[9] have been adopted.

To assess the potential impacts of groundwater to building materials, dissolved sulfate, chloride and pH values are assessed against the aggressivity criteria outlined in the exposure classification criteria for concrete and steel piles presented in the relevant Australian Standard.[10]

Table 17-5 Groundwater quality within the study area

Parameter	Alluvium	Hawkesbury Sandstone
Groundwater temperature	Measured groundwater temperatures varied over a narrow range between 19.6 and 22.1°C. Seasonally, groundwater temperatures are expected to vary by one or two degrees, although there was no variation between aquifers.	Consistent with alluvium
Electrical conductivity	Variable, ranging from 254 µS/cm to 17,100 µS/cm. Elevated electrical conductivity values in excess of 10,000 µS/cm are attributed to tidal mixing with groundwater. The groundwater is generally below 3000 µS/cm which suggests the alluvium is recharged by rainfall infiltration with minimal tidal interaction.	Variable, ranging from 516 µS/cm to 10,400 µS/cm. As for the alluvium the range of results is attributed to the degree of tidal mixing with rainfall infiltration and leakage from the overlying alluvium.
pH	Acidic (pH 5 to 6.5). Some instances of pH greater than 10 which is attributed to interference of cement grout in monitoring wells.	Acidic (pH 5 to 6.5). Some instances of pH greater than 10 which is attributed to interference of cement grout in monitoring wells.
Major cations (calcium, magnesium, sodium and potassium) and major anions (chloride, sulfate, carbonate and bicarbonate)	Groundwater is low in magnesium and sulphate with variable proportions of calcium, sodium, potassium, carbonate, bicarbonate and chloride. The variable proportion of calcium is attributed to variable amounts of shells within the alluvial sands. Similarly the variable proportions of sodium and chloride is attributed to the variable mixing of tidal waters with groundwater.	Groundwater is dominated by sodium and chloride which is attributed to tidal influences and interaction with sea water. Groundwater in the Hawkesbury Sandstone has low proportions of magnesium and sulphate.
Heavy metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc)	Measured background metals concentrations have exceeded the adopted groundwater concentration guideline for arsenic, iron, lead, manganese and zinc. In most cases the guidelines have been marginally exceeded, indicating that background levels are naturally elevated. However the alluvial groundwater consistently has elevated iron, manganese and zinc.	Measured background metals concentrations have exceeded the guideline concentration value for arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc. In most cases the guidelines have been marginally exceeded, however the concentrations of manganese, iron and zinc consistently are elevated. Dissolved iron and manganese in groundwater are known to be elevated within the Hawkesbury Sandstone. The consistent exceedance of dissolved zinc criteria across the study area suggests the elevated dissolved zinc concentrations are at background levels.

[9] National Health and Medical Research Council (NHMRC) Australian Drinking Water Guidelines (2015)
[10] Australian Standard, (2010); Piling – Design and Installation. Australian Standard. Standard AS 2159-2009 Third Edition, including Amendment No 1 (October 2010).

Parameter	Alluvium	Hawkesbury Sandstone
Nutrients (including nitrite as N, nitrate as N, reactive phosphorus), and ammonia	Nitrite and nitrate concentrations ranged from below detection limits to 0.19 and 1.9 milligrams per litre (mg/L) respectively. In comparing these results to the amended Australian Drinking Water Guidelines, nitrite and nitrate concentrations are below the health criteria of three and 50 mg/L respectively indicating background nutrient levels are low. Reactive phosphorous as P concentrations ranged from below detection limits to 0.4 mg/L, indicating phosphorous levels are also low. Ammonia concentration values in the alluvium range from 0.01 to 63 mg/L exceeding the guideline value of 0.91 mg/L. Elevated dissolved ammonia may be due to the proximity to former landfill sites, natural decaying vegetation or the use of fertilisers in parklands constructed over the alluvium.	Dissolved nitrite and nitrate concentrations range from below detection limits to 0.05 and 1.7 mg/L respectively. In comparing these results to the Australian Drinking Water Guidelines, nitrite and nitrate are below the health criteria of 3 and 50 mg/L respectively indicating nutrient levels are low. In comparison to the overlying alluvium, nitrite and nitrate concentrations in the Hawkesbury Sandstone are significantly lower. Ammonia values are relatively consistent ranging from 0.039 to 1.96 mg/L. Phosphorous as P ranged from below detection limits to 0.08 milligrams per litre, indicating phosphorous levels are very low.
Groundwater aggressivity	Groundwater is mildly aggressive with respect to average chloride, pH and sulfate to concrete piles.	Groundwater is mildly aggressive with respect to average chloride, pH and sulfate to concrete piles.

17.2.6 Groundwater contamination

An assessment of contamination risk within the study area is provided in **Appendix J** (Contamination technical report) which is summarised in **Chapter 16** (Soils and contamination). Areas within the vicinity of the project that may contain contaminated soil and/or groundwater due to past or present land use practices have been investigated. A summary of existing potential or known groundwater contamination within the study area is provided in **Table 17-6**. Refer to **Chapter 16** (Soils and contamination) for further information.

Table 17-6 Existing groundwater contamination within the study area

Project area	Groundwater contamination
Mainline tunnel	Groundwater contamination sampling was conducted in five monitoring wells installed along the alignment where areas of former historical landfilling took place. Despite there being many land-uses along the alignment that could impact groundwater quality such as light industry, market gardens and mechanical workshops, there was only one groundwater exceedance detected along the alignment.
Arncliffe ventilation and tunnel site and construction ancillary facility (C1)	There were no groundwater samples analysed during the contaminated land investigation at this location. There is potential for groundwater contamination to be present due to the historical use of pesticides and herbicides at market gardens and a golf course and areas of historical landfilling nearby.
Arncliffe water treatment plant	There were no groundwater samples analysed during the contaminated land investigation at this location. There is potential for groundwater contamination to be present due to historical landfilling, the historical use of pesticides and herbicides at market gardens and potential filling with dredged material from the Cooks River
Rockdale ventilation facility and construction ancillary facility (C2)	One borehole, identified in the NSW Government groundwater database is present at the site and indicates the groundwater level is shallow (less than two metres below the ground surface). There is potential for groundwater contamination to be present due to the historical use of pesticides and herbicides for agricultural purposes and former, current and surrounding industrial properties used for chemical manufacturing.
President Avenue intersection and construction ancillary facility (C3)	There were five groundwater samples analysed during the contaminated land investigation at this location and extensive soil samples were analysed. The soil analytical results indicated that there were some abnormally high metals results which may be due to degraded metal alloy waste in the fill sampled.
Shared cycle and pedestrian pathways and construction ancillary facilities (C4 and C5)	There were no groundwater samples analysed during the contaminated land investigation at this location. There is the potential for groundwater contamination to be present due to the historical use of pesticides and herbicides at market gardens at this location.
Princes Highway construction ancillary facility (C6)	There were no groundwater samples analysed during the contaminated land investigation at this location. The site is currently under assessment by the NSW EPA for contamination. There is the potential for groundwater contamination to be present due to the site's history as a 7-Eleven Service Station.
Permanent power supply corridor	There is potential for groundwater contamination to be present due to the former, current and surrounding industrial properties used for chemical manufacturing.

17.2.7 Groundwater users

A review of bores registered with DPI – Water (as of 10 January 2018) identified 373 boreholes within a two kilometre radius of the project alignment. There may also be other private bores present within the two kilometre radius that have not been registered with DPI – Water. The majority of registered boreholes are shallow and intersect the alluvium of the Botany Sands aquifer. The type and lithology of the registered boreholes are outlined in **Table 17-7** and **Table 17-8**.

Table 17-7 Types of registered boreholes within a two kilometre radius of the project alignment

Borehole type	Number of boreholes
Domestic	345
Industrial	1
Irrigation	7
Monitoring	9
Recreation	7
Test	2
Unknown	2

Table 17-8 Lithology of registered boreholes within a two kilometre radius of the project alignment

Borehole lithology	Number of boreholes
Ashfield Shale	1
Botany Sands	362
Hawkesbury Sandstone	1
Not specified	9

17.2.8 Groundwater dependent ecosystems

The Botany Wetlands/Lachlan Swamps located in Centennial Park is identified as a high priority GDE in the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* and the Botany Sands Groundwater Source extends to these wetlands. Potential impacts to the Botany Wetlands/Lachlan Swamps are assessed in **section 17.3.3**.

The Atlas of Groundwater Dependent Ecosystems 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 beneath 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 tunnelling as part of the New M5 Motorway project indicates a strong hydraulic connection with the new tunnels and the alluvium flanking the Cooks River via fractures in the Hawkesbury Sandstone. Impacts to the Cooks River Castlereagh Ironbark Forest GDE and Cooks River GDE as a result of the project are assessed in **section 17.3.3** and **section 17.4.3**.

A search of the Atlas of Groundwater Dependent Ecosystems also identified the presence of additional GDEs within or near to the project corridor:

- Hinterland sandstone gully forest with moderate to high potential for groundwater dependence at Bardwell Valley Parkland and Broadford Street Reserve
- Coastal sandstone ridgetop woodland with moderate potential for groundwater dependence at Stotts Reserve at Bexley North
- Estuarine fringe forest and mangrove forest with low to moderate potential for groundwater dependence between the southern bank of Wolli Creek and the railway line behind Wolli Creek station.

Potential impacts to these GDEs are assessed in **section 17.3.3** and **section 17.4.3.**

The Rockdale Wetlands are potentially dependent on groundwater. There is likely to be some connection between groundwater and the wetlands, through a direct hydraulic connection, and via the roots of wetland vegetation. The Atlas of Groundwater Dependent Ecosystems identifies that the Landing Lights, Eve Street, Spring Street, King Street and Marsh Street Wetlands do not have groundwater dependence.

Assessment of groundwater dependent ecosystems for the New M5 Motorway project

Impacts to the following GDEs were assessed as part of the EIS for the New M5 Motorway project

- Cooks River Castlereagh Ironbark Forest GDE
- Cooks River GDE
- Hinterland sandstone gully forest with moderate to high potential for groundwater dependence at Bardwell Valley Parkland and Broadford Street Reserve
- Coastal sandstone ridgetop woodland with moderate potential for groundwater dependence at Stotts Reserve at Bexley North
- Estuarine fringe forest and mangrove forest with low to moderate potential for groundwater dependence between the southern bank of Wolli Creek and the railway line behind Wolli Creek station.

Potential impacts to these GDEs were assessed in New M5 Motorway EIS, which determined that there would be low impacts to the Hinterland sandstone gully forest, Estuarine fringe forest and Cooks River GDEs and, moderate impacts to the Coastal sandstone ridgetop woodland and Cooks River Castlereagh Ironbark Forest GDEs. It should be noted that the majority of the Cooks River/Castlereagh Ironbark forest and Cooks River GDE at Kingsgrove would be cleared during the construction of the New M5 Motorway project.

Potential impacts to these GDEs from the New M5 Motorway project are considered to be relevant to the assessment of this project (F6 Extension Stage 1) because the New M5 Motorway is located closer to the GDEs. Impacts anticipated for the New M5 Motorway project would be therefore expected to be greater than impacts associated with this project. Notwithstanding, an assessment of potential impacts to these GDEs for the project has been undertaken and is provided in **section 17.3.3** and **section 17.4.3.** This assessment is informed by the groundwater model for the project and the model domain partially includes the New M5 Motorway to predict cumulative drawdown impacts.

17.3 Potential impacts – construction

Construction works including the construction of permanent infrastructure have the potential to change groundwater behaviour and impact on the surrounding environment. An assessment of potential impacts has been undertaken which is summarised below and provided in full in **Appendix K** (Groundwater technical report).

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

- Reduced groundwater recharge
- Tunnel groundwater inflow
- Groundwater level decline including potential impacts on:
  - GDEs
  - Surface water and baseflow (the groundwater that discharges to a creek or river)
  - Existing groundwater users
- Changes in groundwater quality
- Groundwater drawdown which may result in ground movement (settlement).

A detailed groundwater balance has been calculated for the construction of the project. This is discussed further in **section 17.3.8** and in **Appendix K** (Groundwater technical report).

17.3.1 Reduced groundwater recharge

During construction, the establishment of paved construction ancillary facilities, cut-and-cover tunnel sections leading to the tunnel portals and approach roads would temporarily alter or reduce groundwater recharge. The construction ancillary facilities and paved contractor compounds at the Arncliffe construction ancillary facility (C1), Shared cycle and pedestrian pathways construction ancillary facilities (C4 and C5) and Princes Highway ancillary facility (C6) would create additional temporary impervious surfaces during construction. However, the impacts of these surfaces are temporary and considered minor since their construction would not substantially reduce groundwater recharge during construction. The Rockdale construction ancillary facility (C2) and President Avenue construction ancillary facility (C3) would be located primarily on existing impervious surfaces and would therefore not substantially impact local groundwater recharge during construction.

The risks during construction would be that access roads and bunded isolation areas for stockpiling of construction materials could alter or reduce groundwater recharge. Stockpiling areas would be required for the new cuttings and embankments along President Avenue which would temporarily reduce groundwater recharge, if run-off is directed off-site. These impacts are considered minimal, as the affected areas are small compared to the overall project, and temporary, as the various structures and compounds would be removed at the end of the construction phase of the project.

17.3.2 Tunnel groundwater inflow

Groundwater inflow during construction would be dependent upon a number of factors including tunnelling progress; tunnelling construction methodology (including tunnel lining methods and locations and the success of pre-excavation pressure grouting (pre-grouting)); whether fractured zones are intersected and localised groundwater gradients and storativity (the volume of water released from storage per unit decline in hydraulic head in the aquifer, per unit area of the aquifer). Pre-grouting is undertaken by drilling a pattern of holes in advance of the excavation to conduct packer tests and calculate the hydraulic conductivity. Grout is then injected at a pre-determined pressure to reduce the bulk rock mass permeability.

Initial inflows to tunnels can be large, because of the large hydraulic gradients that initially develop near the tunnel walls; however, these gradients would reduce in time as drawdown impacts extend to greater distances from the tunnels and inflows approach steady state conditions. Higher inflow rates are likely from zones of higher permeability, where saturated geological structural features are intersected by the tunnels.

The tunnel construction program for the New M5 Motorway project at Arncliffe has experienced higher than anticipated groundwater inflows due to fractured sandstone beneath the Cooks River Palaeochannel.[11] Based on the geotechnical investigations and packer tests conducted as part of fields investigations for the project, higher groundwater inflows are expected at the northern ends of the mainline tunnels. During construction these high inflow zones are to be grouted to reduce the inflow rate to below the criterion of one litre per second per any kilometre length of tunnel.

Tunnel groundwater inflow from the Hawkesbury Sandstone is expected to be highest during construction, as hydraulic gradients would be at their highest during this time and would then decline as steady state conditions are reached. Groundwater modelling has predicted groundwater inflows to the tunnels after grouting and access decline during construction, to range between 0.06 megalitres per day (21.9 megalitres per year) in 2021 and 0.37 megalitres per day (135 megalitres per year) in 2023.

Tunnel groundwater inflow from the Botany Sands aquifer would also occur during construction. Over the construction period, tunnel inflow from the Botany Sands aquifer would range from 0.08 megalitres per day in 2021 to 0.19 megalitres per day in 2022.

During tunnel construction, groundwater entering the tunnel would be managed by either capturing the water that enters the tunnels and portals or by restricting inflow, through temporary dewatering or the installation of cut-off walls (which limit the movement of groundwater) in cut-and-cover sections. The volume of groundwater and treatment requirements would differ depending on the depth of the tunnel to be constructed, and the geological units through which it passes. It is recognised that high groundwater inflow during excavation is possible in faulted or fractured zones such as beneath the Cooks River palaeochannel and in the alluvium. The wastewater management system for the project is designed to treat and discharge groundwater as well as stormwater and other intersected water.

During construction, long term water management solutions would also be established such as the installation of water proofing membranes or undrained (tanked) tunnels. Groundwater inflows would be collected via a temporary drainage system collecting water from the road header or tunnel boring machine (refer to **Chapter 7** (Construction) for further information regarding tunnelling methodology) and pumping it to the surface for treatment and discharge. Water inflows, treatment and discharge would be managed in accordance with a water management plan, which would form part of the Construction Environmental Management Plan (CEMP) for the project.

To reduce long term groundwater inflows, pre-grouting may be undertaken, for example, to allow groundwater inflows to be more easily managed. The implementation of this technique is dependent upon the local geology, in particularly the orientation and density of water bearing rock defects. Another option to reduce the bulk rock mass permeability and long term inflows, is the installation of water proofing membranes during construction.

Dewatering during construction

Groundwater extraction from the dewatering of the Botany Sands aquifer during construction has been predicted using the groundwater model during the construction of the entry and exit ramps for the President Avenue intersection (1.5 kilometres long) (Q1 2021 to Q1 2022) and the tunnel access decline to the mainline tunnels (Q1 2021). The model calculated groundwater extraction as follows:

- Entry and exit ramps for the President Avenue intersection: 0.66 megalitres per day (299 megalitres over the period Q1 2021 to Q1 2022)
- Access decline: 1.3 megalitres per day (144 megalitres in total over the period Q1 2021).

[11] Golder Associates (2017); Design Package Report. Hydrogeological Design Report. (FD). The New M5 Design and Construct. Report No M5N-GOL-DRT-100-200-GT-1525-R, dated April.

Water take from the Metropolitan Groundwater Resource

The predicted maximum annual water take from the Metropolitan Groundwater Resource during construction is 431 megalitres (Year 2021) due to tunnel inflows and temporary dewatering associated the entry and exit ramps for the President Avenue intersection and the tunnel access decline excavations. The majority of this extraction (380 ML) is due to the temporary dewatering.

Predicted water take from tunnel inflows for the Botany Sands and Sydney Basin Central groundwater resources compared to the Long Term Average Annual Extraction Limits (LTAAEL) is presented in **Table 17-9**. Comparison of predicted tunnel inflows indicates the reduction in the groundwater availability within the Botany Sands during construction would be reduced by 2.8 per cent of the LTAAEL. Similarly, the predicted reduction in the groundwater availability during construction would be reduced by 0.05 per cent of the LTAAEL for the Sydney Basin Central groundwater resource.

Table 17-9 Groundwater extraction from the Metropolitan Regional Groundwater Resources during construction

Aquifer	LTAAEL (megalitres per year)	Water take (megalitres per year)	Percentage of LTAEEL (%)
Botany Sands	14,684	409	2.8
Sydney Basin Central	45,915	22	0.05

Source: NoW, 2011 and RPS, 2018

17.3.3 Groundwater level decline

Groundwater drawdown

Groundwater drawdown due to construction activities and temporary dewatering could impact the local water table, hydraulic pressures or surface water features where there is hydraulic connectivity. As the majority of the tunnel lengths are drained structures (i.e. not tanked), the tunnel inflows could impact the natural groundwater system and potentially alter regional hydrogeological conditions.

During construction, the regional extent of drawdown impacts due to tunnel construction would be minimal even though groundwater inflows are high. This is due to groundwater storage depletion within the Hawkesbury Sandstone from the immediate vicinity of the tunnel, restricting the lateral extent of drawdown and the relatively short construction timeframe.

As construction continues, the groundwater inflows to the tunnel would decrease but the depressurisation caused by the tunnel inflows would spread to the surface causing the water table to decline and would extend outwards to progressively greater distances until steady state conditions are reached. The longer term regional impacts on groundwater levels would therefore be greater and would progressively increase until steady state conditions are reached which is expected to be well after the completion of construction as predicted by the model.

Grouting (Injecting grout to reduce the bulk rock mass permeability) would be undertaken throughout the construction program to reduce groundwater inflows and hence limit the groundwater level decline. Groundwater levels would be monitored throughout the construction phase in accordance with a Construction Soil and Water Management Plan (CSWMP) to be developed as part of the CEMP. Additional groundwater modelling would be conducted by the contractors during the construction program using measured tunnel inflow rates and monitored groundwater drawdown to better calibrate the model and refine model predictions.

Potential impacts on groundwater dependent ecosystems

The closest high priority GDEs are the Botany Wetlands and Lachlan Swamps within the Botany Sands, located in Centennial Park around eight kilometres north-east of the project footprint. These wetlands are at a sufficient distance from the project footprint to not be impacted by the project during construction and operation.

There is limited information available regarding water level fluctuations within the Rockdale Bicentennial Park Wetland, however the natural variation has been estimated at 0.5 metres. Consequently, according to this criteria a predicted drawdown in excess of 0.05 metres would require adaptive management. Groundwater modelling has predicted that the long term surface water drawdown in Rockdale wetlands is in excess of 0.05 meters (ranging between 0.02 and 0.19 metres)

However the wetlands are not classified as a high priority GDE and the wetlands are highly modified to act as flood mitigation basins. Consequently the projected groundwater drawdown would be less than predicted because of the continual inflow of stormwater and floodwaters.

Potential impacts to the Cooks River Castlereagh Ironbark Forest, Cooks River, Hinterland sandstone gully forest, Coastal sandstone ridgetop woodland and Estuarine fringe forest and mangrove forest GDEs were assessed as being low as a result of groundwater level decline during the construction of the project.

Elsewhere within the study area, wetlands and swamps have limited groundwater dependence and are therefore unlikely to be adversely impacted by groundwater level decline associated with the construction phase of the project.

Long term dewatering caused by tunnel drainage is anticipated to lower the water table water pressure levels within the Hawkesbury Sandstone, which would reduce the amount of groundwater available for shallow rooted plants. The minimum depth of the water table underlying the majority of the project footprint is on average one metre below ground surface. Areas where the water table is shallow, such as along the Rockdale Wetlands corridor, are typically subjected to flood inundation which would provide water periodically for shallow rooted plants that may have some groundwater dependence. At other more elevated topographic areas, such as parts of Arncliffe, the water table is much deeper below ground surface and consequently flora is unlikely to be dependent on groundwater.

Following the completion of tunnel construction, groundwater would be available for partially groundwater dependent flora, as the unsaturated soil zone would not be affected by the project and would continue to receive rain infiltration. Shallow perched water (water located at an elevation higher than the local water table) is expected to be present irregularly along the alignment and could partially sustain surface ecosystems. However, partially groundwater dependent flora would primarily be dependent upon rainfall recharge and moisture within the unsaturated soil zone. In low lying areas, the project is not expected to substantially change the availability of water for plants due to the low permeability of fine soils in combination with frequent rainfall events and higher recharge compared to elevated sites.

An assessment of the impacts to natural processes as a result of the operational discharges which may affect the health of the fluvial, riparian and estuarine systems and landscape health within the study area is provided in **Appendix L** (Surface water technical report). No wetlands, marine waters or natural floodplain systems are considered to be substantially impacted by the project. Impacts to aquatic connectivity and habitat are considered in **Appendix H** (Biodiversity development assessment report).

The mainline tunnels for the project have been designed to minimise high groundwater inflows into the tunnels as described in **section 17.2.1**. Potential impacts associated with groundwater inflows such as groundwater level decline and potential impacts to GDEs have therefore been minimised in the design of the mainline tunnels.

Potential impacts on surface water and baseflow

Surface water features within or in proximity to the project footprint are described in **section 17.2.2**. Where groundwater is hydraulically linked with surface water, groundwater drawdown can impact on surface water flows.

Decreased surface water flows can occur either as a reduction in baseflow, or as streambed leakage that are dependent on the hydraulic connection between the stream channel and alluvium, the underlying sandstone and the relative water levels of the creek and groundwater.

Since the majority of the creeks and drains within the study area are concrete lined, the risk for surface water seep into the tunnels via leakage to the alluvium is considered to be low. There may be some seepage from the creeks due to cracks in the aged concrete.

There is unlikely to be any direct surface water inflow to the tunnels from the alluvium since in the southern part of the alignment where the tunnels intersect alluvium, the tunnels are to be undrained (tanked), or cut and cover sections are to be constructed by diaphragm walls, preventing direct inflow from the alluvium. Elsewhere along the alignment the tunnels are designed to dive beneath the Cooks River Palaeochannel to reduce groundwater ingress to the tunnels from the alluvium.

The Sydney Water proposal to naturalise sections of Muddy Creek is likely to increase groundwater recharge and may partially increase the baseflow to the creek.[12]

Potential impacts to baseflow for major creeks has been modelled and calculated initial baseflow, project baseflow and the reduction in baseflow are summarised in **Table 17-10**.

Table 17-10 Predicted changes to baseflow for the construction of the project

Scenario	Muddy Creek	Spring Street Drain	Cooks River	Wolli Creek	Bardwell Creek
Existing baseflow (m^3 per day)	29.9	198.8	10.6	106.6	126.1
Project baseflow (m^3 per day)	26.5	142.4	10.6	106.6	126.1
Baseflow reduction (m^3 per day)	3.4	56.4	0.0	0.0	0.0
Percentage reduction	11.5	28.4	0.0	0.0	0.0

Muddy Creek and Spring Street Drain are the only streams or channels in the study area that are expected to experience a reduction in baseflow during construction. However, since both channels are predominately concrete lined and tidally influenced, the baseflow contribution to the total streamflow is expected to be negligible. The majority of stream flow would be derived from surface run-off and tidal waters at low elevation. Of this small proportion, there is a predicted 11.5% and 28.4% reduction in baseflow at the end of construction.

Potential impacts on existing groundwater users

A review of current groundwater use has been conducted to identify registered groundwater users within a two kilometre buffer of the project footprint. In accordance with the *NSW Aquifer Interference Policy*, existing groundwater bores impacted by the lowering of groundwater levels in excess of two metres due to the project would be protected by to the 'make good' provisions.

The groundwater model has been used to assess the potential groundwater level drawdown for registered groundwater users. The groundwater modelling indicates that during construction, no registered wells would be drawn down in excess of two metres.

Groundwater drawdown is expected to be comparatively minor during the construction phase compared to the operational phase, as long term groundwater levels would continue to decline until steady state conditions are reached.

Saltwater intrusion

During construction there are unlikely to be any impacts associated with saline groundwater entering the tunnels. Saltwater intrusion would commence as soon as the hydraulic pressure within the aquifer declines due to groundwater drawdown via the tunnels, causing the displacement of the less-saline water along the shoreline with more saline tidal water.

The nearest tidal water bodies are Cooks River, Muddy Creek, and Botany Bay located 450 metres, 700 metres and 1000 metres east of the project alignment respectively. However, during construction saline groundwater would not inflow to the tunnels from tidal areas because the tidal surface waterbodies are a considerable distance from the tunnels. The calculated groundwater travel times from these waterbodies are too long for saline water to reach the tunnels. Close to the shoreline, groundwater quality would become more saline during the construction period due to saltwater intrusion. However the slight salinity increase is unlikely to impact on the environment since the groundwater along the tidal fringe is naturally saline due to tidal mixing. There are no registered water supply wells or priority groundwater dependent ecosystems along this tidal fringe which may be impacted by groundwater intrusion.

[12] https://www.sydneywatertalk.com.au/muddycreek

Ground movement (settlement)

Ground movement (settlement) or subsidence due to the compression of the soil structure from groundwater drawdown is discussed in **section 17.3.9**.

17.3.4 Groundwater quality

Groundwater quality risks from construction activities include potential groundwater contamination from fuel, oil or other chemical spills and from the captured groundwater intersected during tunnelling. There is also potential to intersect acid sulfate soils and contaminated groundwater associated with previous industrial land use. As groundwater drawdown increases due to tunnel inflows, there is the potential for tidal waters to be drawn towards the tunnels, causing saltwater intrusion. Groundwater quality from monitoring wells and groundwater collected during tunnelling would be monitored throughout the construction phase in accordance with the CSWMP. These potential risks to groundwater quality are discussed further in the following sections.

Spills and incidents

There is potential to contaminate groundwater through incidents within the construction ancillary facilities associated with the storage of hazardous materials or refuelling operations. Groundwater could become contaminated via fuel and chemical spills, petrol, diesel, hydraulic fluids and lubricants, particularly if a leak or incident occurs over the alluvium, a palaeochannel or fractured sandstone. Stockpiling of construction materials may also introduce contaminants that could potentially leach into and contaminate local groundwater.

The risks to groundwater as a result of such incidents would be managed through standard construction management procedures in accordance with site specific environmental management plans developed for the project as outlined in **Chapter 16** (Soils and contamination). Runoff from high rainfall events during construction would be managed in accordance with the measures outlined in **Chapter 18** (Surface water and flooding). Following high rainfall events, groundwater quality impacts would be minor, as the majority of runoff would discharge to receiving waters.

Intercepting contaminated groundwater

A number of sites with the potential for groundwater contamination due to various current and historical land-uses are located along the project alignment as outlined in **section 17.2.6**. A potential contamination risk would be associated with the migration of contaminated groundwater plumes towards the tunnels.

The majority of the tunnels are to be constructed within the Hawkesbury Sandstone at depths between 20 metres and up to 62 metres below ground surface level. In general, the risk of intersecting contaminated groundwater decreases the deeper the tunnel depth.

There is potential to intersect contaminated groundwater during construction while excavating the portals and dive structures that are constructed from the top down, although groundwater would typically be isolated from these structures by excavation support options such as diaphragm walls, sheet piled walls or secant piled walls. Contaminated groundwater, if intersected, would enter the tunnels and would be treated prior to discharge at one of the water treatment plants.

During ground excavation works associated with the construction of the entry and exit ramps at the President Avenue intersection, potentially contaminated shallow groundwater is likely to be encountered within the alluvium and would require management during construction. During this construction phase localised temporary dewatering may be required subject to the detailed design of the project. Groundwater would be pumped to the on-site temporary water treatment plants at the President Avenue construction ancillary facility (C3) and discharged in accordance with the adopted discharge criteria.

Groundwater and surface water captured as a result of tunnelling is likely to be contaminated with suspended solids and increased pH due to tunnel grouting activities. These flows would be captured and treated prior to discharge via water treatment plants located at construction ancillary facilities. Where possible, the treated water would be reused during construction for purposes such as dust suppression, wheel washing and plant washing, rock bolting, earthworks or irrigation before discharge. Groundwater reuse would be undertaken in accordance with *National Water Quality Management Strategy* (DPI–Water 2006). The volume of recycled water required for beneficial use would be variable and dependent on site conditions and would be likely be driven by a demand for beneficial use water.

Large portions of the Botany Sands are known to be contaminated from a variety of sources primarily related to previous industrial land-use, however the groundwater in the project area has generally low levels of contamination compared to the groundwater within Botany Management Zone 1, north of the project.

Given the tunnel depth, location of the tunnel in relation to the contaminant sources and low predicted inflow rates, the risk of intercepting contaminated groundwater within the Hawkesbury Sandstone is considered to be low. The risk of contaminated groundwater ingress from the alluvium is also considered low because the tunnel is to be tanked in the alluvium, restricting groundwater movement from the alluvium.

Groundwater treatment

The volume of groundwater and treatment requirements would differ depending on the depth of the tunnel, and the geological units and structures through which the tunnel passes. During construction, the wastewater generated in the tunnel would be captured, tested and treated at a construction water treatment plants prior to reuse or discharge, or disposal offsite if required.

Based on the knowledge gained from the adjoining tunnelling projects (M4 East, New M5 Motorway and M4-M5 Link as part of the WestConnex program of works), it is likely that the water treatment plants would be required to include pH correction as well as the ability to reduce concentrations of iron, manganese, suspended solids, ammonia, nitrate and hydrocarbons. The existing groundwater quality within the study area (refer to **section 17.2.5**) indicates that the groundwater may require treatment for these compounds as well as nitrogen and total phosphorus. Other metals including copper, chromium, lead, nickel and zinc were also recorded at elevated levels on a limited number of occasions within the study area. The type, arrangement and performance of the construction of water treatment facilities would be developed and finalised during detailed design in consideration of ANZECC (2000) guideline levels (marine, freshwater and recreational protection levels).

The receiving waterways and ambient water quality of Muddy Creek and Botany Bay are highly disturbed compared to the treated water discharge quality. The level of groundwater treatment would consider the characteristics of the discharge and receiving waterbody, any operational constraints or practicalities and associated environmental impacts and be developed in accordance with ANZECC (2000). If the project is approved, discharge criteria would be specified in the project conditions of approval.

The assessment of the potential impacts of the quality of water discharged from the water treatment plants during construction is discussed in **Chapter 18** (Surface water and flooding).

Acid sulfate soils

The majority of the tunnels for the project would be deep and extend below the areas where potential acid sulfate soils (PASS) would be expected to be found. However, PASS have been identified at the following areas within the vicinity of the project:

- Within locally derived fill associated with the palaeochannel beneath the project alignment near Bay Street at Bright-Le-Sands
- Within low-lying natural soil in the area that would be excavated for the entry and exit ramps at the President Avenue intersection at Kogarah.

The excavation entry and exit ramps at the President Avenue intersection may uncover PASS which would require treatment and removal in accordance with the CEMP developed for the project.

When exposed to air, the iron sulphides (commonly pyrite) within acid sulfate soils can oxidise, producing sulphuric acid. The soils become exposed to air by either excavation or dewatering. Components of the project that could intercept acid sulfate soils include:

- Temporary and permanent surface infrastructure including building foundations, roads and stormwater drainage structures
- Ventilation and access shafts
- Underground components of bridge and portal structures
- Shallow areas of tunnels located within alluvium.

PASS could be disturbed by the project and may cause the generation of acidic runoff and/or the increased acidity of groundwater. The risks associated with PASS and acid sulfate soil would be managed under a CSWMP as part of the CEMP prepared in accordance with *NSW Acid Sulfate Soils Manual* (Stone *et al* 1998). At locations where works would disturb alluvium acid sulfate, tests should be conducted. The CSWMP would include water quality monitoring and acid sulfate soil management.

Soil salinity

Salts naturally present in soil and rock are mobilised in the subsurface by the movement of groundwater. The concentration of salts within the soil is related to the geological unit from which the soil is derived.

Salt concentrations within soils derived from the Hawkesbury Sandstone are typically low. Concentrations of salts within alluvium can be extremely variable depending on the origin of the alluvium. Salt concentrations within marine derived alluvium or alluvium that is tidally influenced would be high, whereas fluvial sediments (sediments derived from rivers or creeks) deposited in a fresh water creek system would be expected to have low salt concentrations. Under shallow groundwater conditions, saline groundwater may be drawn to the ground surface, precipitating the salts as the water evaporates.

Urban salinity is a problem when the natural hydrogeological balance is disturbed by human interaction through the removal of deep rooted trees (causing groundwater levels to rise and potentially dissolve and mobilise salts from the soil profile) or construction of structures that intersect the water table. Since the majority of deep rooted trees were removed from the study area over 150 years ago, a new equilibrium has been established and the removal of any further remaining trees on the new equilibrium would not be substantial. The development of urban salinity may cause corrosion of building materials, degrade surface water quality or prevent the growth of all but highly salt tolerant vegetation.

During construction of the project, there is potential for salts within the alluvium beneath the entry and exit ramps at the President Avenue intersection to be mobilised by local dewatering or associated with the tunnel construction program. Tunnels constructed within the alluvium are to be undrained (tanked), and consequently could alter local flow paths creating groundwater mounding causing the dissolution of soil salts. Groundwater collected during the temporary dewatering program would be directed towards a modified drainage system for off-site discharge removing any mobilised salts from the system.

17.3.5 Groundwater monitoring

Groundwater monitoring would be carried out during construction. The monitoring program would be designed to monitor:

- Groundwater levels (manual monitoring and automatic monitoring by data loggers)
- Groundwater quality (within key monitoring wells and tunnel inflows)
- Groundwater inflows to the tunnels.

Groundwater would be monitored in the alluvium and Hawkesbury Sandstone. The construction groundwater monitoring network would use a sub-set of the current monitoring wells identified in this chapter and **Appendix K** (Groundwater technical report). It may be necessary to construct additional monitoring wells if some of the existing wells are damaged during construction or other key areas are identified during the detailed design phase where monitoring is required.

It is expected that manual groundwater level monitoring and groundwater quality monitoring would be undertaken monthly. The quality and volume of tunnel inflows are expected to be monitored weekly.

The following analytes are likely to be sampled:

- Field Parameters (pH, electrical conductivity, dissolved oxygen, temperature and redox conditions)
- Metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc)
- Nutrients (nutrients (nitrate, nitrite, Total Kjeldahl Nitrogen (TKN), ammonia and total phosphorous)
- Major cations (sodium, potassium, calcium, magnesium) and anions (chloride, sulphate, carbonate, bi-carbonate).

The analytes to be sampled and the frequency and type of reporting would be confirmed by the construction contractors.

The monitoring program would be developed in consultation with the NSW Environment Protection Authority (NSW EPA), NSW Department of Industry – Water (DI-Water) and Bayside Council and documented in the CSWMP to be developed as part of the CEMP for the project.

17.3.6 Construction ancillary infrastructure and facilities

The majority of ancillary infrastructure proposed as part of the project is above ground and would not impact the hydrogeological regime. Ancillary infrastructure that may impact groundwater during construction includes:

- Tunnel portals
- Ventilation shafts and tunnels
- Water treatment facilities
- Ancillary facilities
- Drainage channels and wetland areas.

During the construction of below ground tunnel ancillary infrastructure such as ventilation shafts or tunnel portals, sheet piling may be installed to assist temporary dewatering. Construction barrier structures such as sheet piling would be in place temporarily and groundwater levels would be restored after the barriers are removed. The tunnel portals and cut-and-cover construction options may include secant piled walls or diaphragm walls socketed into the underlying bedrock to prevent the ingress of alluvial or perched groundwater into the tunnels. Ventilation tunnels and facilities are to be constructed as drained tunnels. This infrastructure has been included in the groundwater model.

The water treatment facilities are to be constructed to enable captured groundwater and surface water to be treated and discharged within the appropriate guideline concentration values. The water treatment plants are not expected to impact groundwater other than groundwater being taken from the local hydrogeological system (refer to **section 17.3.3**). Potential surface water impacts such as discharge from the water treatment plant that could increase flows to local waterways are discussed in **Chapter 18** (Surface water and flooding).

17.3.7 Utility adjustments

Utility adjustments would be required during the construction phase. These would include the protection of existing utilities, construction of new utilities and relocation of existing utilities. The majority of the utility adjustments would occur in new utility service corridors along President Avenue and along the cut and cover sections linking the tunnels with the entry and exit ramps at the President Avenue intersection. The utilities to be impacted include:

- Sewer
- Water mains
- Electricity cables
- Telecommunications including fibre optic cables
- Gas mains.

These works would involve excavating utility trenches to varying depths and are likely to intersect the shallow water table within the alluvium. During trench excavations sheet piling may be required to temporarily provide support in the alluvium and to restrict groundwater inflows to the trench. Once the sheet piling is removed, groundwater levels would return to pre excavation levels. The trenches may be encased in concrete or plastic pipes to water proof the utility service corridors. Deeper trenches or excavations may require temporary dewatering during the construction phase.

Where feasible, the new utility corridors are designed to contain multiple utilities to minimise the land required for construction. These works would be undertaken in accordance with the CSWMP to manage potential impacts to groundwater. Refer to **Chapter 14** (Property and land use) for further information regarding utility works for the project.

17.3.8 Groundwater balance

The simulated water balance for the end of construction (Year 2024) is summarised in **Table 17-11**. The groundwater balance confirms that the major water inflows during the construction phase would be from rainfall infiltration, river leakage and storage. Conversely, the major outflows would be via evapotranspiration, river baseflow and regional flow with additional water being extracted as the tunnels progress. The net loss in storage of 1.06 megalitres per day indicates the tunnel is draining water from the local hydrogeological system.

Table 17-11 Simulated groundwater balance – construction (Year 2024)

Water component	Inputs (recharge) (megalitres per day)	Output (discharge) (megalitres per day)
Rainfall infiltration	4.92	0.00
Evapotranspiration	0.00	4.22
Groundwater Extraction[1]	0.00	0.03
River inflow/outflow	3.24	1.56
Tunnels (M5 East and New M5 Motorway)	0.00	1.10
Regional boundary flow	0.34	1.15
Tidal seepage	0.15	1.65
Storage	3.28	2.22
TOTAL	11.93	11.93

Notes:
1 Extraction from Alexandria Landfill

17.3.9 Ground movement (tunnel induced)

Areas most likely to be affected by ground movement are usually those where tunnelling is closest to the ground surface (shallowest), such as around the tunnel portals and entry and exit ramps, and in areas where the soils are more compressible such as where palaeochannels are infilled with alluvial and marine deposits. Areas overlying locations where the mainline tunnels are at greater depths and in bedrock are unlikely to experience ground movement.

Short term ground movements (settlement or ground heave) due to the tunnel excavation and associated construction works are likely to occur during the construction phase. Settlement due to groundwater drawdown is likely to develop over a period of time post tunnel construction (discussed in **section 17.4.10**).

Tunnel Induced Movement

Tunnel induced ground movements arise when the actual ground loss caused by the excavation exceeds the theoretical excavation volume. For the F6 Stage 1 Mainline this is thought to be the prevalent mechanism causing ground movement, given the tunnel profile is primarily located within competent bedrock with minimal impact to the groundwater profile.

Ground movements would occur primarily during the construction phase of the project and would typically be in the form of a surface settlement trough which develops ahead, above and behind the tunnel excavation face. Generally settlements would be greatest in magnitude directly above the tunnel centreline and subside to the sides and ahead of the tunnel face.

Tunnel induced ground movements would only occur during the construction phase, but consolidation and compression settlement could commence in the construction phase and continue into the operational phase.

Preliminary, indicative, estimates of the tunnel induced ground settlements are provided **Table 17-12**. These predicted impacts are shown on **Figure 17-7**.

Table 17-12 Preliminary, indicative tunnel inducted ground settlement estimates

Tunnel Element	Depth below Ground Surface	Estimated Settlement
Cut and cover structure	5-10 metres	Nil
Twin Tunnels	<40 metres	10mm to 25mm
Twin Tunnels	40 metres to 60 metres	5mm to 10mm
Twin Tunnels	>60 metres	2mm to 5mm
Cavern	40 metres	10mm to 30mm

Impacts to Structures

The manner in which a structure responds to ground movements depends upon its size, design and materials. For instance a timber or steel frame structure may be flexible, deflecting as the ground moves. In contrast, a masonry building, subject to similar displacements, may behave in a more brittle manner. The degree of movement experienced by a structure is also dependant on its foundation type. Deep foundations might support a structure from outside the zone of movement, isolating the structure from the adjacent surface level changes. Settlement assessments of all potentially affected structures, utilities and civil infrastructure would be undertaken during detailed design prior to construction.

It is generally accepted that the risk of damage to surface features is negligible when subjected to total settlements of less than 10 mm. For the majority of the tunnel length, the ground settlement is predicted to be less than 10mm due to the depth of the tunnel. Increased levels of settlement (up to around 30mm) may be observed at the southern end of the project, where the tunnel is shallower.

Monitoring of settlement throughout the construction program would be included as part of the CEMP and may include the installation of settlement markers or inclinometers. Pre-construction condition surveys of property and infrastructure that could be impacted by settlement would be undertaken before the commencement of construction activities. In the event that project settlement criteria (which would be determined in the conditions of approval for the project, if approved) are exceeded during construction for property and infrastructure, measures would be taken to 'make good' or to manage the impact (refer to **section 17.1.7** for further information regarding settlement criteria). Environmental management measures to control groundwater inflows (which influence groundwater drawdown and therefore ground movement) during construction are outlined in **section 17.6**.

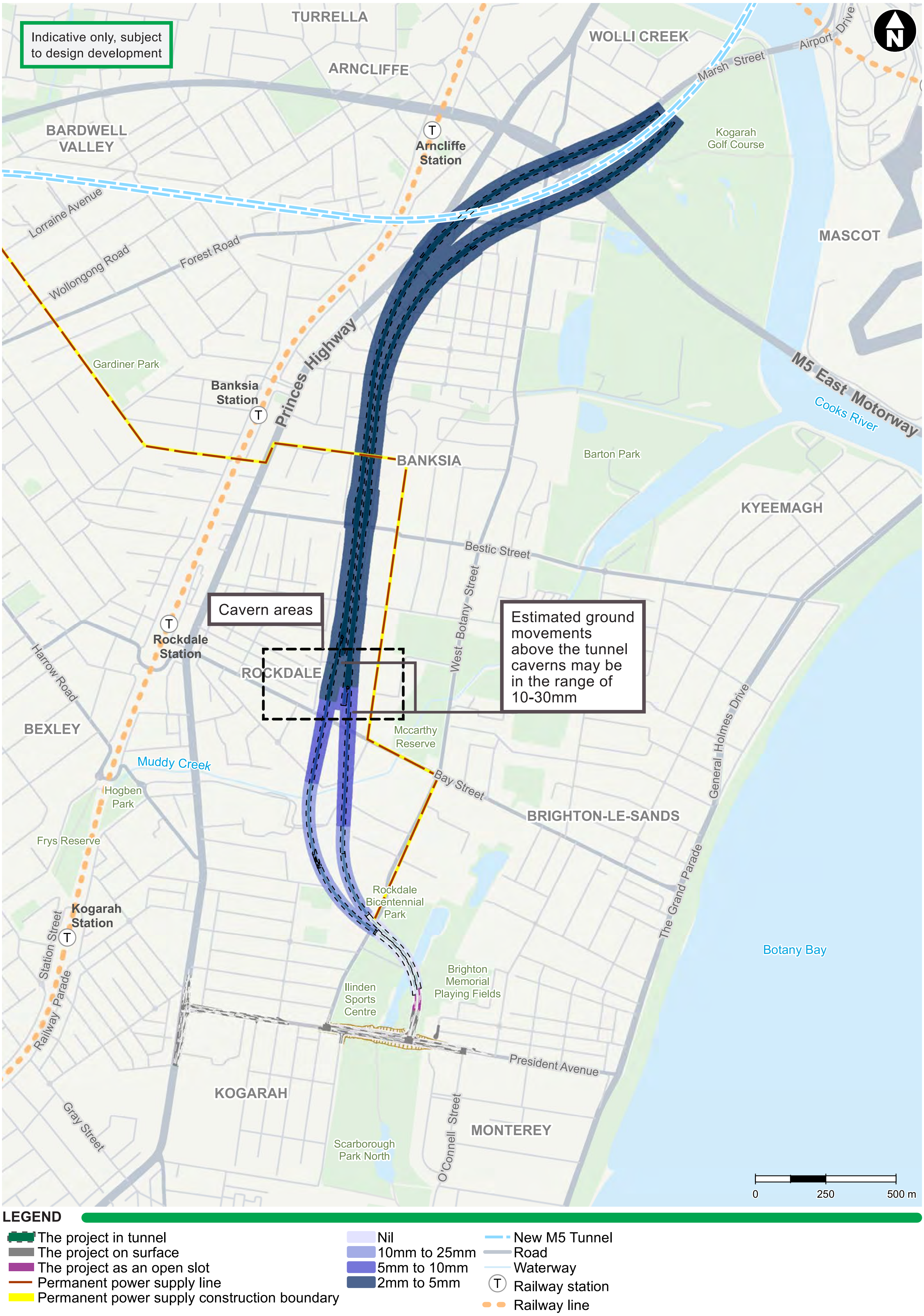


Figure 17-7 Preliminary indicative ground movements as a result of the project

17.4 Potential impacts – operation

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

- Reduced groundwater recharge
- Tunnel groundwater inflow
- Groundwater level decline including impacts on:
  - Long term groundwater flow
  - Groundwater drawdown
  - GDEs
  - Existing groundwater users
  - Baseflow
  - Ground settlement
- Groundwater quality
- Barriers to groundwater flows from operational infrastructure and ancillary infrastructure.

A detailed water balance has been calculated to predict the long-term impacts from operation of the project. This is discussed further in **section 17.4.9** and in **Appendix K** (Groundwater technical report).

17.4.1 Reduced groundwater recharge

The alluvium along the Rockdale Wetlands corridor is recharged by direct rainfall and leakage from the Rockdale Wetlands. A new pavement drainage system to accommodate road widening at President Avenue would direct runoff into water quality basins before discharge into either Rockdale wetland or North Scarborough Pond. Although the runoff to the ponds is likely to marginally increase due to the higher volumes of captured run-off, groundwater recharge should remain the same as the rate of leakage from the Rockdale Wetlands should remain constant. The Rockdale Wetlands and Scarborough Ponds would continue to behave as a flood storage area which would reduce the impacts of flooding along the connected wetland system.

The development of impervious surfaces along the alignment such as the widened road at President Avenue would increase the volume and rate of runoff, and reduce local groundwater recharge.

The majority of the project is below ground surface and is unlikely to directly impact groundwater recharge. Given the limited increase in surface area of the surface road infrastructure, including operational infrastructure such as the motorway operations complexes, ventilation infrastructure, substations and water treatment plants, it is considered that the reduction in rainfall recharge across the study area would be negligible.

17.4.2 Tunnel groundwater inflow

Inflow to the drained tunnel is influenced by tunnel construction methods, as well as the local geology and hydrogeological features of geological features such as hydraulic conductivity, storativity and hydraulic connectivity.

The project tunnels would be excavated primarily from Hawkesbury Sandstone with some sections transitioning through alluvium. To reduce groundwater inflow, the tunnels are designed to minimise intersecting the alluvium by diving beneath the Cooks River Palaeochannel. Where the tunnels rise to the surface at the President Avenue intersection entry and exit ramps, it is not possible to avoid the alluvium so the tunnels would be undrained (tanked) to reduce groundwater inflow.

Conservative estimates of tunnel inflows can be made by assuming a maximum uniform groundwater inflow rate of one litre per second per kilometre along the whole drained tunnel length during operation of the project. The total tunnel length including motorway and ventilation tunnels is around 8,460 metres. The total tunnel length of drained tunnel is 6,840 metres.

Assuming a worst case scenario of a uniform groundwater inflow rate of one litre per second per kilometre along the whole tunnel length, a groundwater inflow of around 6.84 litres per second (0.6 megalitres per day) would be expected. This approach is a conservative inflow estimate as the tunnels are designed to restrict groundwater inflow to below one litre per second per any kilometre length.

Long term groundwater inflows have been modelled and vary over time as local conditions change. After the commencement of operations in 2024, the estimated long term inflows into the motorway tunnels are predicted to be 222 megalitres per year, reducing to 216 megalitres per year in 2100.

Inflow from specific hydrogeological units

Groundwater inflow from the Hawkesbury Sandstone is expected to be low along the majority of the alignment due to low bulk hydraulic conductivity values of typically 0.008 metres per day.

The alignment intersects the Botany Sands Source Management Zone, however there would be no direct inflow of groundwater from the Botany Sands into the tunnels because the sections of tunnels intersecting the alluvium are to be undrained (tanked). There are however likely to be indirect inflows from the Botany Sands aquifer, as the Hawkesbury Sandstone is likely to be hydraulically connected to the Botany Sands aquifer. These indirect inflows would be low given the low bulk hydraulic conductivity of Hawkesbury Sandstone.

There is no direct inflow to the tunnels from the alluvium since the tunnels are designed as undrained (tanked) where the alluvium is intersected. Cut-and-cover sections that intersect the saturated alluvium are to be constructed with cut-off walls and diaphragm walls to restrict long term tunnel leakage from the alluvium. There may be indirect inflows however, given that alluvium is hydraulically connected to surface waterbodies and that water can potentially leak from the wetlands, ponds and creeks via the alluvium and fractured sandstone (refer to **section 17.4.3** for further information regarding leakage).

Dykes may affect tunnel drainage in the short term as competent (fresh) dykes or dykes weathered to clay can form natural hydraulic barriers. Conversely the zone around a dyke within sandstone can be fractured causing a conduit for groundwater flow.

Water take from the Metropolitan Groundwater Resources

The predicted long term water take from each of the Greater Metropolitan Regional Resources due to tunnel inflows and compared to the LTAAEL is summarised in **Table 17-13**. Comparison of predicted tunnel inflows indicates the long term reduction in the groundwater availability within the Botany Sands over the life of the project would vary from 66 megalites per year (2025) to 51 megalitres per year (2100) which represents 0.35 to 0.45 per cent of the LTAAEL. Annual rainfall recharge to the Botany Sands Aquifer is 30,424 megalitres. Therefore the predicted groundwater 'take' from the Botany sands represents between 0.17 and 0.22 percent of the available recharge.

Similarly the predicted long term tunnel inflows represent a small percentage of the LTAAEL for the Sydney Basin Central which range from 0.47 per cent to 0.48 per cent. Long term inflows to the Sydney Basin Central Regional Groundwater Resources decline as storage declines over the project life.

Table 17-13 Groundwater extraction from the Metropolitan Regional Groundwater Resources during operation

Aquifer	LTAAEL (megalitres per year)	Water take (megalitres per year)		Percentage of LTAEEL (%)
Botany Sands	14,684	66	51	0.35 to 0.45
Sydney Basin Central	45,915	222	216	0.47 to 0.48

Source: NoW, 2011 and RPS, 2018

Management of groundwater inflows

Grouting and the installation of waterproof membranes would reduce groundwater inflow to the tunnels. Groundwater inflow at dive structures, ventilation shafts and cut-and-cover sections would be restricted by the construction of diaphragm walls and cut-off walls constructed in good quality Hawkesbury Sandstone. Tunnel inflows would be monitored in accordance with a groundwater monitoring plan (GMP) which would form part of the Operational Environmental Management Plan (OEMP) or Environmental Management System (EMS) for the project. The GMP would outline the process of monitoring and management measures for groundwater inflows. Groundwater flow meters would be spaced at a minimum of one kilometre intervals to ensure the minimum inflow criteria is being met.

Measures to manage groundwater inflows are summarised in **section 17.6**.

17.4.3 Groundwater level decline

Long term groundwater inflow

Previous tunnelling in the Hawkesbury Sandstone in the Sydney region has shown that groundwater inflow is typically highest during construction and then steadily reduces as an equilibrium or steady state conditions are reached. This equilibrium is achieved when the tunnel inflow is matched by rainfall recharge via infiltration and/or surface water inflows.

Based on historical groundwater inflows to other drained Sydney tunnels, the long term inflow rate into the project tunnels is expected to be below the one litre per second per kilometre for any kilometre tunnel length. Specific zones capable of higher rates of inflow identified during construction would require treatment such as grouting, to reduce the bulk permeability of the rock mass to reduce inflow rates to meet the design inflow criterion.

Groundwater modelling has calculated inflows for the construction and operations phases. At project opening (2024) tunnel inflows are estimated to be 222 megalitres per year, declining to 216 megalitres per year at the end of the model simulation in 2100. As observed in other Sydney tunnels, inflow is likely to decrease with time.

Groundwater drawdown

Construction of drained tunnels beneath the water table is expected to cause long term ongoing groundwater inflow to the tunnels, inducing groundwater drawdown along the project footprint during its operation. Actual groundwater drawdown of the water table would be dependent on a number of factors including hydraulic parameters and proximity to the project footprint. Immediately after tunnelling is completed, groundwater inflows would be at their highest. With time, groundwater inflow to the tunnel would decrease, while the water table would gradually decline until a new equilibrium is reached.

Groundwater drawdown within the palaeochannels and river alluvium within the study area would be minimal as the hydraulic heads within saturated sediments are in part maintained by direct hydraulic continuity with surface water, supported by a reduction in stream baseflow (refer to **section 17.4.3**).

Calculated long term (Year 2100) drawdown for the project within the alluvium and Hawkesbury Sandstone is presented in **Figure 17-8** and **Figure 17-9** respectively.

Long term (Year 2100) drawdown for the project within the alluvium is centred on Spring Street Drain and Muddy Creek. The maximum drawdown within the alluvium is 5.3 metres where Spring Street Drain directly overlies the tunnels. The drawdown extent to the 2.0 metre drawdown contour extends approximately 200 metres either side of the drain. To the south at Muddy Creek and the access decline drawdown reaches a maximum of 0.6 metres.

Long term (Year 2100) drawdown for the project within the Hawkesbury is elongated along the tunnel alignment extending approximately 350 metres from the tunnel alignment to the two metres drawdown contour. The maximum drawdown is 33 metres over the access decline to the north decreasing to 30 metres at Arncliffe.

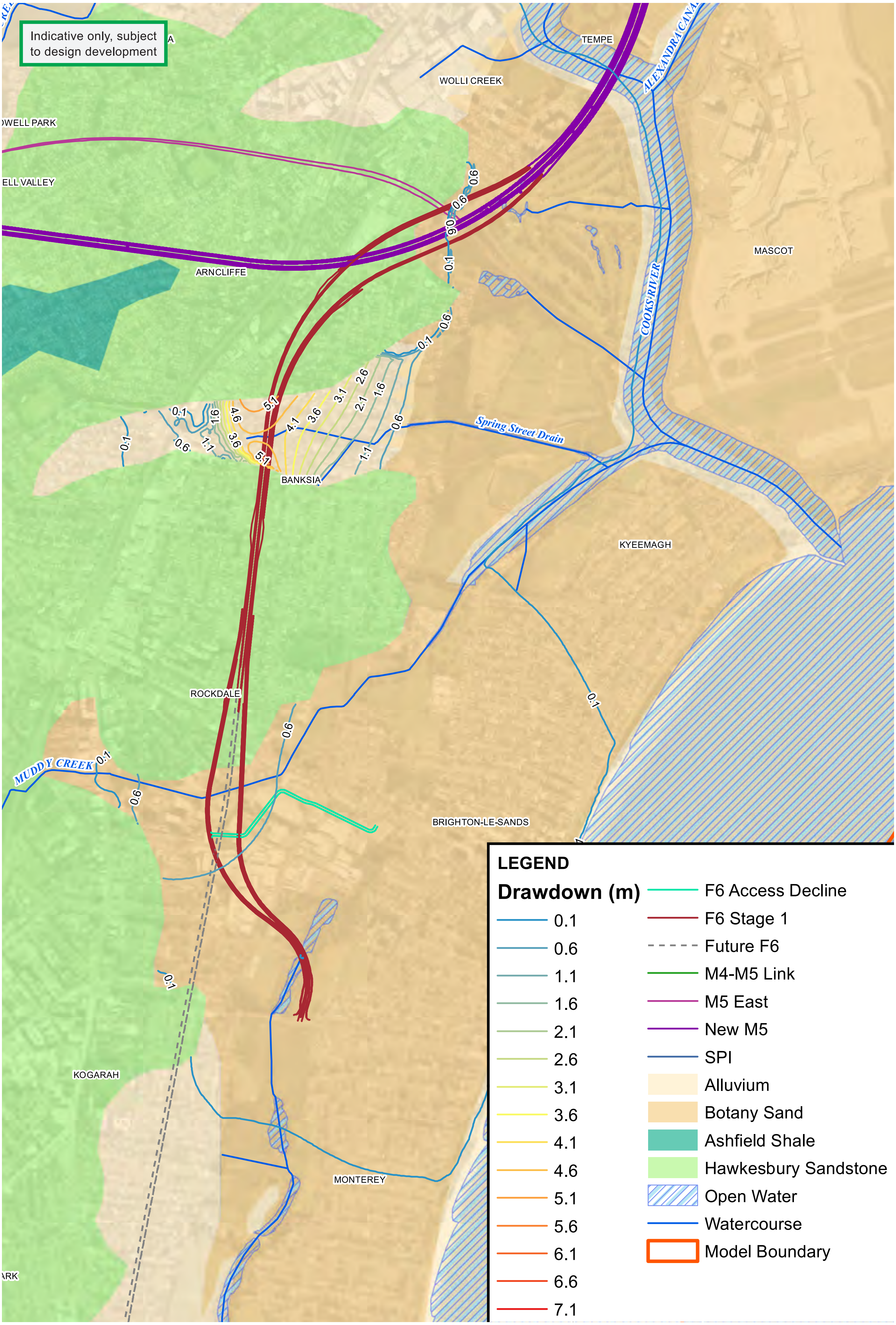


Figure 17-8 Predicted long term (Year 2100) drawdown in the alluvium for the project (RPS, 2018)

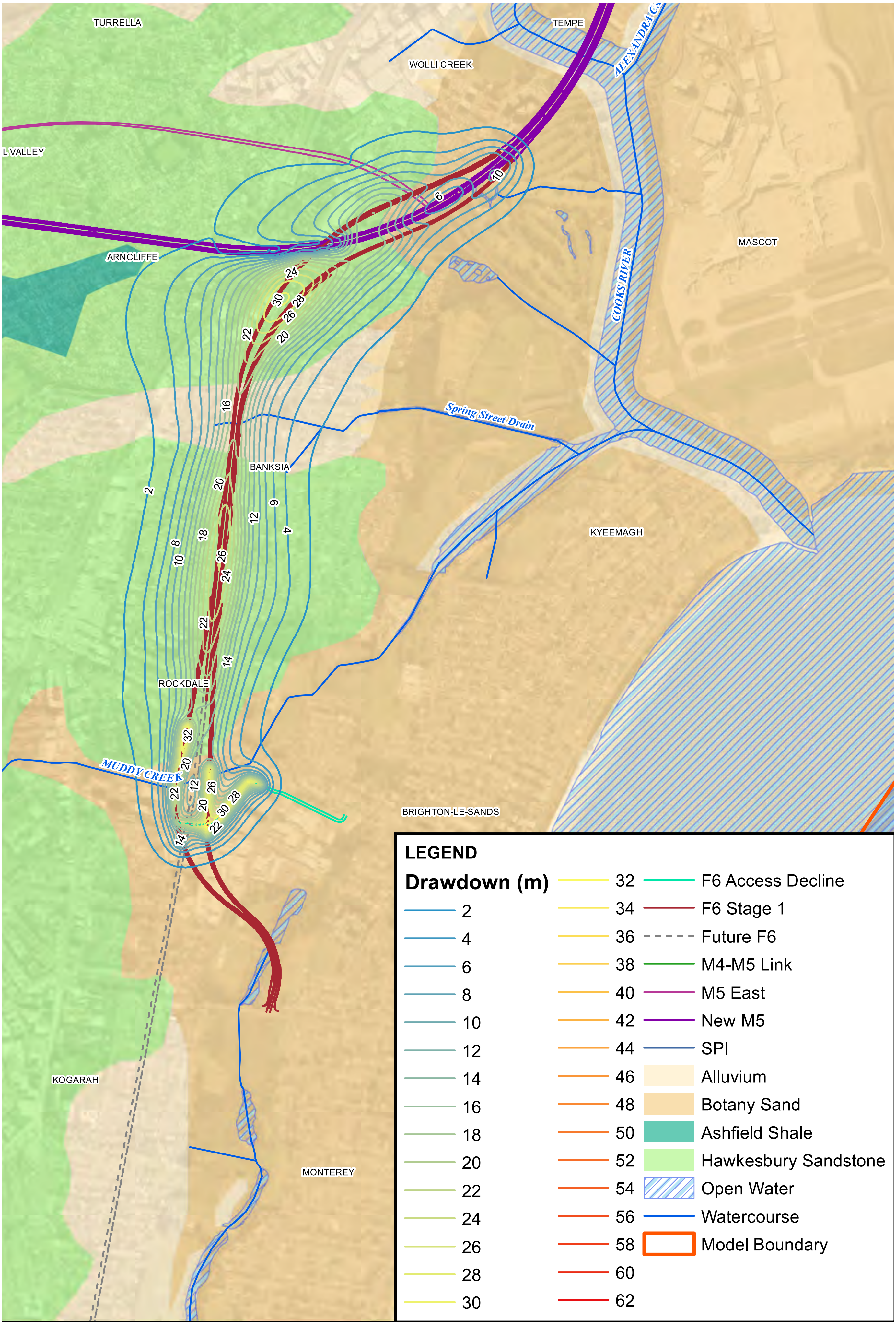


Figure 17-9 Predicted long term (Year 2100) drawdown in the Hawkesbury Sandstone for the project (RPS, 2018)

Potential impacts to groundwater dependent ecosystems

Wetlands within the project area include the Landing Lights, Eve Street, Spring Street, King Street and Marsh Street Wetlands. The potential for impacts drawdown at these locations has been investigated for the project. Drawdown in excess of the seasonal variation of 0.05 metres is predicted at these wetlands with long term drawdown predicted to vary from 0.28 metres at Landing Lights Wetland to 0.47 metres at the Marsh Street Wetland. These predicted drawdowns are not considered to be of concern because the wetlands are not dependent on groundwater as described in **section 17.2.8**.

For the Rockdale wetlands, groundwater modelling predicts the long term surface water drawdown in as being in excess of 0.05 meters. However, as described in **section 17.3.3** the wetlands are not classified as high priority and in fact are highly modified to act as flood mitigation basins. Consequently the predicted groundwater drawdown would be less than predicted because of the continual inflow of stormwater and floodwaters.

Long term dewatering caused by tunnel drainage is predicted to lower the water table and water pressure levels within the Hawkesbury Sandstone, reducing the amount of groundwater available for some shallow rooted plants as described in **section 17.3.3**.

Potential impacts to the Cooks River Castlereagh Ironbark Forest, Cooks River, Hinterland sandstone gully forest, Coastal sandstone ridgetop woodland and Estuarine fringe forest and mangrove forest GDEs were assessed as being low as a result of groundwater level decline during the operation of the project.

An assessment of the impacts to natural processes as a result of the operational discharges which may affect the health of the fluvial, riparian and estuarine systems and landscape health within the study area is provided in **Appendix L** (Surface water technical report). No wetlands, marine waters or natural floodplain systems are considered to be substantially impacted by the project. Impacts to aquatic connectivity and habitat are considered in **Appendix H** (Biodiversity development assessment report).

Potential impacts on existing groundwater users

The majority of registered bores within two kilometres of the project footprint are shallow bores extracting groundwater from the Botany Sands for domestic use. A total of 360 boreholes within a two kilometre radius of the project footprint are registered for water supply or irrigation.

Groundwater modelling has been used to predict drawdown at the location of registered bores across the project footprint. In accordance with the *NSW Aquifer Interference Policy,* a predicted drawdown of greater than two metres would require adaptive management. Only five bores are predicted to be impacted by a long term drawdown in excess of two metres, directly attributable to the project. These bores are shallow water supply wells as summarised in **Table 17-14** with a maximum predicted long term drawdown of 3.78 metres (GW024062).

Table 17-14 Predicted long term drawdown in registered bores in excess of two metres

Registered Bore ID	Use	Depth (metres)	Screened Geology	Drawdown (metres) Year 2100
GW024062	Water Supply	3.6	Alluvium	3.78
GW108295	Domestic	8.0	Alluvium	2.07
GW108439	Domestic	8.0	Alluvium	2.32
GW110735	Domestic	8.0	Alluvium	2.16
GW023194	Water Supply	4.8	Sandstone	2.51

Potential impacts on surface water and baseflow

Predicted long term changes in baseflow as a result of the project are summarised in **Table 17-15**. Although the baseflow component of surface flow is reduced in several of the water courses, the volumes are small and it is possible that the overall contribution to river flow from groundwater input is even smaller due to the waterways being mostly lined channels, including Muddy Creek.

Table 17-15 Predicted long term changes to baseflow (Year 2100)

Scenario	Muddy Creek	Spring Street Drain	Cooks River	Wolli Creek	Bardwell Creek
Existing baseflow (m^3 per day)	36.6	139.8	14.1	55.6	103.7
Project baseflow (m^3 per day)	29.2	83.2	14.1	55.6	103.7
Baseflow reduction (m^3 per day)	7.4	56.6	0.0	0.0	0.0
Percentage reduction	20.4	40.5	0.0	0.0	0.0

Muddy Creek and Spring Street Drain are the only streams or channels in the study area that are expected to experience a long term reduction in baseflow from the operation of the project. However since both channels are predominately concrete lined and tidally influenced, the baseflow contribution to the total streamflow is expected to be a negligible proportion. The majority of stream flow would be derived from surface run-off and tidal waters at low elevation. Of this small proportion, there is a predicted long term 20.4% and 40.5% reduction in baseflow. Further afield but within the model domain, there are no predicted impacts on Wolli Creek and Bardwell Creek during construction caused by the project.

The Rockdale wetlands and Scarborough Ponds are not concrete line and are therefore in hydraulic connection with the underlying alluvium. Any decline in water levels in these waterbodies is likely to be in part balanced with diverted stormwater and floodwaters in the flood mitigation scheme for the project (refer to **Chapter 18** (Surface water and flooding)).

Sydney Water is proposing to naturalise parts of creek channels within the project footprint, including sections of Muddy Creek. Removal of sections of the concrete-lined base would allow more groundwater and surface water interaction leading to a higher contribution of baseflow to surface water flow in the creeks. The impact of a reduction in baseflow due to the project and a reduction in hydraulic heads would be in part balanced by the proposed naturalisation works, resulting in future additional surface water recharge via bed leakage when the water table is below the creek bed.

No permanent springs that contribute to surface flow or river baseflow have been identified within the project footprint.

Saltwater intrusion

Saltwater intrusion would commence as soon as the hydraulic pressure within the aquifer declines due to groundwater drawdown via the tunnels causing the displacement of fresher water along the shoreline with more saline tidal water. In some locations, saline intrusion could cause saline water to reach the tunnels.

A capture zone analysis has been undertaken as part of the groundwater modelling to investigate the movement of saline water. From this analysis it is not possible to quantify volumes or concentrations of saline water entering the tunnels and consequently the following discussion is qualitative.

The capture zone analysis indicates that groundwater from the tidal zones associated with the Botany Sands aquifer, Cooks River/Alexandra Canal, Wolli Creek and Spring Street Drain would at some stage be drawn down, increasing in velocity towards the tunnels. There is potential for saline intrusion of tidal waters to impact the water quality of natural groundwater at Spring Street Drain and in the alluvial aquifer at Arncliffe which may reduce the quality of groundwater being used to irrigate the Kogarah Golf Course. Salt water intrusion of the saline waters of Botany Bay is not predicted to be drawn towards the tunnels as the gradient near Botany Bay remains towards the coast.

Travel times for tidal water to enter the tunnels in the project area range from 46 years at Spring Street Drain to 127 years at the project mainline tunnel.

Initial saline groundwater inflows represent extremely small inflow which would slowly become a larger proportion of flow over time. Groundwater quality in the tunnel catchment zones would slowly become more saline over thousands of years. Since the operational lifetime for major infrastructure is in the order of 100 years, the slow salinity increase would have minimal impacts on the tunnels, infrastructure and the environment in the short term. There is the potential to increase the salinity in registered groundwater bores due to saltwater intrusion however, the slow progress of saline groundwater is expected to have a minimal impact on these bores over a period of 100 years.

Groundwater quality and inflow would be routinely monitored and treated as required prior to discharge in accordance with the OEMP for the project.

Ground movement (settlement)

Potential impacts related to settlement during operation from groundwater drawdown are discussed in **section 17.4.10**.

17.4.4 Groundwater quality

Intercepting contamination groundwater

The tunnel drainage infrastructure is designed to capture two separate drainage streams consisting of groundwater ingress and stormwater ingress consisting of runoff from portals, spills, maintenance washdown water and fire suppressant deluge. The quality of the two tunnel streams are expected to vary considerably and consequently are to be treated differently prior to discharge.

Groundwater quality monitoring indicates the groundwater within the study area is brackish with elevated metals and nutrients recorded during groundwater sampling. In order to prevent adverse impacts on downstream water quality within the Cooks River, treatment facilities would be designed so that the effluent would be of suitable quality for discharge to the receiving environment (refer to **Appendix L** (Surface water technical report) for further information)).

Water treatment may involve:

- Flocculation to reduce total suspended solids
- Ion exchange to reduce salinity, nutrients and dissolved solids
- Reduction of iron and manganese concentrations
- Reverse osmosis to reduce salinity and remove organic impurities
- pH correction through the addition of lime or acid.

During the operational phase collected groundwater is to be transferred to the water treatment plant at the Arncliffe Motorway Operations Complex (MOC1). The tunnel operational water treatment facilities would be designed such that effluent would be of suitable quality for discharge to the receiving environment (refer to **Appendix L** (Surface water technical report)). Nutrient treatment options (for example ion exchange or reverse osmosis) within the water treatment plant would be investigated during detailed design with consideration to other factors such as available space, increased power requirements and increased waste production.

Corrosion by groundwater

Tunnel infrastructure including the construction of ancillary infrastructure would be mostly located below the water table and the building materials would therefore potentially be subjected to corrosion due to interaction with groundwater. There are a number of factors that contribute to corrosion, which are related to groundwater aggressivity and include chloride, sulfate, pH and resistivity. The presence of dissolved chloride and sulfate in groundwater is one of the main factors contributing to corrosion potential of concrete and steel.

The aggressivity assessment (**section 17.4.4**) indicates that groundwater within the alluvium and Hawkesbury Sandstone is mildly aggressive to concrete piles with respect to chloride, pH and sulfate. For steel piles, groundwater within the alluvium and Hawkesbury Sandstone is non aggressive to steel piles with respect to chloride and pH but is severely aggressive with respect to resistivity.

17.4.5 Barriers to groundwater flow from operational infrastructure

Below ground infrastructure, such as a tunnels, can create physical barriers that cause temporary or permanent interruptions to groundwater flow. Temporary impacts may be seen after heavy rainfall, when infiltration to the water table and lateral flow are slowed by the barrier, creating a build-up of groundwater behind the barrier (groundwater mounding).

During the operation of the tunnels, physical barriers to groundwater flow are unlikely for a number of reasons. The majority of the tunnels (including ventilation tunnels) are designed to be drained, which would allow groundwater to seep into the tunnel rather than creating a physical barrier to groundwater flow.

Only limited sections of the tunnels are to be undrained (tanked) preventing groundwater ingress. These sections of the tunnels are to be constructed within alluvium and are unlikely to create a physical barrier as the tunnels would not fully penetrate the alluvium which would allow groundwater to flow around (above or below) the tunnel. Grouting of highly permeable zones to reduce the bulk hydraulic conductivity and tunnel inflows are unlikely to create hydraulic barriers to regional flow, as the grouting would be localised and not applied through the full thickness of the aquifer.

Although the project tunnels are unlikely to create physical barriers, drained tunnels may create hydraulic barriers impacting local groundwater flow patterns. The hydraulic barrier is formed by lowering groundwater levels centred on the tunnel alignment and, in some cases, locally reversing the groundwater flow direction. Permanent drawdown around the drained tunnels is likely to occur as discussed in the sections above. The creation of a groundwater ‘sink’ would occur along the alignment and extend to a level beneath the tunnel invert.

At tunnel portals or cut-and-cover sections (such as at the President Avenue intersection entry and exit ramps), the potential interruption of groundwater and possible groundwater mounding caused by the installation of cut-off walls would be avoided by the inclusion of drainage blankets or drains in the detailed design.

17.4.6 Barriers to groundwater flow from ancillary infrastructure

The following ancillary infrastructure may impact groundwater during operation of the project:

- Tunnel portals
- Ventilation tunnels and systems
- Utility adjustments
- Drainage channels and wetland areas.

Options for the construction of tunnel portals and cut-and-cover structures include secant piled walls or diaphragm walls socketed into the underlying bedrock to prevent the long term ingress of alluvial or perched groundwater into the tunnels. The construction of these structures would potentially alter local groundwater flow directions and could act as barriers to groundwater flow. Mitigation measures such as the installation of drainage blankets to direct groundwater around these barriers would be explored during the detailed design of the project.

Ventilation tunnels are likely to be constructed as drained tunnels. Impacts to the hydrogeological regime due to additional drained tunnels are likely to slightly increase groundwater inflows and the lateral extent of groundwater drawdown. This infrastructure has been included in the groundwater model which informs this assessment.

Utility corridors and drainage channels are unlikely to be constructed at a depth to impact groundwater. Potential impacts due to discharge are discussed in **Appendix L** (Surface water technical report).

17.4.7 Impacts to the final landform

The primary impact on the final landform would likely to be due to groundwater drawdown in the alluvium, Botany Sands and bedrock aquifers. Drawdown in the unconsolidated alluvial sediments and Botany Sands could result in ground settlement, which is discussed in **Chapter 14** (Property and land use). Groundwater drawdown in the Hawkesbury Sandstone beneath the alignment is unlikely to cause substantial settlement due to the competent nature and the geotechnical properties of the sandstone. Ongoing groundwater inflow near tidal surface water features may cause localised saltwater intrusion over time, resulting in an increase in groundwater salinity.

Groundwater settlement within the alluvium is likely to be greater compared to the Hawkesbury sandstone because of the unconsolidated lithology within the alluvium. Settlement induced by groundwater drawdown would only occur in the alluvium when the drawdown exceeds the natural range of groundwater level fluctuation. The natural level of fluctuation in the area is estimated to be one metre and therefore the majority of the project alignment would not be impacted by settlement within the alluvium. Groundwater settlement may occur within the alluvium beneath the Spring Street Drain where the maximum drawdown in the alluvium is predicted to be 5.3 metres. The amount of settlement would depend on the geotechnical properties of the alluvium and is predicted to extent approximately 200 metres to the east and 400 metres to the west of the alignment.

Operational infrastructure would occupy excavated areas for the project. The final landform for the project would not include voids that would require management or rehabilitation during operation. Proposed landscaping details for the final landform are provided in **Appendix C** (Place making and urban design).

17.4.8 Groundwater monitoring

The groundwater monitoring program prepared and implemented during construction (**section 17.3.5**) would be augmented and continued during the operational phase. Groundwater would be monitored during the operation phase for three years or as otherwise required by the project conditions of approval and would include trigger levels for response or remedial action based on monitoring results and relevant performance criteria.

The exact nature and frequency of the ongoing groundwater monitoring during operation would be determined by the project operator in consultation with the NSW EPA, DI-Water and the Bayside Council and would be documented in the OEMP or EMS. Additional groundwater monitoring wells are likely to be required once the tunnels are constructed. The location, depth and purpose of monitoring wells would be decided in consultation with the NSW Department of Planning and Environment (DP&E) and DI-Water.

17.4.9 Groundwater balance

The simulated water balance for the long term operation phase (Year 2100) is summarised in **Table 17-16**. The water balance has been developed based on the transient groundwater model, averaged over the operational life of the project.

The operational water balance confirms that regional boundary flows and rainfall infiltration is the primary recharge parameter and the primary discharge parameters are evapotranspiration, river leakage and discharge to tidal areas.

Table 17-16 Simulated groundwater balance – construction (2024)

Water component	Inputs (recharge) (megalitres per day)	Output (discharge) (megalitres per day)
Rainfall infiltration	4.35	0.00
Evapotranspiration	0.00	4.90
Groundwater Extraction[1]	0.00	0.05
River inflow/outflow	2.68	1.98
Regional boundary flow	0.31	1.17
Tidal seepage	0.10	1.67

Water component	Inputs (recharge) (megalitres per day)	Output (discharge) (megalitres per day)
Tunnels (M5 East and New M5 Motorway)	0.00	0.38
Total without storage	7.44	10.15
Storage	5.72	3.01
Total with storage	13.16	13.16
Net change in storage	-2.71	

Notes:
1 Extraction from Alexandria Landfill

A complete water balance for surface water and groundwater inputs and outputs is provided in **Chapter 18** (Surface water and flooding) and in **Appendix L** (Surface water technical report).

17.4.10 Ground movement (settlement)

Ground movement induced by tunnel excavation during construction is discussed in **section 17.3.9**. Impacts related to settlement during operation may be caused by groundwater drawdown, which occurs over a longer timeframe as opposed to settlement impacts from tunnel construction.

When groundwater levels are drawn down, the unconsolidated sediments hosting the groundwater are subjected to an increase in effective stress (the force that keeps soil particles together), and the sediment may experience settlement. If the degree of settlement is sufficient, it can result in damage to structures within the groundwater drawdown zone of influence. Settlement associated with construction tunnelling occurs within a shorter timeframe compared to settlement associated with groundwater drawdown, which occurs over a longer timeframe.

The tunnels have been designed to dive beneath the majority of the Cooks River Palaeochannel to reduce groundwater ingress to the tunnels from the alluvium and therefore reduce settlement. Where tunnels rise to the ground surface in the southern part of the alignment, the alluvium would be intersected. Tunnel sections intersecting the alluvium would be undrained (tanked) to minimise groundwater ingress. Cut and cover sections forming part of the entry and exit ramps at the President Avenue intersection would be constructed with diaphragm walls to reduce tunnel groundwater ingress. Elsewhere along the alignment, the hydraulic conductivity of the Hawkesbury Sandstone would be decreased by grouting which would decrease groundwater inflow and hence reduce settlement.

Small scale dewatering of the alluvium and Hawkesbury Sandstone may be required during construction which would result in an increase in effective stress potentially leading to ground settlement. It is anticipated that dewatering the Hawkesbury Sandstone would result in negligible settlement.

Although the groundwater model has predicted groundwater drawdown within the alluvium, the model is a regional groundwater model and is not considered appropriate for use in estimating groundwater induced settlement at a more localised level. Detailed settlement modelling would be required to be undertaken by the construction contractors during the detailed design phase, as part of the detailed design where the water table within alluvium may be drawn down.

A geotechnical model of representative geological and groundwater conditions would be prepared during detailed design. The model would be used to assess predicted settlement impacts and ground movement caused by excavation and tunnelling on adjacent property and infrastructure.

Consolidation of the soil profile

The sensitivity of individual geotechnical units to settlements is a function of their strength, stiffness, and the stress history of the unit. The estuarine and aeolian soils infilling the palaeochannels along the project alignment range from very soft to firm in consistency, and the sands range from very loose to medium dense in density. Such soils have limited bearing capacity and are susceptible to settlement primarily by consolidation. If the vertical stress regime is increased, the clay soils would undergo consolidation settlement as well as creep settlement, resulting in settlement possibly continuing over a long period of time.

In order to reduce the magnitude settlements in the upper soil profile due to groundwater drawdown, tunnel alignments have been designed to dive below the palaeochannel on the mainline. However, at President Avenue the tunnel alignments intercept the deep palaeochannels or come in close proximity. For these locations watertight cut and cover structures or tanked tunnel sections have been nominated to minimise the amount of groundwater drawdown and potential for tunnel induced ground loss.

It is anticipated that where compressible soils are exposed under loaded structural elements, the loads would be transferred by into more competent bedrock, thereby limiting the creep settlement component.

With the exception of the palaeochannels, groundwater drawdown caused by the tunnel is expected to be generally confined to bedrock and not induce consolidation in the soils overlying the bedrock. On this basis, surface settlement due to drawdown of groundwater is expected to be negligible along the tunnel alignment other than at the palaeochannels in the vicinity of Spring Street, Bay Street and President Avenue. Preliminary estimates of the ground settlements at these locations are provided in **Table 17-17**.

Table 17-17 Preliminary estimates for ground settlements overlying palaeochannels

Location	Estimated Groundwater Drawdown		Preliminary estimates for ground settlement
Spring Street Palaeochannel	6.1m	23.5m	30mm to 50mm
Bay Street Palaeochannel	0.7m	17m	10mm to 20mm
President Ave Palaeochannel	0.3m	21m	2mm to 5mm

Muddy Creek constructed channel

The Muddy Creek constructed channel is a concrete lined stormwater drain managed by Sydney Water. The project tunnels would be located more than 50 metres below the channel level.

The Muddy Creek constructed channel lies within a palaeochannel eroded into Sandstone bedrock and is infilled with a thick sequence of alluvial and marine deposits. Depths to rock are expected to exceed 30 metres. The hydrogeology is anticipated to be complex with the potential for aquifers in the alluvial and marine deposits, and bedrock. Groundwater flows in bedrock would be influenced by localised areas of relatively high permeability rock associated with stress relief under the palaeochannel.

The project’s tunnels would cross under the palaeochannel, with a cover of about 20 metres of rock between tunnel crown and the base of the palaeochannel. Groundwater inflows into the tunnels beneath Muddy Creek may be significant and measures such as grouting to reduce rock mass permeability and/or localised tanking would be used to meet the contractual tunnel inflow limits. However, it is anticipated that groundwater inflow into the tunnels would induce groundwater drawdown in the alluvium at Muddy Creek, which would potentially result in settlement impacts to the Muddy Creek channel. The risks associated with water table drawdown within the alluvium beneath Muddy Creek and associated dewatering induced settlement is dependent upon the amount of groundwater drawdown within the alluvium and the geotechnical properties of the soil. The tunnels have been designed to reduce groundwater drawdown within the unconsolidated sediments by constructing tanked (undrained) tunnel sections through the alluvium which would also minimise settlement in these areas.

The range of potential settlement impacts to the Muddy Creek channel may include concrete cracking, opening of expansion joints, pooling water, and misalignment of slabs. A geotechnical model of representative geological and groundwater conditions would be prepared during the detailed design phase prior to the commencement of tunnelling. The model would be used to assess predicted settlement impacts (including at Muddy Creek) and ground movement during the construction and operation of the project.

17.5 Potential impacts – cumulative

Cumulative impacts are those that act together with other impacts to affect the same resources or receptors in a way where the sum of the impacts is greater than the individual. Cumulative groundwater impacts can be related to groundwater extraction (active and passive), groundwater drawdown, and groundwater quality.

The groundwater model has been used to predict cumulative groundwater tunnel inflows at the end of construction (Year 2024) and throughout the operations phase (to Year 2100) of the project. The maximum calculated inflow rates are summarised in **Table 17-18**.

Table 17-18 Predicted maximum cumulative tunnel inflows

Modelling scenario	Combined tunnel length	Year	Max inflow (megalitres per day)	Max inflow (litres per second per kilometre of tunnel)
Scenario 1	4 kilometres	2016	0.32	0.92
Scenario 2	21.2 kilometres	2023	0.95	0.52
Scenario 3	27.7 kilometres	2023	1.52	0.62

During construction, cumulative impacts on groundwater would be greatest at the northern extremity of the project near the confluence with the New M5 Motorway at Arncliffe. Modelling predicts an increase in drawdown of 0.5 metres (total drawdown of 4.1 metres) within the alluvium beneath Spring Street Drain due to cumulative impacts with the nearby New M5 Motorway tunnelling in September 2024. Cumulative drawdown within the Hawkesbury Sandstone at the end of construction is predicted to reach 61 metres to the invert of the tunnel at the connection with the New M5 Motorway at Arncliffe.

Once the full extent of the WestConnex projects is operational, groundwater drawdown due to the cumulative impact of the three tunnel projects is not expected to be greater than in any one section of the overall project footprint.

Long term cumulative groundwater tunnel inflows may cause groundwater salinity to increase due to surface water from tidal reaches being drawn into or towards the tunnels. Initially, the saline water would be a small fraction of total tunnel ingress but this is expected to increase over time as water is drawn from further afield, although it would always be a minor component of total inflow.

The groundwater modelling has predicted that five registered bores would be drawn down in excess of two metres due to the project and two additional bores would be impacted due to the cumulative impacts of nearby tunnel projects. No additional cumulative impacts are expected at the Rockdale Bicentennial Park and Scarborough Park wetlands.

Cumulative groundwater drawdown has the potential to contribute to settlement. Settlement within the Hawkesbury sandstone is not expected to exceed likely project settlement criteria due to the competent nature of the sandstone. Additional settlement within the alluvium around Spring Street Drain due to cumulative drawdown may occur. Localised groundwater modelling would be undertaken during the detailed design phase to support a detailed settlement analysis.

Refer to **Appendix K** (Groundwater technical report) for further information regarding the assessment of cumulative groundwater impacts.

17.6 Management of impacts

Mitigation and management measures would be implemented during construction and operation of the project to reduce or eliminate the risks to the existing groundwater regime. These environmental mitigation measures, including management, engineering solutions and monitoring, are summarised in **Table 17-19**. These measures would be complemented by the environmental management measures outlined in **Chapter 16** (Soils and contamination) and **Chapter 18** (Surface water and flooding).

Based on the mitigation and management measures it is considered that potential groundwater impacts that may arise as a result of the construction and operation of the project can be effectively managed.

Table 17-19 Environmental management measures – Groundwater and geology

Impact	Reference	Environmental management measures	Timing
Groundwater			
Operational tunnel inflows higher than expected which may exceed the inflow criteria of 1 L/sec/km for any kilometre length of tunnel.	GW1	Where fractured Hawkesbury Sandstone is intersected, a combination of techniques will be investigated to reduce the bulk hydraulic conductivity.	Construction
	GW2	Appropriate measures will be identified and included in the detailed design to reduce the inflow into the tunnels. A target of one litre per second per kilometre for any kilometre length of the tunnel during operation will be adopted.	Detailed design
Groundwater drawdown impacting a water supply well water level by more than two metres	GW3	Impacts on water supply bores will be 'made good' as soon as practicable. Where water supply bores cannot be made good, alternate measures are to be implemented to replace supply.	Construction and Operation
Alteration of groundwater flows and levels due to the installation of subsurface project components	GW4	Measures to reduce potential impacts to groundwater flows due to subsurface components of the project will be identified and included in the detailed construction methodology and the detailed design as relevant.	Detailed design
Actual groundwater inflows and drawdown in adjacent areas exceed predictions	GW5	A detailed groundwater model will be developed by the construction contractor. The model will be used to predict groundwater inflow rates and volumes within the tunnels and groundwater levels (including drawdown) in adjacent areas during construction and operation of the project.	Detailed design
	GW6	Groundwater inflow and groundwater levels will be monitored during construction and compared to the model predictors and groundwater performance criteria. The detailed groundwater model will be updated based on the results of the monitoring as required and proposed management measures to minimise potential groundwater impacts adjusted accordingly to ensure that groundwater inflow performance targets are met.	Construction
Impacts to groundwater quality, groundwater levels or groundwater flows	GW7	Prior to construction, a groundwater monitoring program will be prepared and implemented to monitor groundwater levels, construction and operational groundwater inflows in the tunnels, and groundwater quality in the three main aquifers impacted by construction works. The program will identify groundwater monitoring locations, performance criteria in relation to groundwater inflow and levels, and potential remedial actions that will be considered to address potential impacts. As a minimum, the program will include monthly manual groundwater level and quality monitoring and weekly monitoring of inflow volumes and quality.	Prior to construction

Impact	Reference	Environmental management measures	Timing
Adverse impacts on the local hydrogeological regime due to groundwater discharge	GW8	An operational water treatment plant will be constructed at the Arncliffe Motorway Operations Complex (MOC1) to manage and treat groundwater from the tunnel prior to discharge. Discharge will be undertaken in accordance with the approval conditions and agreed discharge criteria. A summary of the proposed discharge criteria is provided in Chapter 18 (Surface water and flooding).	Operation
Treated groundwater may be discharged to stormwater without consideration to a suitable sustainable use.	GW9	Sustainable water re-use options will be reviewed for treated groundwater during operations.	Construction
Geology (ground movement)			
Ground movements may cause impacts to structures on the surface.	GM10	A geotechnical model of representative geological and groundwater conditions will be prepared by the construction contractor during the detailed design phase prior to the commencement of tunnelling. The model will be used to assess predicted settlement impacts and ground movement during the construction and operation of the project	Detailed design
	GM11	Further assessment of potential settlement impacts, including numerical geotechnical modelling will be undertaken prior to excavation and tunnelling to assess the cumulative predicted settlement, ground movement, stress redistribution and horizontal strain profiles caused by excavation and tunnelling, including groundwater drawdown and associated impacts, on adjacent surface and sub-surface structures. Criteria for surface and sub-surface structures at risk will be determined in consultation with the owner(s) of the structures. Where modelling predicts exceedances of these criteria, an instrumentation and monitoring program will be implemented to measure settlement, distortion or strain as required. Appropriate mitigation measures will be identified and implemented in consultation with the owner(s) prior to excavation and tunnelling works to where possible not exceed the settlement criteria.	Detailed design

17.7 Environmental risk analysis

An environmental risk analysis was undertaken for groundwater and is provided in **Table 17-20** below.

A level of assessment was undertaken commensurate with the potential degree of impact the project may have on that issue. This included an assessment of whether the identified impacts could be avoided or minimised (for example, through design amendments). Where impacts could not be avoided, environmental management measures have been recommended to manage impacts to acceptable levels.

The residual risk is the risk of the environmental impact after the proposed mitigation measures have been implemented. The methodology used for the environmental risk analysis is outlined in **Appendix O** (Methodologies).

Table 17-20 Environmental risk analysis – Groundwater

Summary of impact	Construction/ operation	Management and mitigation reference	Likelihood	Consequence	Residual risk
Impacts to groundwater dependent ecosystems resulting from groundwater drawdown	Construction and operation	GW6, GW7, GW8, GW9	Likely	Minor	Low
Potential for large quantities of inflows of groundwater during construction which would result in increased groundwater drawdown	Construction	GW1, GW2, GW3, GW4, GW5	Likely	Minor	Low
Impacts to structures and surfaces resulting from ground movements.	Construction	GM10, GM 11	Likely	Minor	Low

(blank page)

18 Surface water and flooding

This chapter describes the potential surface water and flooding impacts associated with the project. The chapter has been informed by surface water and flooding assessments provided in **Appendix L** (Surface water technical report) and **Appendix M** (Flooding technical report). **Table 18-1** sets out the SEARs relevant to surface water and flooding and identifies where the requirements have been addressed in this EIS.

Table 18-1 SEARs - Surface water and flooding

Assessment requirements	Where addressed in this EIS
Water - Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users e.g. bore water for domestic use and irrigation, and for ecological purposes and groundwater dependent ecosystems) likely to be impacted by the project, including rivers, streams, wetlands and estuaries as described in Appendix 2 of the *Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects* (OEH, 2014).	Section 18.2 discusses and maps the existing surface water hydrological regime Chapter 17 (Groundwater and geology) Chapter 12 (Biodiversity)
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake and discharge locations (including mapping of these locations), volume, frequency and duration for both the construction and operational phases of the project.	Section 18.3.1 and Section 18.4.1 discuss surface water balance Chapter 17 (Groundwater and geology)
3. The Proponent must assess and model the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: (a) natural processes within rivers, wetlands, estuaries and floodplains that affect the health of the fluvial, riparian and estuarine systems and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity, water-dependent fauna and flora and access to habitat for spawning and refuge;	Section 18.3.1 and Section 18.4.1 discuss discharges and waterway disturbance during construction Chapter 12 (Biodiversity)
(b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, change in ground water levels, barriers to flows, implications for groundwater dependent on surface flows, ecosystems and species, groundwater users and the potential for settlement;	Chapter 17 (Groundwater and geology)
(c) changes to environmental water availability and flows;	Section 18.3.1 and Section 18.4.1
(d) direct or indirect increases in erosion, siltation, destruction of aquatic and riparian vegetation or a reduction in the stability of river banks or watercourses;	Section 18.3.1 and Section 18.4.1 discusses erosion, scour, siltation and bank stability impacts associated with discharges and waterway disturbance during construction Section 18.2.2 and Chapter 12 (Biodiversity) discusses impacts on riparian vegetation
(e) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of the existing stormwater systems where discharges are proposed through such systems or modifications are proposed to these systems; and	Section 18.3.1 and Section 18.6
(f) measures to mitigate the impacts of the proposal and manage the disposal of produced and incidental water.	Section 18.6

Assessment requirements	Where addressed in this EIS
4. The assessment must provide details of the final landform of the sites to be excavated or modified (e.g. portals and cut and cover works), including final void management and rehabilitation measures.	Chapter 13 (Landscape and visual)
5. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Section 18.6 Appendix L (Surface water technical report)
6. The assessment must include details of proposed surface and groundwater monitoring.	Section 18.6 Chapter 17 (Groundwater and geology)
7. The proposed tunnels must be designed to minimise impacts on aquifers and minimise impacts on groundwater flows and groundwater dependent ecosystems.	Chapter 17 (Groundwater and geology)
Water - Quality	
1. The Proponent must: (a) describe the background conditions for any surface or groundwater resource likely to be affected by the development;	Section 18.2 Chapter 17 (Groundwater and geology)
(b) state the ambient NSW Water Quality Objectives (NSW WQO) (as endorsed by the NSW Government [see www.environment.nsw.gov.au/ieo/index.htm]) and environmental values for the receiving waters (including groundwater where appropriate) relevant to the project and that represent the community's uses and values for those receiving waters, including the indicators and associated trigger values or criteria for the identified environmental values in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government;	Section 18.1 and Appendix L (Surface water technical report)
(c) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Section 18.3.1 and Section 18.4.1 discuss quality and quantity of groundwater pollutants.
(d) identify the rainfall event that the water quality protection measures would be designed to treat;	Section 18.6 discusses construction of sediment basins. Section 18.4.1 discusses rainfall events
(e) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	Section 18.3.1 and Section 18.4.1
(f) demonstrate how construction and operation of the project (including mitigating effects of proposed stormwater and wastewater management) would, to the extent that the project can influence, ensure that: – where the NSW WQOs for receiving waters are currently being met they would continue to be protected; and – where the NSW WQOs are not currently being met, activities would work toward their achievement over time;	Section 18.3.1 and Section 18.4.1 Appendix L (Surface water technical report)
(g) justify, if required, why the WQOs cannot be maintained or achieved over time;	Section 18.3.1 and Section 18.4.1
(h) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Section 18.6

Assessment requirements	Where addressed in this EIS
(i) identify sensitive receiving environments (which may include wetlands/ estuarine waters upstream and downstream of the project including their catchments) and develop a strategy to avoid or minimise impacts on these environments; and	Section 18.2
(j) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	Section 18.6 Appendix L (Surface water technical report)
2. The assessment should consider the results of any current water quality studies, as available, in the project catchment.	Section 18.2 Appendix L (Surface water technical report)
3. The assessment should include concept designs for water quality treatment structures taking into account water sensitive urban design principles	Section 18.2 and Section 18.6
Flooding	
1. The EIS must map the following features relevant to flooding as described in the *NSW Floodplain Development Manual 2005* (NSW Government, 2005) including: (a) Flood prone land; (b) Flood planning areas, the area below the flood planning level; and (c) Hydraulic categorisation (floodways and flood storage areas).	Figures 18-2 – 18-4 Appendix M (Flooding technical report)
2. The Proponent must assess and model, where appropriate, the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and increased storm intensity due to climate change) including:	Potential flooding impacts during construction and operation are assessed in section 18.3.2 and section 18.4.2 respectively.
(a) how the tunnel entries and cut-and-cover sections of the tunnels would be protected from flooding during construction works;	Measures to manage potential flooding impacts are described in section 18.6
(b) any detrimental increases in the potential flood affectation of the project infrastructure and other properties, assets and infrastructure;	Section 18.3.2 and Section 18.4.2
(c) consistency (or inconsistency) with applicable Council floodplain risk management plans;	Section 18.4.2
(d) compatibility with the flood hazard of the land;	Section 18.2 Section 18.4
(e) compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land;	Section 18.1.2
(f) whether there would be adverse effect to beneficial inundation of the floodplain environment, on, or adjacent to or downstream of the site;	Section 18.3.2 and Section 18.4.2
(g) downstream velocity and scour potential;	Section 18.3.2 and Section 18.4.2
(h) impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Services and Council;	Section 18.4.2
(i) any impacts the development may have on the social and economic costs to the community as consequence of flooding;	Section 18.4.2
(j) any mitigation measures required to offset potential flood risks attributable to the project (these mitigation measures must be discussed with the State Emergency Services and Council where appropriate).	Section 18.6
3. The assessment should take into consideration any flood studies undertaken by local government councils, as available.	Section 18.1

Assessment requirements	Where addressed in this EIS
4. The EIS must assess and model the effect of the proposed development (including fill) on current flood behaviour for the 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 18.4.2
Environmental Impact Statement	
1. (i) a demonstration of how the project design has been developed to avoid or minimise likely adverse direct and indirect impacts during construction and operation of the project	Section 18.3, Section 18.4 and Section 18.6

18.1 Assessment approach

18.1.1 Overview

Two technical assessments were undertaken to inform the assessment of surface water and flooding impacts on the project (refer to **Appendix L** (Surface water technical report) and **Appendix M** (Flooding technical report)). Each of these assessments are summarised in this chapter.

The study area for the assessments discussed in this chapter includes the project's construction boundary and operational infrastructure footprint, as well as areas where potential surface water and flooding impacts could occur as a result of the construction or operation of the project. The layout of the construction ancillary facilities, tunnel alignment and permanent power supply alignment is presented in **Chapter 6** (Project Description) and **Chapter 7** (Construction).

Surface water

The method of assessment for surface water included:

- A desktop review and analysis of existing information to determine potential receptors, characterising the existing environment and identify potential issues
- A field assessment including collecting samples from monitoring sites to confirm and supplement the findings of the desktop analysis and refine understanding of potential issues
- Assessment of potential construction and operational impacts related to hydrology, geomorphology, water quality and water quantity, including:
  - Review of estimated surface water and groundwater inputs and construction discharge volumes
  - Qualitative assessment of how construction discharges may impact the receiving environment and the effects of physical disturbance to the waterways during construction
  - Identification of potential pollutants of concern in surface water and estimation of the quality and quantity of pollutants in tunnel groundwater to inform the qualitative assessment of the effect of the proposed discharges of treated construction water on the receiving environment
  - Water balance to estimate combined operational surface water discharge volumes and qualitative assessment of how operational discharge may impact the receiving environment
  - Modelling of the existing and proposed conditions to inform the types of stormwater treatment devices using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). See **Appendix L** (Surface water technical report) for further information and MUSIC modelling results
  - Development of a box model to simulate the mixing of treated discharges from the New M5 Motorway water treatment plant at Arncliffe with the Cooks River.
- Identifying appropriate measures to mitigate potential impacts.

Flooding

The method of assessment for flooding included:

- A review of available data and existing flood studies within the catchments that are crossed by the project
- Development of a set of hydrologic and hydraulic models (collectively referred to as 'flood models') of the catchments that are located within the study area. Rainfall-runoff modelling software packages were used to generate design discharge hydrographs for input to the hydraulic models, while flooding patterns in the vicinity of the project were defined using the TUFLOW two-dimensional (in plan) hydraulic modelling software
- Running the flood models and preparing exhibits showing flood behaviour under present day conditions for design floods with a range of Annual Exceedance Probability's (AEP), as well as the probable maximum flood (PMF). AEP refers to the frequency of floods, see **Appendix M** (Flooding technical report) for further details of flood frequency
- Assessment of the impact the project would have on flood behaviour and flood hazards for the aforementioned design flood events
- Assessment of the impact a partial blockage of major hydraulic structures would have on flood behaviour under operational conditions
- Assessment of the impact future climate change would have on flood behaviour under operational conditions
- Assessment of potential measures which are aimed at mitigating the risk of flooding to the project and its impact on existing flood behaviour and flood hazards.

Relevant guidelines and policies

The following key guidelines and policies were considered in the assessment:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000) (the 'ANZECC Water Quality Guidelines')
- NSW Water Quality Objectives (WQOs) (NSW Department of Environment, Climate Change and Water (DECCW) 2006)
- *Managing Urban Stormwater (MUS) – Soils and Construction* series of handbooks
- *Botany Bay and Catchment Water Quality Improvement Plan* (BBWQIP) (SMCMA 2011)
- *Floodplain Development Manual* (DIPNR 2005)
- NSW government planning directions and guidelines, including the *Guideline on Development Controls on Low Flood Risk Areas and Direction 4.3 - Flood Prone Land*
- *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC 2007)
- Council flood related planning controls, including *Rockdale Local Environmental Plan 2011* (RCC 2011b) and *Sydney Regional Environmental Plan No 33 – Cooks Cove*
- *Rockdale Technical Specification - Stormwater Management* (RCC 2011c).

Further details on the relevance and use of these guidelines in the assessment is provided in **Appendix L** (Surface water technical report) and **Appendix M** (Flooding technical report), in addition to a list of other relevant guidelines and policies that apply to the project.

Previous studies

A number of previous studies into various aspects of surface water and flooding in the study area have been reviewed to inform the assessment, these are listed in **Appendix L** (Surface water technical report) and **Appendix M** (Flooding technical report).

NSW Water Quality Objectives

For each catchment in NSW, the state government has endorsed the community's environmental values for water, known as the NSW Water Quality Objectives. The NSW Water Quality Objectives (WQOs) (NSW Department of Environment, Climate Change and Water (DECCW) 2006) are consistent with the agreed national framework of the ANZECC Water Quality Guidelines and are '*primarily aimed at maintaining and improving water quality, for the purposes of supporting aquatic ecosystems, recreation and where applicable water supply and the production of aquatic foods suitable for consumption and aquaculture activities*' (DECCW 2006).

The NSW WQOs include qualitative and quantitative objectives related to protecting aquatic ecosystems, visual amenity, recreation and aquatic foods and are presented in full in **Appendix L** (Surface water technical report).

18.1.2 Project features

The project features relevant to surface water and flooding are summarised below. Further details can be found in **Chapter 6** (Project description) and in **Appendix L** (Surface water technical report) and **Appendix M** (Flooding technical report). The existing and proposed surface flooding and drainage system is shown in **Chapter 6** (Project description).

Surface water

During construction, the Arncliffe construction ancillary facility (C1) and Rockdale construction ancillary facility (C2) would have a construction water treatment plant to treat groundwater inflows into the tunnel. The President Avenue construction ancillary facility (C3) would have a construction water treatment plant to treat groundwater that is extracted for the cut and cover structure during excavation of the ramps at President Avenue. Each of the construction ancillary facilities would also include a groundwater pre-treatment basin. Surface runoff from unsealed surfaces would be directed to sediment basins.

During operation, the project would be located in areas where existing stormwater drainage systems presently control runoff from the surrounding urbanised catchments. As a result, it would be necessary to upgrade, alter or augment the existing stormwater drainage systems for operation of the project. This would include a new pavement drainage system along President Avenue to accommodate the proposed road widening and a new pit and pipe drainage system to control runoff from the proposed Rockdale Motorway Operations Complex (south) (MOC3). Runoff captured before entering the tunnel portals would be pumped to a water quality basin within Rockdale Bicentennial Park where it would be treated before discharge into Scarborough Ponds.

The tunnel drainage system has been designed to have a separate groundwater and surface water collection system. The tunnel groundwater collection system would capture groundwater ingress from the drained sections of the tunnel.

The tunnel surface water collection system would capture:

- Tunnel maintenance wash down water
- Fire system (i.e. deluge) water
- Water from an accidental rupture of a fire main or hydrant
- Accidental spills of fuels or other chemicals carried by vehicles using the tunnel
- Water transported into the tunnel by vehicles
- Fire system testing water.

The project would construct its own water treatment plant at Arncliffe Motorway Operations Complex (MOC1) to treat tunnel groundwater flows from the tunnels.

Figures showing the proposed tunnel and stormwater drainage concept are provided in Figure 5-2 and 5-2 for construction and Figure 6-1 to 6-4 for operation in **Appendix L** (Surface water technical report).

Flood mitigation

The following flood mitigation measures would be incorporated into the project works:

- Upgrading the existing box culvert structure that crosses President Avenue at Scarborough Ponds and raising the level of President Avenue in order to improve its level of flood immunity
- Providing flood protection barriers around, or raising the level of the tunnel portals and tunnel ancillary facilities where there is a risk of inundation from flooding
- Lowering of ground elevations in the vicinity of Rockdale Bicentennial Park in order to control major overland flow and local drainage (further discussed below).

The project has been designed to minimise changes in the conveyance and storage of floodwaters in order to minimise impacts on existing flooding behaviour. This has included provision of compensatory floodplain storage within Rockdale Bicentennial Park to offset the displacement of floodplain storage caused by the project. Further details are provided in **Appendix M** (Flooding technical report).

18.2 Existing Environment

This section provides an overview of the study area relating to the catchments, waterways and wetlands in the study area and the existing water quality, drainage infrastructure and flood behaviour in these water bodies.

18.2.1 Key water bodies

Five key water bodies are located along the route of the project, which form part of the larger Botany Bay catchment. The water bodies and catchments are shown in **Figure 18-1**. **Table 18-2** and **Table 18-3** provide a brief description of the water bodies and a summary of the water quality and patterns of main stream flooding and major overland flow under present day conditions. **Figure 18-1** shows the surface water monitoring locations. The present day flooding patterns at one per cent AEP are shown in **Figure 18-2** to **Figure 18-4**. A one per cent AEP means that there is a one per cent chance that there would be floods of equal or greater magnitude each year, giving an average recurrence interval of 100 years.

Further information can be found in **Appendix L** (Surface water technical report) and **Appendix M** (Flooding technical report).

Table 18-2 Key water bodies within the study area

Water body	Project components	Description of water quality	Existing flood behaviour
Cooks River - the Cooks River catchment covers an area of around 10,000 hectares in south western Sydney, discharging to Botany Bay at Mascot. The Cooks River catchment is highly urbanised and has a history of intensive land development with land uses ranging from residential to heavy industry. Within the catchment it is estimated that roughly 89 per cent of stormwater travels through a combination of pit and pipe networks, open concrete channels, metal sheet piled channels and rock armoured channels.	Construction • Arncliffe construction ancillary facility (C1) Operation • Northbound and southbound tunnels connecting to stub tunnels from the WestConnex New M5 Motorway • Ventilation tunnels which connect the tunnels to a surface ventilation facility on the site of the Kogarah Golf Course • Operational tunnel water which would be pumped to the New M5 Motorway water treatment plant at Arncliffe, with treated flows ultimately discharged to the Cooks River.	Surface water monitoring was undertaken as part of the WestConnex New M5 Motorway project[1]. Two monitoring points were used, represented by SW3 and SW4 as shown in Figure 18-1. Median concentrations for total nitrogen, total phosphorus, reactive phosphorus, cadmium, chromium, copper, lead and zinc were above ANZECC (2000) slightly to moderately disturbed trigger levels with nitrate, arsenic, mercury and nickel also exceeding on some occasions. It is noted that the limit of reporting for cadmium, copper and chromium was set above the slightly to moderately disturbed trigger level on some occasions. Median lead concentrations were also above the ANZECC (2000) 80 per cent species protection level and zinc consistently exceeded the aquatic foods criteria. Median concentrations of ammonia exceeded the ANZECC (2000) recreational water quality criteria with iron also exceeding the respective criteria on some occasions. The results are indicative of a highly disturbed urban waterway.	Kogarah Golf Course is affected in flood events. A ponding area forms in the northern portion of the golf course. High hazard flooding conditions and floodway areas are generally confined to the main channel of the Cooks River in the vicinity of the golf course and M5 East Motorway.

[1] AECOM, 2015, New M5 Environmental Impact Statement

Water body	Project components	Description of water quality	Existing flood behaviour
Muddy Creek - The Muddy Creek catchment covers an area of approximately 615 hectares and flows in a north-easterly direction until it meets the Cooks River. High density residential and commercial development is present along the major transport corridors, as well as the Rockdale town centre, while an industrial area is centred on West Botany Street and Lindsay Street[2]. The Muddy Creek channel has been highly modified as a result of urbanisation and consists of a series of concrete and brick lined channels and closed box culvert structures that extend from Willison Road in Carlton to Bestic Street in Kyeemagh.	Construction • The construction water treatment plants for C2 and C3 would discharge to stormwater drainage ultimately draining to Muddy Creek. Operation • The shared cycle and pedestrian pathway between Bestic Street and Bay Street for pedestrians and cyclists is located within the Muddy Creek catchment. The tunnel also passes through the catchment.	Surface water monitoring was undertaken as part of the Project (SW1 and SW2 on **Figure 18-1**) within Muddy Creek. Median concentrations of total nitrogen, total phosphorus, reactive phosphorus, copper and zinc exceeded ANZECC (2000) slightly to moderately disturbed trigger levels with lead, nitrate and ammonia also exceeding on some occasions. Median zinc concentrations exceeded the aquatic foods criteria and zinc, copper, lead and ammonia concentrations were also above the 80% species protection level on some occasions. Median ammonia and zinc concentrations exceeded the recreational water quality criteria on some occasions. Zinc consistently exceeded the aquatic foods criteria. The pH was below the ANZECC (2000) slightly to moderately disturbed low range level on one occasion at SW1. The results are indicative of a highly disturbed urban waterway.	A number of locations between Bay Street and Bestic Street are affected during flood event. High hazard flooding conditions are generally confined to the main channel of Muddy Creek where it runs between West Botany Street and Bestic Street, adjacent to the alignment of the proposed shared cycle and pedestrian pathway. A section of West Botany Street and Bruce Street to the south of Muddy Creek acts as a floodway during a flood event.

2 Lyall and Associates, 2017, Southlink Motorway Flooding and Drainage Investigation, Volume 1 – Report

Water body	Project components	Description of water quality	Existing flood behaviour
Scarborough Ponds - Scarborough Ponds catchment covers an area of approximately 400 hectares and comprises a series of three pond systems including Rockdale wetland, the Northern Scarborough Pond and the Southern Scarborough Pond. The western and eastern sides of the catchment predominantly comprise medium density residential development with some industrial development situated around the northern edges of the Rockdale wetland. Stormwater runoff from urbanised areas is conveyed by a pit and pipe network into Scarborough Ponds via a series of piped outlets[2].	Operation • Tunnel portals with entry and exit ramps connecting the project tunnels with President Avenue • Widening and raising of President Avenue between Oakdale Avenue and O'Connell Street to accommodate the new connection • Rockdale Motorway Operations Complex (north) (MOC2) which would house the Operational Motorway Control Centre, car parking, deluge tanks, workshop, office, bulky equipment store, pump station and pump room and a work yard • Rockdale Motorway Operations Complex (south) (MOC3) which would house the Rockdale Ventilation Facility and an electrical substation • Network adjustments at the Princes Highway/ President Avenue intersection to provide additional southbound left turn and northbound right turn lanes onto President Avenue • Shared cycle and pedestrian pathway between Bay Street and Civic Avenue for pedestrians and cyclists • Operational water quality basin in the south-eastern corner of Rockdale Bicentennial Park which would discharge to Rockdale wetland • Construction access decline, deluge system and maintenance depot near West Botany Street.	Surface water monitoring was undertaken at the Rockdale wetland (SW3) and the Northern Scarborough Ponds (SW4) as part of the Project. In Rockdale wetland, median concentrations of ammonia, total nitrogen, total phosphorus, reactive phosphorus, copper and zinc exceeded ANZECC (2000) freshwater trigger levels with chromium, nitrate and lead also exceeding on some occasions. Iron and manganese concentrations also exceeded the ANZECC (2000) recreational water quality criteria. Ammonia, copper, lead and zinc concentrations exceeded the 80% species protection level on some occasions. All iron concentrations exceeded the recreational water quality criteria as did the median ammonia concentrations. In Northern Scarborough Ponds, median concentrations of total nitrogen, total phosphorus, copper and zinc exceeded the estuarine/marine trigger levels. All ammonia concentrations exceeded the recreational water quality criteria and iron concentrations exceeded the recreational water quality criteria on some occasions. The pH was outside the trigger levels range on some occasions. Some of the total nitrogen concentrations were higher than levels typical of urban stormwater inflows indicating the elevated levels are likely to be related to another source. Equatica[3] indicated that the elevated nitrogen levels in the Rockdale wetland were likely to be attributable to groundwater inflows affected by residual waste within a landfill located adjacent to the Rockdale wetland. Water quality monitoring was conducted by GHD in 2016-17 on behalf of Bayside Council, Equatica in 2012-13 on behalf of the former Rockdale City Council and in 1999 by Rockdale City Council. The key findings in relation to water quality within the receiving waters of Rockdale wetland and Northern Scarborough Pond are detailed in Appendix M (Surface water technical report). The results are indicative of a highly disturbed urban waterway. There are existing odour issues at the Scarborough Ponds associated with temperature inversions (a natural phenomenon common to lakes and waterways). Refer to section 4.1.3 of Appendix M (Surface water technical report) for further information.	Capacity constraints in the piped drainage system which runs under Rockdale Bicentennial Park results in flooding being experienced in a number of commercial / industrial properties which are located on the western side of West Botany Street for flood events. Existing commercial / industrial development located at the eastern end of Bermill Street is also impacted by flooding during storms. While existing residential development is not impacted by main stream flooding along Scarborough Ponds Creek, several properties located along the eastern and western sides of the open space corridor through which the creek runs are impacted during a flooding event. The reach of Scarborough Ponds as it runs through the Rockdale Bicentennial Park acts principally as a flood storage area for flood events. Depths of ponding along this reach of Scarborough Ponds are sufficient to result in hazardous conditions arising during a flood.

Table 18-3 Other water bodies within the study area

Water body	Project components	Existing flood behaviour
Spring Street Drain - The Spring Street Drain sub-catchment covers an area of approximately 257 hectares and flows in an easterly direction through a concrete lined channel until it meets Muddy Creek. A sub-branch of the Spring Street Drain runs in a north-easterly direction and joins the main channel approximately 160 metres upstream of West Botany Street. This sub-branch comprises a series of channel and culvert reaches, ending in a concrete lined channel where it discharges into Spring Street Drain[2].	The mainline tunnel crosses under the Spring Street Drain. No surface works are proposed within the catchment. As the project would not impact the waterway or catchment at surface, surface water impacts within this catchment have not been considered any further.	While the project is in tunnel where it crosses the Spring Street Drain catchment, it is noted that floodwater originating from the Spring Street Drain catchment discharges to Muddy Creek along Bestic Street.
Eve Street Wetland – Eve Street Wetland covers an area of approximately 28 hectares and drains to the west. The catchment is predominantly low to medium density residential development with some areas of open space in its lower reaches. Stormwater runoff from urbanised areas is conveyed by a pit and pipe network into Eve Street Wetland. Flows that surcharge the Eve Street Wetland are conveyed via a vegetated channel in an easterly direction under the bridged section of the M5 Motorway, prior to discharging into the Cooks River[2].	The mainline tunnel crosses under the Eve Street Wetland catchment. No surface works are proposed within the catchment. As the project would not impact the waterway or catchment at surface, surface water impacts within this catchment have not been considered any further.	While the project is in tunnel where it crosses the Eve Street Wetland catchment, it is noted that floodwater originating from the Eve Street wetland discharges to Muddy Creek along Bestic Street.
Kogarah Golf Club drain - An unnamed watercourse runs easterly through the Kogarah Golf Club course. The drain, an artificial, tidally affected watercourse. Its catchment is around 15 hectares receiving runoff from the southern portion of the golf course.	A portion of the stormwater runoff generated within the project operational water treatment plant would be discharged to the drain.	N/A
Other waterways	The proposed power supply connection between the Ausgrid Canterbury sub-transmission substation and the Rockdale Motorway Operations Complex south runs through the catchments of Cup and Saucer Creek, Wolli Creek, Bardwell Creek, Muddy Creek and Rockdale wetland. As the project would not impact the waterway or catchment at surface, surface water impacts within this catchment have not been considered any further.	N/A

[3] Equatica, 2011. Bicentennial Park Wetland Concept Report, prepared for Rockdale City Council

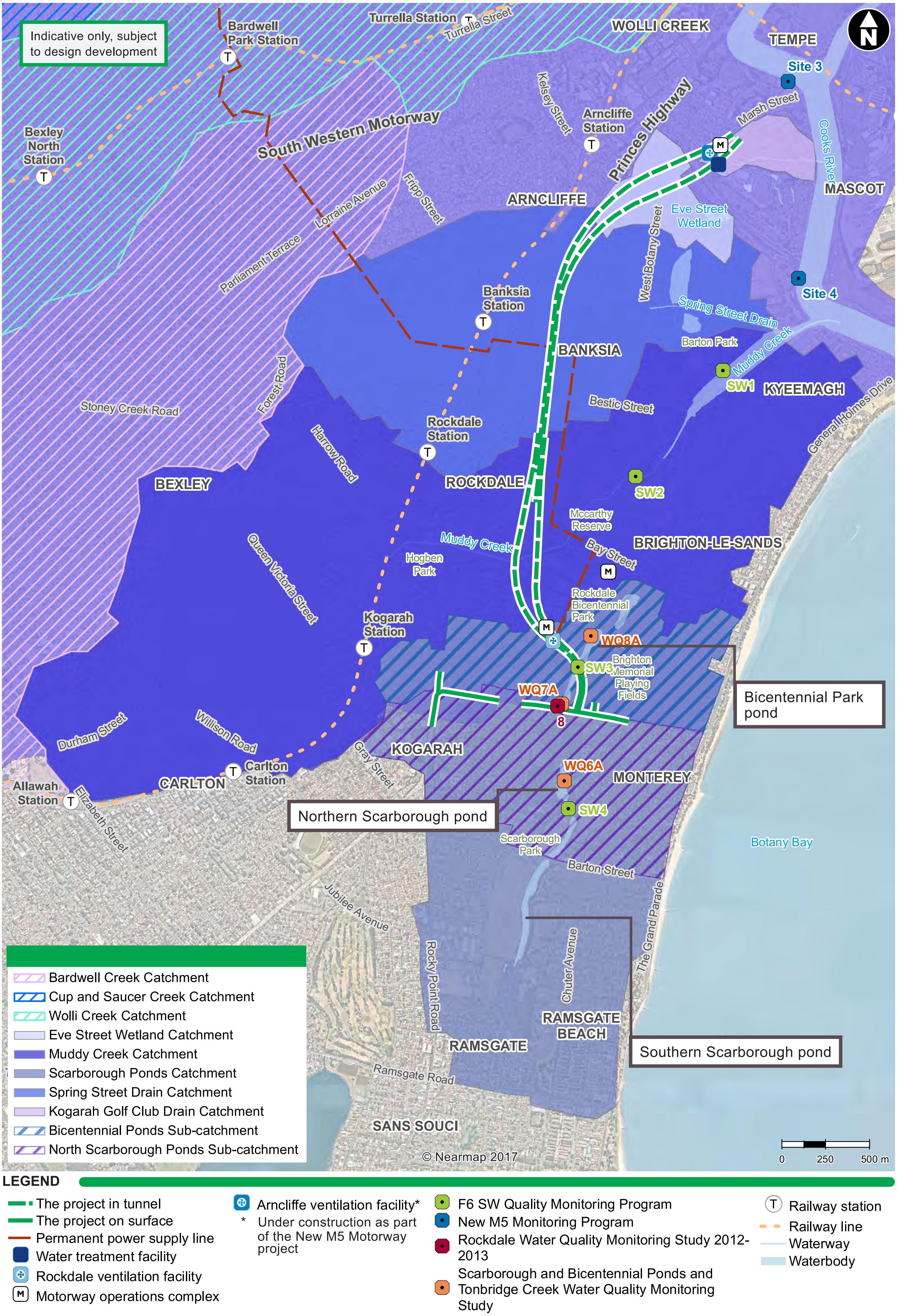


Figure 18-1 Surface water hydrology and monitoring locations

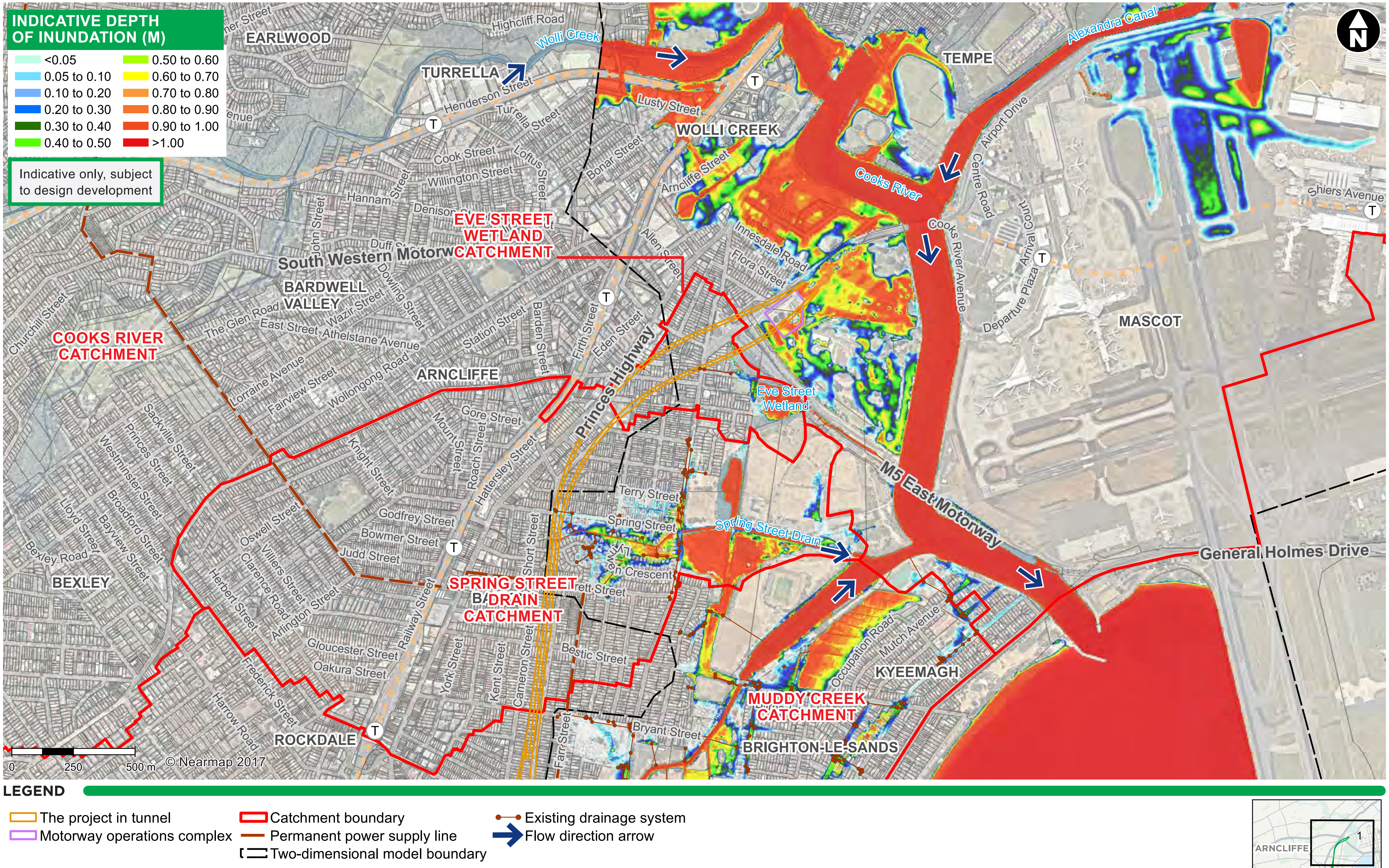


Figure 18-2 Present day flooding patterns at one per cent AEP

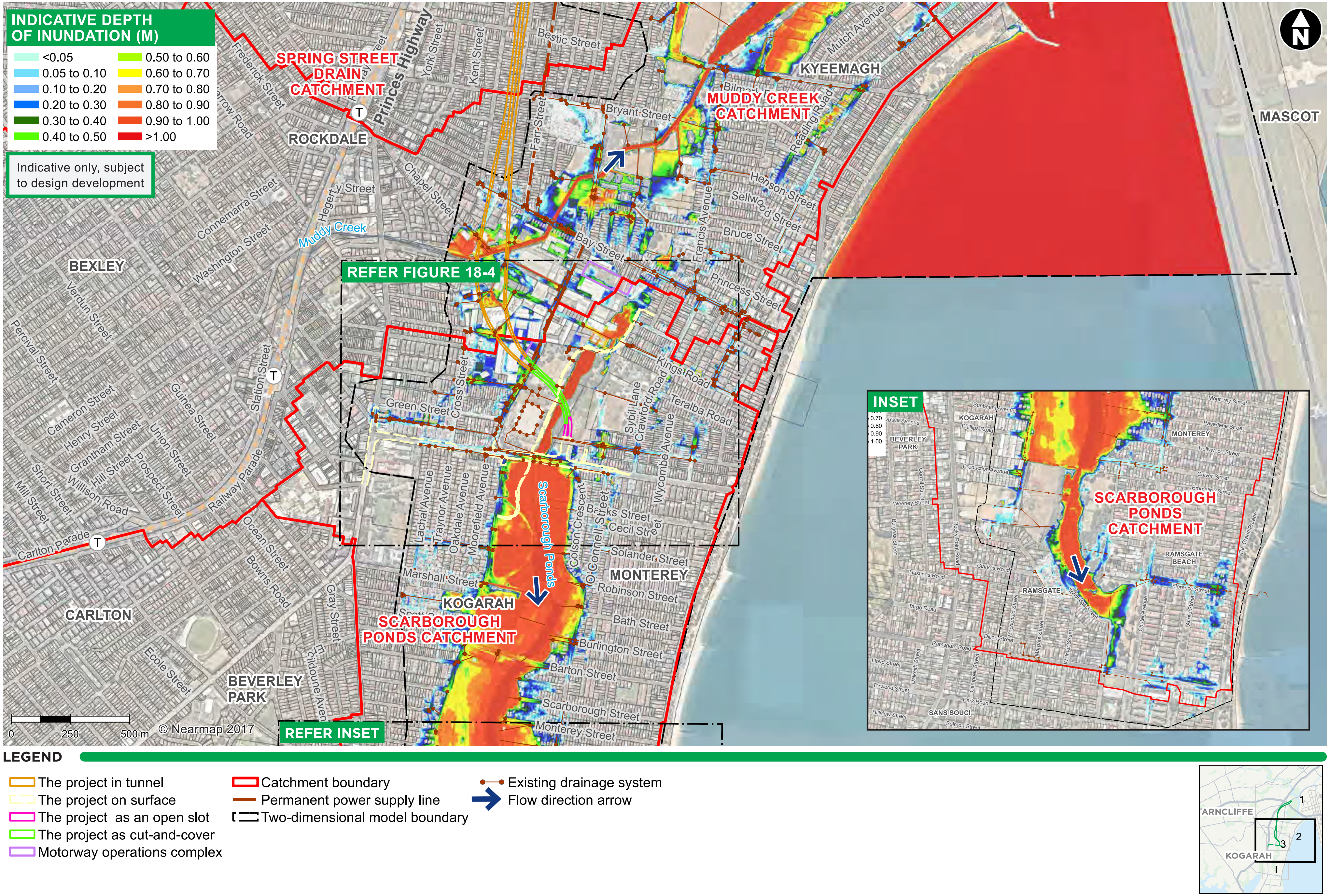


Figure 18-3 Present day flooding patterns at one percent AEP

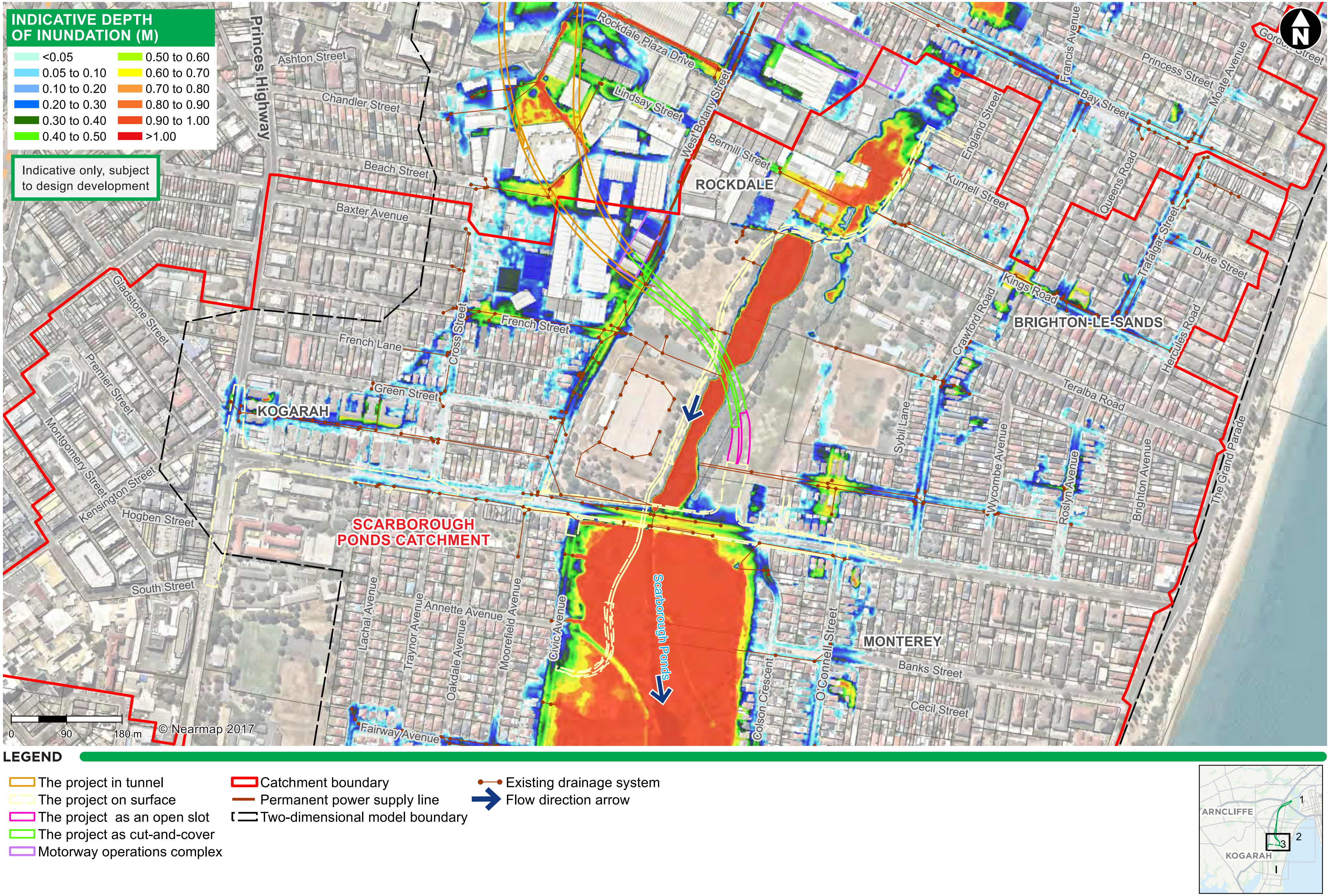


Figure 18-4 Present day flooding patterns at one per cent AEP

18.2.2 Riparian corridors

Existing riparian vegetation has been identified and assessed within EIS **Appendix H** (Biodiversity development assessment report). A summary of the riparian vegetation is provided in **Table 18-4** below.

Table 18-4 Summary of riparian vegetation

Surface water feature	Description of riparian vegetation
Rockdale wetland	Dense cover of native trees with scattered shrubs and groundcovers. Dense weeds such as *Lantana camara* (Lantana) and *Erythrina crista-galli* (Cockspur Coral Tree) occurred in patches.
Open channel between President Avenue and Northern Scarborough Pond	A dense reedland of *Typha orientalis* (Typha) and *Phragmites australis* (Common Reed) extended westward of the channel, whilst the eastern bank supported scattered *Casuarina glauca* (She Oak) trees.
Muddy Creek upstream of Bestic Street	Saltmarsh and mangroves present. High impact weeds included *Juncus acutus* (Sharp Rush) at the southern extent of the saltmarsh. Vegetation within drainage lines entering Muddy Creek included a narrow mangrove forest originating from a stormwater culvert at Cairnsfoot Special School. The other was west of the C A Redmond football field, comprised of mown lawn and reeds (*Phragmites australis*).

18.2.3 Sensitivity of receiving environments

A summary and assessment of the sensitivity of the receiving environments (including estuarine and marine environments downstream) to hydrological and water quality impacts associated with the project is provided within **Table 18-5**.

The chain of ponds which make up Scarborough Ponds are considered to be of moderate sensitivity due to having good ecological habitat despite being highly modified systems. Botany Bay is considered to be a moderately sensitive downstream environment considering its high conservation value and significant tidal exchange. Cooks River and Muddy Creek are considered to be of low sensitivity due to their limited ecological habitat and significant tidal exchange.

Table 18-5 Sensitivity of receiving environments

Surface water feature	Description of surface water feature in study area	Condition	Sensitivity
Receiving Environments			
Lower Cooks River	Estuarine, anthropogenic banks, poor water quality, limited riparian vegetation in reach within study area, key fish habitat, some recreational use.	Highly disturbed	Low
Muddy Creek	Estuarine, anthropogenic channel, poor water quality, limited riparian vegetation, some ecological value in estuarine reach, some recreational use.	Highly disturbed	Low
Rockdale wetland	Freshwater, modified open water body, poor water quality with tendency for algal blooms, provides ecological habitat and passive recreational use.	Highly disturbed	Moderate
Northern Scarborough Ponds	Tidally influenced, modified open water body, poor water quality, provides ecological habitat and passive recreational use.	Highly disturbed	Moderate
Southern Scarborough Ponds	Tidally influenced, modified open water body, provides ecological habitat and passive recreational use.	Highly disturbed	Moderate
Botany Bay	Estuarine, largely unmodified, good water quality, high ecological value, high recreational value.	High conservation value	Moderate

18.3 Potential impacts – construction

18.3.1 Surface Water

This section identifies and assesses the potential construction phase impacts to the hydrology, geomorphology, natural processes and water quality of surface waters.

Surface Water Balance

A water balance was conducted to estimate the annual volumes of surface water and groundwater that would be used and discharged during construction of the project. The water balance for each construction ancillary facility is summarised in **Table 18-6**. **Table 18-7** provides the estimated volumes of water that would be discharged during construction from each facility. The proposed construction discharge points are shown in **Appendix L** (Surface water technical report).

Table 18-6 Construction surface water balance

Construction Ancillary Facility	Surface Water inputs (ML/year)	Groundwater inputs (ML/year)	Groundwater / Surface Water losses following reuse (ML/year)	Total discharge volume (ML/year)
C1	37	193	1	229
C2	37	84	2	119
C3	140	Variable – 265 typical [1]	5	400
C4	0.9	0	Negligible	0.9
C5	0.6	0	Negligible	0.6
C6	1.8	0	Negligible	1.8

[1] Based on daily discharge volume during periods where dewatering of cut and cover tunnel works required.

Table 18-7 Construction daily discharge volumes

Construction Ancillary Facility	Daily discharge volume (ML/day)
C1	0.6
C2	Variable - 0.3 typical, up to 1.5 short term rate [1]
C3	Variable – 0.8 typical, up to 2.0 short term rate [1]
C4	0.0025
C5	0.0017
C6	0.0049

[1] Based on daily discharge volume during periods where dewatering of cut and cover tunnel works required

It is noted that groundwater discharge volumes estimated for the President Avenue construction ancillary facility (C3) reflect what is considered to be an upper bound of potential inflows as a result of dewatering of cut and cover tunnel works. Construction methods, staging and sequencing would require further consideration during detailed design to ensure that inflows are maintained at manageable levels within the constraints of the construction site.

During construction, treated groundwater and surface water would be discharged to the surface water environment from each of the construction ancillary facilities. A comparison between the discharge volumes and daily flows within the waterways is provided in **Table 18-8**.

During dry periods, water levels in the Rockdale wetland are controlled by local groundwater levels and the Rockdale wetland weir. Therefore an increased inflow from construction discharges is unlikely to significantly affect the water level within the pond with the additional flow discharging over the weir and being conveyed to the Northern Scarborough Pond.

Table 18-8 Assessment of discharge volume impacts during construction

Potential impact	Estimated mean daily flow	Estimated tidal inflow per tidal cycle
Northern Scarborough Pond	3 ML/day	< 6 ML/day
Muddy Creek	13 ML/day	76 ML/day
Cooks River	230 ML/day	2170 ML/day
C1	0.6 ML/day	Not applicable
C2	0.3 typical, up to 1.5 short term rate [1]	Not applicable
C3	0.8 ML/day up to 2.0 [1] ML/day short term rate	Not applicable
C4	0.0025 ML/.day	Not applicable
C5	0.0017 ML/day	Not applicable
C6	0.0049	Not applicable

[1] Based on daily discharge volume during periods where dewatering of cut and cover tunnel works required.

The increase in flow would likely have a minor impact on water levels within the Northern Scarborough Pond. The additional flow may increase flushing through the system which may temporarily alter stratification conditions during construction.

Due to the relatively higher sensitivity of Northern Scarborough Pond (including existing odour issues) and with consideration to the estimated discharge volumes when compared to daily flows and tidal exchange within that waterway, the continuous discharges from the construction water treatment plant at the Rockdale construction ancillary facility (C2) would instead be directed via stormwater drainage to the less sensitive Muddy Creek. Whilst volumes associated with dewatering of excavations and groundwater inflows at the President Avenue construction ancillary facility (C3), prior to sealing of the base of the cut and cover structure, are likely to be relatively minor, there is potential for short term higher inflows to occur if rock fractures are intercepted. To manage this risk, it is assumed discharges from the construction water treatment plant at the President Avenue construction ancillary facility (C3) are also directed to Muddy Creek.

Connection works in West Botany Street would be required to facilitate a pumped connection to stormwater drainage towards Muddy Creek and siting of the water treatment plant in the north west portion of the President Avenue construction ancillary facility (C3). Surface water discharges from the facility would continue to be directed to Rockdale wetland and Northern Scarborough Pond.

Discharges from the shared cycle and pedestrian pathways construction ancillary facilities (C4 and C5) would be minor only due to their relatively small footprint, with negligible hydrologic impact. There would be no change in the impervious area for the Princes Highway construction ancillary facility (C6) footprint, therefore discharges would not change from existing conditions. Discharges from other localised road and power supply connection works would also be minor due to their relatively small footprint, with negligible hydrologic impact due to the existing surfaces being primarily impervious.

Waterway disturbance

Construction activities at the President Avenue construction ancillary facility (C3) would result in the direct disturbance of a large proportion of the Rockdale wetland and a small portion of the open channel south of President Avenue (which drains to the Northern Scarborough Pond). Construction activities for the project would not directly disturb the Northern Scarborough Pond.

Diaphragm walls would be installed from the surface to form a water tight wall prior to the cut and cover excavation works commencing for the construction of the ramps and portals. The Rockdale wetland bed and banks inside the diaphragm walls would be dewatered and excavated and require complete restoration following construction. A temporary diversion channel would be provided within the Rockdale wetland to divert water flows around the disturbance footprint during construction.

The cut and cover tunnel excavation works would not commence within the pond until management measures such as a coffer dam and the water tight diaphragm wall had been installed. Therefore, with the proposed diversion channel providing hydrologic connectivity within the pond and a continuous groundwater inflow, the cut and cover tunnel construction and associated dewatering is considered to pose a negligible impact to flows through the Rockdale wetland. Impacts to water levels within areas of the Rockdale wetland outside the construction footprint are also likely to be negligible.

Hydrologic connectivity and the hydraulic control between the Rockdale wetland and Northern Scarborough Pond may be disrupted during the works to widen President Avenue. Temporary measures to drain storm flows between the Rockdale wetland and Northern Scarborough Pond would be required throughout construction.

Whilst the Rockdale wetlands bed and banks would be significantly disturbed within the coffer dam/diaphragm wall, and its surface area would be reduced, around 90% of the Rockdale wetland surface area would be retained throughout construction. Therefore geomorphic processes such as sedimentation of suspended solids conveyed in stormwater runoff would continue to occur.

Floating wetlands have been installed by Bayside Council in the southern part of Rockdale wetlands. A trash rack is also installed on the stormwater outlet located downstream of the Rockdale Bicentennial Park car park. The floating wetlands are unlikely to be directly disturbed as a result of the construction works, but would need to be protected and maintained during construction. The stormwater pipe would be diverted around the cut and cover structure and the trash rack relocated or replaced.

The pond would eventually be restored following completion of the tunnelling and shared cycle and pedestrian pathway works. Potential opportunities to incorporate improvements to the Rockdale wetland system as part of the restoration works are described in **section 18.6**.

A small portion of the open channel south of President Avenue would be filled in as part of the widening of President Avenue. However this would not result in any adverse impacts to the channel's hydraulic or hydrologic function, albeit slightly reducing its length.

The disturbance to the bed and banks of the Rockdale wetland and open channel would significantly increase the turbidity within the Rockdale wetland and open channel within the disturbance footprint temporarily during construction. If not properly managed, disturbance of the Rockdale wetland and open channel has the potential to result in erosion and mobilisation of bed and bank sediments downstream. These sediments could potentially contain toxicants and elevated nutrients.

The proposed power supply connection would cross the catchments of Cup and Saucer Creek, Wolli Creek, Bardwell Creek, Spring Street Drain and Muddy Creek. Where the power supply connection corridor crosses the watercourses of Wolli Creek, Bardwell Creek and Muddy Creek, it would be installed in a conduit attached to existing bridges. The power supply connection corridor alignment would be finalised during detailed design with the alignment realigned around (or bored under) sensitive environmental features including Bardwell Creek. With implementation of the proposed management measure listed in **section 18.6**, potential impacts to these waterways are considered to be negligible for the power supply connection.

Discharge water quality

Assessment of the potential impacts of proposed discharges of treated construction wastewater and surface water on the receiving environment included identification of potential pollutants of concern in surface water together with a qualitative assessment of the impact, with consideration to the proposed water management systems and typical management practices adopted for road and tunnel projects. Due to the high level of uncertainty in pollutant quality, pollutant quantities were not estimated for surface waters. The quality and quantity of pollutants in tunnel groundwater were estimated based on available groundwater quality data, the discharge criteria and estimated tunnel water discharge volumes during construction. Given the high level of uncertainty in pollutant generation from other sources in construction tunnel water, pollutant quantities were not estimated for the other sources. Potential pollutants of concern were identified for consideration when identifying management measures.

Construction wastewater

Wastewater generated from the following construction zones / activities is considered to be 'construction wastewater' and would be captured, tested and treated at a construction water treatment plant (if required) prior to reuse, discharge, or disposal offsite if necessary. Construction wastewater would be generated from the following sources:

- Tunnelling works
- Surface works which intercept groundwater
- Any areas within the site compound which are identified during construction to be of high risk of contaminating surface waters (e.g. vehicle refuelling areas, chemical and fuel storage areas, concrete washout areas, vehicle washdown areas).

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

- Groundwater ingress
- Rainfall runoff in open cut tunnel portals and ventilation shafts
- Dust suppression water
- Wash down runoff
- Concrete washout.

A high proportion of the water generated from tunnelling would be collected from groundwater seepage. Natural groundwater quality along the alignment is spatially and temporally variable. The groundwater quality review indicates that groundwater inflows into the tunnel works would likely contain elevated levels of chromium, iron, nickel, zinc, total nitrogen, total phosphate and ammonia. Groundwater inflows into the cut and cover construction works in Rockdale Bicentennial Park before the base is lined are likely to contain elevated concentrations of arsenic, iron, lead, nickel, zinc, total nitrogen and ammonia, which could lead to impacts such as increased turbidity, lower dissolved oxygen levels and nutrients, increases in toxicant concentration and increased alkalinity.

The use of chemicals in the treatment and curing process of concrete as well as the concrete dust itself could result in the tunnelling wastewater having an increased alkalinity.

Rainfall runoff in excavated tunnel portals and ventilation shafts may account for loading of atmospheric pollutants such as nitrogen into the tunnel wastewater, however the loads are likely to be negligible in comparison to the respective loading from groundwater inflows.

Wastewater from vehicle refuelling areas and fuel storage areas would be captured within bunded areas, tested and then either treated within the construction water treatment plant or discharged at a licensed facility.

Wastewater generated by dewatering activities during trenching of the proposed power supply connection would be managed in accordance with Managing Urban Stormwater Soils and Construction, Volume 2A Installation of services (DECC, 2008a) to minimise potential impacts to downstream waterways.

Water quality and discharge volumes from the tunnels are likely to be highly variable due to the program of activities during construction. A high level estimate of the quantity of pollutants likely to be discharged from each treatment plant is provided in **Table 18-9**. The assumptions for this estimate are described in section **Appendix L** (Surface water technical report).

Provided that the treatment measures discussed in **Section 18.6** achieve the recommended discharge criteria, tunnel wastewater discharges during construction are likely to have a negligible impact on receiving water quality.

Table 18-9 Construction wastewater pollutant quantities at discharge locations

Pollutant	Arncliffe (C1) Groundwater discharge (DP1) (kg/yr)	Rockdale (C2) Groundwater discharge (DP2) (kg/yr)	President Avenue (C3) discharge (DP3) (kg/yr)
Arsenic	1.9	2.0	5.5
Cadmium	0.01	0.01	0.05
Chromium (III + VI)	0.1	0.1	0.4
Copper	0.1	0.1	0.4
Iron	57.6	60	78
Lead	0.1	0.1	1.9
Manganese	71.0	74	164
Mercury	0.005	0.01	0.006
Nickel	1.0	1.0	1.9
Zinc	4.2	4.4	11
Total Nitrogen	192	442	571
Total Phosphate	38	50	3.1
Ammonia	307	322	441

Construction surface water

The quality and quantity of the pollutants generated within the construction areas would be variable and subject to the soil profile, phase of works, extent of disturbance, extent of pavement and roofs, construction activities and climatic influences (e.g. rainfall).

The key pollutants of concern from unsealed construction areas would be sediment (e.g. total suspended solids), oil and grease and pH. Other pollutants (such as nutrients) may also be bound to the sediment or present in dissolved form. Their concentrations would be variable but providing appropriate erosion and sediment controls are implemented, they are considered to pose a low risk to the surface water environment and human health during the construction phase of the Project.

The tunnelling construction ancillary facilities would be paved at the commencement of the project. Water quality and the volume of surface water being discharged from the construction ancillary facilities are likely to be highly variable due to the program of activities during construction.

Provided that the management measures are implemented during construction and the discharge criteria is achieved (see **section 18.6**), short term impacts are expected to be manageable With the measures in place, the pollutant load being discharged from the project will be minor compared to the pollutant load being discharged to the receiving waterways from the wider catchment and with consideration to the tidal flushing effect which will occur within the estuarine receiving environments resulting in a negligible impacts on receiving water quality are considered to be negligible.

Assessment of potential construction impacts

The potential construction impacts on surface water hydrologic and geomorphic processes and water quality are summarised in **Table 18-10**.

Table 18-10 Potential construction impacts on surface water

Construction activities/source of pollutants	Potentially affected waterways	Potential impacts
Discharge from construction water treatment plants	Rockdale wetland North Scarborough Pond Cooks River Muddy Creek	Increase in baseflow rate to receiving waterways Impacts to ambient water quality from the presents of pollutants as a result of poorly treated discharges
Discharged of wastewater directly to receiving waterways or significant increase in discharge volume	Rockdale wetland North Scarborough Pond Cooks River	Mobilisation of sediment and scour
Construction activities associated with President Avenue interchange and shared cycle and pedestrian pathway	Rockdale wetland North Scarborough Pond	Impacts to the hydrological and geomorphic processes within Scarborough Ponds from changes to discharge volumes
Construction of surface works at President Avenue and the construction of main tunnel, ventilation tunnel and shared cycle and pedestrian pathway	Rockdale wetland North Scarborough Pond	Disturbance of Scarborough Ponds bed and banks resulting in increased erosion and sedimentation
Construction activities at the President Avenue construction ancillary facility (C3)	Rockdale wetland	Direct disturbance of Rockdale wetland and a small portion of the open channel south of President Avenue resulting in disrupted hydrologic connectivity and increased turbidity
Open cuts, batter slopes and stockpiles Direct disturbance of waterway bed and/or banks as a result of earthworks and construction of instream structures	Rockdale wetland Northern Scarborough Pond Cooks River Muddy Creek	Erosion and mobilisation of exposed soils from stormwater runoff and wind, leading to sedimentation in receiving waterways and impacts on water quality (increased turbidity, lower dissolved oxygen levels and nutrients which could lead to algal blooms and aquatic weed growth, increases in toxicant concentration and reduced visual amenity)
Dust, litter and other pollutants associated with building materials and demolition waste	Rockdale wetland Northern Scarborough Pond Cooks River Muddy Creek	Mobilisation of pollutants into waterways leading to impacts on water quality and reduced visual amenity
Leakage or spills of petroleum hydrocarbons, oils and greases from machinery, equipment or plant or during refuelling Washdown water from construction plant washing or concrete washout water Mobilisation of dust to waterways	Rockdale wetland Northern Scarborough Pond Cooks River Muddy Creek	Pollutants being conveyed to downstream waterways leading to impacts on water quality Increases in alkalinity and toxicant concentration which could lead to fish kills and other undesirable impacts
Construction activities associated with the permanent power supply installation. Open cuts, batter slopes and stockpiles	Cup and Saucer Creek Wolli Creek Bardwell Creek Spring Street Drain Muddy Creek Rockdale wetland	Impacts to ambient water quality as a result of poorly treated dewatered groundwater from power supply connection trench. Oil sheen on water surface and increases toxic concentration which could lead to fish kills and other undesirable impacts.

Measures to manage potential impacts associated with waterway disturbance, hydrological processes and construction discharges are provided in **section 18.6**. The assessment of impacts and management of potentially contaminated sediments, acid sulphate soils and salinity are provided in **Chapter 16** (Soils and contamination).

Measures to manage potential impacts include the development of discharge criteria for the construction water treatment plant at the President Avenue construction ancillary facility (C3) during construction. The criteria have been developed in accordance with ANZECC (2000) and with consideration of the NSW WQOs. The discharge criteria for the construction water treatment plant are provided in **Table 18-21**.

The proposed surface water management measures aim to minimise short term impacts on the receiving waterways during construction. With the implementation of the management measures, and in the context of the overall catchment, any potential short term impacts are unlikely to have a material impact on ambient water quality within the receiving waterways.

Therefore the project is likely to have a negligible influence on whether the NSW WQOs are protected (if currently met) or achieved (if currently not met) during the construction phase.

The likely approach to surface and tunnel water management is outlined in **Figure 18-5**.

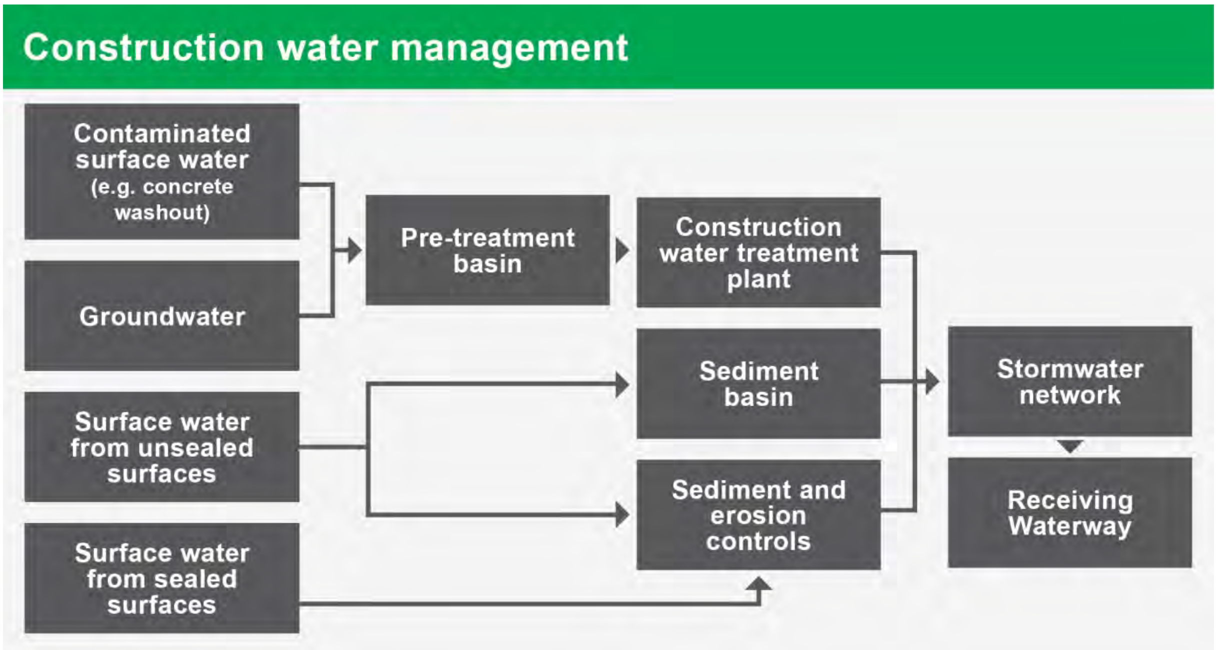


Figure 18-5 Surface water and tunnel water management during construction

18.3.2 Flooding

Construction works 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 for the project (i.e. potential inundation of project sites).

Construction of the project would involve a range of activities at sites of both permanent and temporary occupancy. The construction activities associated with the project that could result in impacts if not mitigated include:

- A range of site facilities including offices, staff amenities, workshops and parking at the five construction ancillary facilities. Site facilities located on the floodplain could pose a safety risk to construction personnel
- The construction of the project would generate a significant amount of spoil which would need to be temporarily stored in stockpile areas. Stockpiles located on the floodplain have the potential to obstruct floodwater and thereby alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to significant quantities of material being washed into the receiving drainage lines and waterways
- Tunnel excavation would likely be carried out using road headers that would be launched from Arncliffe construction ancillary facility (C1) and Rockdale construction ancillary facility (C2). While the tunnel boring arrangement would be designed to accommodate a nominal amount of stormwater runoff, the ingress of floodwater to the tunnel excavations poses a significant risk to personnel safety. It also has the potential to cause damage to machinery and delays in the project timetable
- The construction of cut and cover structures would be carried out at Rockdale construction ancillary facility (C2) and President Avenue construction ancillary facility (C3). The potential for ingress of floodwater into the open excavations poses a significant risk to personnel safety, as well as having the potential to cause damage to machinery and delays to the project timetable
- The main area of surface earthworks on the project would be the construction of the proposed interchange at President Avenue and the associated widening and raising of the existing road. Surface earthworks would also be required to construct the sections of shared cycle and pedestrian pathway that are not located on elevated structures. The inundation of the surface earthworks by floodwater has the potential to cause scour of disturbed surfaces and the transport of sediment and construction materials into the receiving waterways
- A dedicated shared bridge would be constructed over President Avenue and a section of Scarborough Park North. In order to construct the bridge it would be necessary to provide a temporary access road, as well as a series of working pads within Scarborough Park North in an area that is inundated by floodwater that surcharges to Scarborough Ponds during storms. The inundation of the access road and working pads by floodwater has the potential to cause the transport of sediment and construction materials into the receiving waterways as well as damage to machinery and delays to the project timetable. Conversely, raising the access road and working pads to reduce the potential for flooding to the work areas would have the potential to displace floodwaters and exacerbate flood behaviour in adjacent development
- The provision of temporary measures such as site sheds, stockpiles, noise walls and flood protection walls could obstruct the passage of floodwater and overland flow through, which in turn could exacerbate flooding conditions in existing development located outside the construction footprint. Potential increases in peak flood levels could have social and economic impacts on the surrounding community such as damage to residential properties and increased need for emergency response procedures from state emergency services during times of flood.
- The installation of the permanent power supply would be underground either by trenching or, where required, under-boring. The power line would be located within the existing road reserves, with the exception of where it would cross Bardwell Valley Golf Club and pass along the edge of Silver Jubilee Park. The construction site has the potential to be inundated during wet weather events, including trenches and areas of ground disturbance. Dirty floodwater has the potential to scour disturbed surfaces and transport sediment and construction materials into the receiving waterways.

Assessment of potential construction impacts

Potential impacts on flood behaviour at each site during a one per cent AEP design storm are summarised in **Table 18-11**. Further details, including figures showing flooding patterns under construction phase conditions and the increase in water level that could potentially be caused by blocking effects of the construction site, are provided in **Appendix M** (Flooding technical report). The extent to which the proposed construction activities would increase above-floor inundations is subject to further hydraulic assessment during detailed design.

Table 18-11 Potential construction impacts on flooding

Location	Proposed facilities and activities	Potential impacts on flood behaviour
Arncliffe construction ancillary facility (C1)	Site facilities Spoil management Tunnel launch and support	Potential displacement of water due to blocking effects of the construction site. Potential increase in peak flood levels at 16 residential and commercial properties and two lots currently being used for car parking to the north of Marsh Street between 20 and 400 mm. Potential increase in the depth of above-floor inundation on at least one residential property.
Rockdale construction ancillary facility (C2)	Site facilities Spoil management Cut and cover structures Surface earthworks	Potential displacement of water due to blocking effects of the construction site. Potential increase in peak flood levels in two residential properties in West Botany Street by a maximum of 120 mm. Potential increase in above-floor inundation and flood damages in the affected properties
President Avenue construction ancillary facility (C3)	Site facilities Spoil management Cut and cover structures Surface earthworks Bridge structures	Potential displacement of water due to blocking effects of the construction site. Potential increase in peak flood levels in 12 residential properties and one industrial property by a maximum of 20 mm. Potential increase in above-floor inundation and flood damages in the affected properties.
Shared cycle and pedestrian pathways east (C4) construction ancillary facilities	Site facilities Spoil management Surface earthworks	Potential displacement of water due to blocking effects of the construction site. Negligible impacts on existing flood behaviour
Shared cycle and pedestrian pathways west (C5) construction ancillary facilities	Site facilities Spoil management Surface earthworks	Potential displacement of water due to blocking effects of the construction site. Negligible impacts on existing flood behaviour
Princes Highway ancillary facility (C6)	Laydown and parking area for construction vehicles and equipment required for the construction of the President Avenue and Princes Highway intersection upgrade. The site would also include some offices, amenities and workshops	Potential displacement of water due to blocking effects of the construction site. Negligible impacts on existing flood behaviour in its immediate vicinity.
Bestic Street to Bruce Street shared cycle and pedestrian pathway	Surface earthworks (Shared cycle and pedestrian pathway)	Potential displacement of water due to temporary construction works.

Location	Proposed facilities and activities	Potential impacts on flood behaviour
England Street to Kings Road shared cycle and pedestrian pathway	Surface earthworks (Shared cycle and pedestrian pathway)	Potential displacement of water due to blocking effects of the construction site.
President Avenue to Civic Avenue shared cycle and pedestrian pathway	Surface earthworks (Shared cycle and pedestrian pathway) Bridge structures	Potential increase in peak flood levels by a maximum of 12 mm in the section of Scarborough Ponds to the south of President Avenue, as well as a significant number of properties that are located along the eastern and western sides of the open space corridor through which the watercourse runs. Potential displacement of water due to blocking effects of the construction site.
Princes Highway and President Avenue intersection upgrade	Surface earthworks	Potential displacement of water due to blocking effects of the construction site.
Permanent power supply alignment	Surface earthworks Spoil management	Potential displacement of water due to blocking effects of the construction site. The works would be localised, temporary and would involve minimal areas of disturbance. Impacts on the existing flood behaviour would be negligible.

While all ten construction sites would involve works within the floodplain that would need to be managed, the preliminary investigation found that the greatest potential for adverse impacts on flood behaviour in adjacent development is associated with Arncliffe construction ancillary facility (C1), Rockdale construction ancillary facility (C2), President Avenue construction ancillary facility (C3) and the President Avenue to Civic Avenue shared cycle and pedestrian pathways. There is also the potential for all ten construction sites to impact local catchment runoff.

While the findings of the initial assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be undertaken during detailed design, as layouts and staging diagrams are further developed. Consideration would also need to be given to setting an appropriate hydrologic standard for mitigating the impacts of construction activities on flood behaviour, taking into account their temporary nature and therefore the likelihood of a flood of a given AEP occurring during the construction period.

Management measures which would be implemented to mitigate the potential construction related flooding impacts of the project are contained in **section 18.6**.

18.4 Potential impacts – operation

18.4.1 Surface Water

This section identifies and assesses the potential operation phase impacts to the hydrology, geomorphology, natural processes and water quality of surface waters.

Surface water balance

The project does not propose to extract surface water directly from any of the unregulated water sources within the study area during operation, discussed further in **Appendix L** (Surface water technical report).

A surface water balance was undertaken to estimate the operational impacts of the project to the annual volume of flow discharged to the surface water environment as a result of modified surface runoff and treated tunnel water discharges. A summary of the surface water balance for existing and operational conditions is provided in **Table 18-12** and **Table 18-13**. The proposed operational discharged points (ODP) are shown in Appendix L (Surface water technical report).

Table 18-12 Existing conditions surface water balance

Discharge point	Rainfall (ML / year)	Losses (ML / year)	Stormwater runoff volume (ML / year)	Treated tunnel groundwater discharge volume (ML / year)	Total discharge volume (ML / year)
ODP1	137.8	40.2	97.6	0.0	97.6
ODP2	61.1	25.2	35.9	0.0	35.9
ODP3	60.5	23.9	36.6	0.0	36.6
ODP4	169.6	72.3	97.4	0.0	97.4
ODP5	48.0	11.3	36.7 [1]	901.9 [2]	938.6
ODP6	47.1	4.2	42.8	0.0	42.8
ODP7	4.9	0.4	4.4	0.0	4.4
ODP8	21.7	17.6	4.1	0.0	4.1

Notes: 1 From existing New M5 Motorway Arncliffe construction compound; 2 From New M5 Motorway water treatment plant once operational

Table 18-13 Design operational conditions surface water balance

Discharge point	Rainfall (ML / year)	Losses (ML / year)	Stormwater runoff volume (ML / year)	Treated tunnel groundwater discharge volume (ML / year)	Total discharge volume (ML / year)	Impact to discharge volume (ML / year)
ODP1	137.8	38.7	99.1	0.0	99.1	1.6
ODP2	61.1	19.8	41.3	0.0	41.3	5.4
ODP3	60.5	23.8	36.6	0.0	36.6	0.0
ODP4	169.6	66.6	103.1	0.0	103.1	5.7
ODP5	1.3	0.1	1.2	1204.7 [1]	1205.9	268.3
ODP6	47.1	4.2	42.8	0.0	42.8	0.0
ODP7	4.9	0.4	4.4	0.0	4.4	0.0
ODP8	55.0	32.4	22.6	0.0	22.6	18.5

Notes: 1 Includes New M5 Motorway water treatment plant and F6 water treatment plant

Stormwater quality

The project includes sections of aboveground roadway, and interchanges with existing surface roads, and subsurface road tunnels. New surface roadway exposed to direct rainfall is proposed at the intersection of President Avenue and Princes Highway. The tunnel ramps at President Avenue would also generate a minor amount of surface runoff which would be captured and pumped to the surface for treatment.

Increases in impervious area (such as road pavement) exposed to direct rainfall would contribute to an increase in runoff volume and pollutant mobilisation. Runoff from road pavement would typically contain pollutants such as sediments, nutrients, oils and greases and heavy metals, from atmospheric deposition, vehicle leaks, operational wear, road wear or spills. These pollutants could potentially impact on water quality when discharged to receiving waterways.

A preliminary stormwater drainage strategy including treatment measures has been developed for the project which would be finalised during detailed design. The final selection and design of treatments would consider the sensitivity of the environment, changes in imperviousness as a result of the project, environmental, operational and hydraulic constraints and the BBWQIP objectives, which set targets for pollutant load reductions (discussed further in **Appendix L** (Surface water technical report)).

The stormwater drainage strategy would include the water quality basin to treat runoff from the tunnel portal at President Avenue. The water quality basin which incorporates biofiltration and swales are commonly used water sensitive urban design (WSUD) systems. They take into account WSUD principles by using vegetation and soil media to attenuate, filter and treat runoff prior to release to surface waters. Other opportunities to implement stormwater treatments (including passive treatments) for existing pavements and non-road pavement project elements would be investigated during detailed design.

Stormwater treatment of project elements may include:

- Landscaped areas will be suitably profiled, vegetated and stabilised to control erosion
- Passive treatment of stormwater from the shared cycle and pedestrian pathway pavement. This could include diverting stormwater to a grass or vegetated buffer adjacent to the pavement or through use of a permeable pavement system
- Incorporation of rainwater harvesting and proprietary devices to treat runoff from ancillary buildings and pavement where feasible and reasonable.

The above passive treatment and rainwater harvesting measures take into account WSUD principles by replicating a natural system through infiltration and reuse respectively to reduce runoff volumes.

Specifying a rainfall event for operational stormwater treatment measures is not considered to be appropriate. Operational measures are designed based on pollutant load reduction (rather than a rainfall event).

Tunnel water quality

The tunnels would require drainage infrastructure to capture two separate drainage streams, the first to collect groundwater ingress (tunnel groundwater) and a second to collect stormwater ingress at portals as well as spills, maintenance washdown water, fire suppressant deluge and other potential water ingress events.

The two tunnel drainage streams are expected to produce flows containing a variety of pollutants. The pre-treatment water quality of each drainage stream is expected to vary considerably, and consequently it is likely that the two drainage streams would need to be collected and treated separately as follows:

- Tunnel groundwater would be captured and pumped to the operational water treatment plant at Arncliffe.
- Tunnel surface water would be captured in the sump (pit that collects water) where it would undergo some treatment (sediment and free oil screening). The water would be tested and a determination made whether it can be:
  - pumped to surface and treated at the operational water treatment plant (if of suitable quality for the treatment plant to treat)
  - pumped to surface and discharged without further treatment
  - removed directly from the sump by tanker for treatment and disposal offsite.

Tunnel Groundwater

The groundwater quality review indicates that tunnel groundwater from the tunnel would likely contain concentrations of iron, total nitrogen and ammonia which are elevated in relation to the New M5 Motorway discharge criteria. The anticipated manganese concentration, whilst below the discharge criteria, is significantly elevated in comparison to ambient water quality within the Cooks River.

A “box model” was developed to assess how the quality and quantity of pollutants associated with treated releases from the operational water treatment plant would impact the Cooks River for two scenarios:

- Scenario 1 – The project’s treated tunnel water discharges (9.6 L/s Flow)
- Scenario 2 – Cumulative discharge of the project + New M5 Motorway + M4M5 Link treated tunnel water (38.2 L/s).

The findings are summarised in **Appendix L** (Surface water technical report).

The results indicate that impacts to ambient water quality within the Cooks River would be negligible with the exception of manganese for Scenario 2.

The adopted manganese concentration is likely to be conservative as some manganese would likely be removed during the primary sedimentation process. In any case, water quality (0.009 mg/L) would still be below both the ANZECC (2000) slightly to moderately disturbed criteria (3.6 mg/L) and recreational water quality criteria (0.1 mg/L) for manganese. No detrimental impacts as a result of the slight increase in concentration are likely to occur.

Iron, total nitrogen and ammonia treatment would likely be required to achieve the New M5 Motorway discharge criteria. The assumed zinc concentration in tunnel groundwater was only slightly above the proposed discharged criteria for Scenario 2. The benefits of treatment are considered to be negligible, therefore further investigation at detailed design would be required to determine whether zinc treatment is warranted.

Treated tunnel water discharges are likely to be fresher than the estuarine receiving waters in the Cooks River with groundwater drawdown at the tunnel potentially leading to an increase in tunnel water salinity over time (refer to Groundwater technical report (**Appendix K**)). The tunnel discharges are likely to provide a freshening effect to waters within the immediate vicinity of the outlet, which would be similar to the effect of fresh stormwater discharges occurring at the outlet. The freshening affect would diminish within close proximity of the outlet as mixing occurs. The freshening affect is also likely to diminish at the outlet overtime as tunnel water salinity increases. The box model indicates that impacts to ambient water quality within the Cooks River would be negligible due to the mixing and regular flushing of the system with the impact shown to diminish as tunnel water salinity increases.

Tunnel Surface water

The volume and quality of tunnel surface water would be highly variable. Surface water discharge volumes to the Cooks River would therefore also be highly variable with some highly polluted surface water potentially removed for treatment and disposal elsewhere. It is therefore not practical to assess the quantity of pollutants which could potentially be discharged. Tunnel surface water discharges would be intermittent and the quality would be consistent with the discharge criteria for the Cooks River. Therefore impacts as a result of tunnel surface water discharges to the Cooks River would be negligible.

The likely approach to operational water management is outlined in **Figure 18-6**.

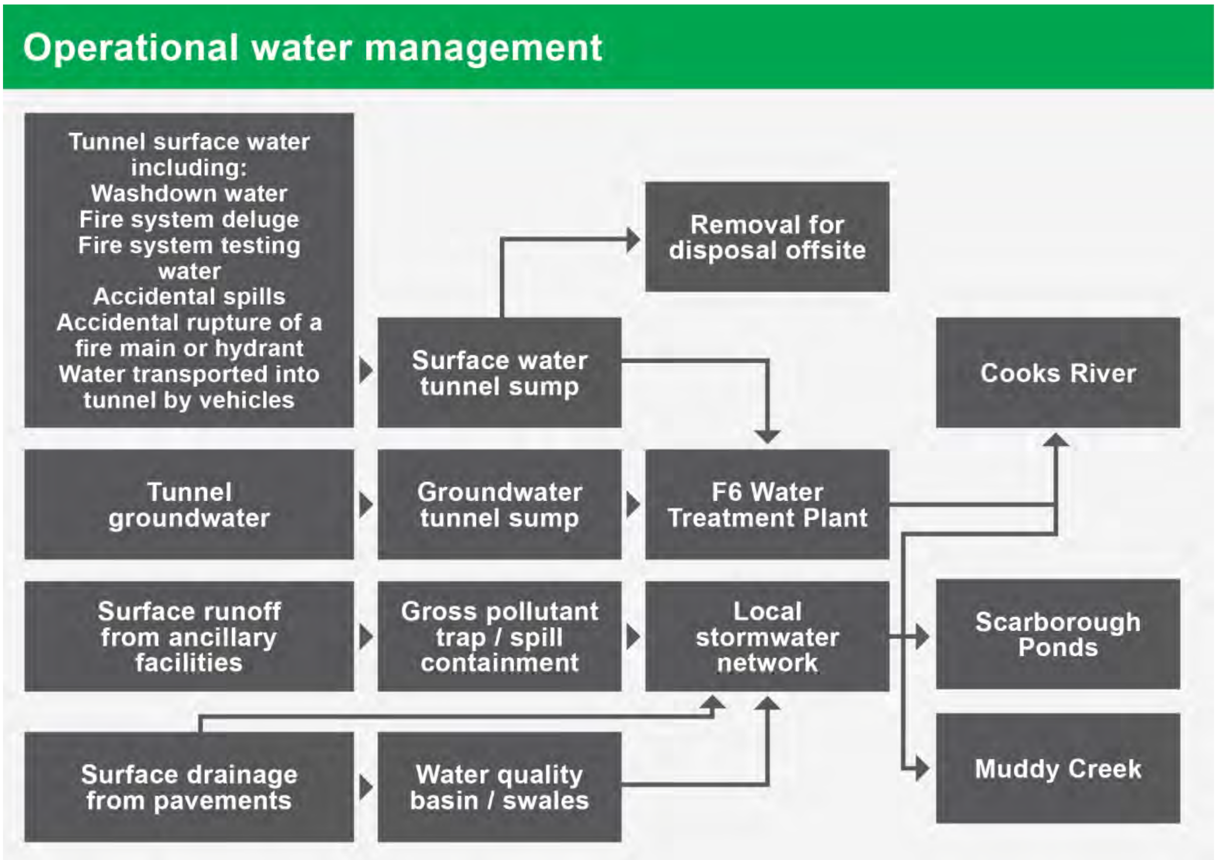


Figure 18-6 Operational water management

Spills

Spills of oils, lubricants, hydraulic fluids and chemicals could potentially occur during the operation of the project due to vehicle or plant and equipment leakages or a vehicle crash. Any contaminant spill within the project footprint has the potential to pollute downstream waterways, if conveyed to waterways via the stormwater network. The severity of the potential impact depends on the magnitude and/or location of the spill in relation to sensitive receptors, emergency response procedures and/or management controls implemented on site, and the nature of the receiving environment.

The preliminary stormwater drainage strategy and tunnel drainage strategy identified the need for spill containment facilities at the following locations:

- President Avenue water quality basin
- Mainline tunnel sump
- Ancillary facilities site at West Botany Street
- Water treatment plant site at Arncliffe

The proposed spill containment facilities would be designed to manage the potential risks to an acceptable level. Impacts to Scarborough Ponds and Cooks River are therefore likely to be minimal.

Impacts and management measures for contaminated runoff and spills are discussed further in **Chapter 16** (Soils and contamination).

Assessment of potential operational impacts

The potential operational impacts on surface water hydrologic and geomorphic processes and water quality are summarised in **Table 18-14**.

Table 18-14 Potential operational impacts on surface water

Activities/source of pollutants	Potentially affected waterways	Potential impacts
Continuous discharge from operational water treatment plant	Cooks River	Increase in baseflow rate to receiving waterways Impacts to ambient water quality as a result of poorly treated discharges
Increase in imperviousness in affected catchments	Rockdale wetland Northern Scarborough Pond	Increase in stormwater runoff volume
Discharges of wastewater at new discharge locations or where discharge volumes are significantly increased at existing locations	Rockdale wetland North Scarborough Pond Cooks River	Mobilisation of sediment and scour
Modifications to hydraulic controls and infilling to widen President Avenue	Rockdale wetland Northern Scarborough Pond	Impacts to hydrological regime
Poorly treated tunnel groundwater or surface water releases from the operational water treatment Poorly treated stormwater Spill events Increases in impervious area, such as road pavement, exposed to direct rainfall contributing to an increase in runoff volume	Cooks River Rockdale wetland Northern Scarborough Pond	Impacts to water quality (increased turbidity, lower dissolved oxygen levels and nutrients increases in toxicant concentration, increased alkalinity)

Impacts to the hydrologic and geomorphic processes, environmental water availability and flow would be negligible during operation. Management and mitigation measures are discussed in **section 18.6**.

Measures to manage potential impacts include the development of discharge criteria for the operational water treatment plant at Arncliffe. The criteria have been developed in accordance with ANZECC (2000) and with consideration of the NSW WQOs. The discharge criteria for the operational water treatment plant are provided in **Table 18-22**.

Impact on NSW Water Quality Objectives

Scarborough Ponds

The preliminary stormwater drainage strategy (which includes the water quality basin proposed at Rockdale Bicentennial Park) and proposed management measures discussed in **section 18.6** would minimise impacts to ambient water quality within Scarborough Ponds such that impacts to Scarborough Ponds are likely to be negligible.

Water quality within the Scarborough Ponds does not currently meet the NSW Water Quality Objectives.

Opportunities for the project to provide further stormwater quality improvements and to work towards achievement of the NSW WQOs for Scarborough Ponds would be considered during detailed design. MUSIC modelling (refer *Modified Treatment Opportunity*) indicates that by providing gross pollutant traps at two operational discharge points (ODP1 and ODP3), an overall reduction in pollutant loads could be achieved. As the operational surface infrastructure is only a small portion of the overall catchment, improvements to ambient water quality within Scarborough Ponds would still likely be negligible.

Ambient water quality improvements could also be achieved by incorporating measures to remove nutrients within Rockdale wetland as part of the restoration of the pond. These opportunities would be further investigated during detailed design.

Indicative discharge volumes from C3 are likely to be of a similar order of magnitude to tidal inflows in Northern Scarborough Pond. Provided the treatment measures achieve the recommended discharge criteria, impacts to toxicant and nutrient levels within Scarborough Ponds are considered to be negligible, if discharges are directed to Scarborough Ponds. Discharge of treated construction wastewater to Scarborough Ponds would increase the daily freshwater inflow to Northern Scarborough Ponds. This would alter the stratified salinity profile within the Northern Scarborough ponds in a similar way to intermittent fresh stormwater flows, although the impact would be continuous during construction. Given the receiving environment regularly receives fresh stormwater inflows, the temporary impact to the salinity profile during construction is unlikely to adversely impact the waterway.

Cooks River

Treated flows from the operational water treatment plant would increase the volume of water discharged into the Cooks River. Whilst it is unlikely that the project would have a beneficial impact on ambient water quality when increasing discharge volumes, the proposed treatment facilities would minimise the impact by treating groundwater to a quality suitable for discharge to the Cooks River. As discussed above, impacts to ambient water quality are likely to be negligible. Therefore the project is considered to have a negligible influence on stakeholder goals to achieve the NSW WQOs for the Cooks River over time.

Muddy Creek

Runoff from a portion of the shared cycle and pedestrian pathway would ultimately discharge to Muddy Creek during operation. With implementation of the proposed management measures, pollutant loading from the shared cycle and pedestrian pathway is considered to be negligible. Therefore the project is considered to have a negligible influence on stakeholder goals to achieve the NSW WQOs for Muddy Creek overtime.

18.4.2 Flooding

The flood models were used to assess the impact of flooding to the project as well as the potential for the project to exacerbate flooding conditions in areas outside the project. **Table 18-15** summarises the hydrologic standards that were adopted in this assessment. These standards would be incorporated into the design of the project. The structure of the models that were originally developed to define flood behaviour under present day conditions (based on the existing stormwater drainage system) were adjusted to incorporate details of the project under operational conditions.

Appendix M (Flooding technical report) contains a series of figures showing flood behaviour under pre- and post-project conditions for a range of storm events (between 20 per cent and 0.2 per cent in magnitude). The assessment presented in the technical report is primarily focussed on the 1% AEP storm as the impacts during this event are typically greater than more frequent storm events.

Table 18-16 identifies the potential operational impacts the various components of the project would have on flood behaviour.

Table 18-15 Summary of adopted assessment criteria and hydrologic standards

Aspect	Requirement
Flooding of tunnel portals and ancillary facilities	• Tunnel portals are to be located above the PMF level or the 1% AEP flood level plus 0.5 metres (whichever is greater). This level of security against ingress is commensurate with the consequence of flooding to the tunnels and the risk to road users and is consistent with the current standard adopted in the design of road and rail tunnels in NSW. • The same hydrologic standard would apply to operational tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwater would have the potential to inundate the tunnel or infrastructure that it is reliant upon for its safe operation. • The same hydrologic standard would apply to emergency facilities such as disaster recovery sites and tunnel deluge systems as well as electrical substations that are reliant for the safe operation of the motorway and its ancillary facilities.
Flooding of motorway ramps and local road connections	• A 1% AEP hydrologic standard has been adopted for motorway ramp and local road connections, where feasible, based on the extent of upgrade requirements and the hydrologic standard of the local road network (e.g. President Avenue intersection).
Modifications to existing road network	• As a minimum, modifications to existing roads are to be configured to ensure the existing level of flood immunity is maintained. Ideally, local road modifications are to provide a minimum hydrologic standard of 10% AEP.
Shared cycle and pedestrian pathways	• A 1 Exceedance per Year (EY) hydrologic standard has been adopted for shared cycle and pedestrian pathways in accordance with the current standard adopted by Roads and Maritime for cycleways and shared user paths that are separated from the road corridor. • Consideration is also to be given to the flood risk to cyclists and pedestrians during larger floods (e.g. 1% AEP event) as a result of high hazard flooding conditions.
Impact of project operation on flooding and existing development	• Floods up to 1% AEP in magnitude are to be considered in the assessment of measures which are required to mitigate any adverse impacts on flood behaviour attributable to the project. • Changes in flood behaviour under larger floods up to the PMF event are also to be assessed in order to identify impacts on critical infrastructure and vulnerable development, as well as to identify potentially significant changes in flood hazard as a result of the project.
Impact of flooding on proposed construction activities	• Construction related flood risks and impacts need to be evaluated in the context of the construction period in order to set requirements that are commensurate to the period of time that the risk exposure occurs. To this end, this report identifies the risks and impacts associated with each construction activity such that informed decisions can be made on the flood criteria that are set as part of the flood risk management plan for the construction of the project.
Impact of future climate change on flood behaviour	• The assessment of the potential impact future climate change could have on flood behaviour in the vicinity of the project was based on: – increases in 1% AEP design rainfall intensities ranging between 10 and 30 per cent in accordance with the NSW Government's *Floodplain Risk Management Guideline: Practical Considerations of Climate Change* (DECC 2007)[1]; and – rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 in accordance with the NSW Government's *Sea Level Rise Policy Statement* (NSW Government 2009). • The assessment of the impact of the project on flood behaviour under future climate change was based on assessing the effect of the proposed works on present day flood behaviour during a 0.5 % and 0.2 % AEP event as proxies for assessing the sensitivity to an increase in rainfall intensity on the 1% AEP event due to climate change.

Table 18-16 Potential operational impacts on flooding

Location	Proposed facilities	Potential impacts on flood behaviour
Arncliffe motorway operations complex	No additional permanent surface works are proposed beyond those that are to be constructed as part of the New M5 Motorway.	Potential increase in peak flood levels in the open space of the Kogarah Golf Course and the road reserve of Marsh Street by a maximum of 11 mm.
Rockdale motorway operations complex (north)	Motorway ancillary facility comprising motorway control centre, tunnel deluge system, maintenance and storage facilities. The motorway ancillary facility would be raised relative to existing ground levels so that the openings to the motorway control centre and the tunnel deluge system are located above the PMF level.	Potential increase in peak flood levels in two residential properties in West Botany Street by a maximum of 120 mm. Potential increase in above-floor inundation and flood damages in the affected properties.
Rockdale motorway operations complex (south)	Motorway ancillary facility comprising ventilation exhaust and supply, electrical substation and disaster recovery facility. The tunnel ancillary facility would be raised relative to existing ground levels so that the openings to the elements listed above are located above the PMF level. Lowering of ground levels within an area of the Rockdale Bicentennial Park adjoining West Botany Street by an average of 1.2 m to provide compensatory floodplain storage. This compensatory floodplain storage could be provided as part of the re-establishment of Rockdale Bicentennial Park following the construction of the cut and cover structure.	Potential increase in peak flood levels along West Botany Street by a maximum of 20 mm.

Location	Proposed facilities	Potential impacts on flood behaviour
President Avenue interchange and surface works	Surface road works and tunnel portal to connect President Avenue to the F6 Extension - Stage 1 tunnels. A new pavement drainage system would intercept runoff generated by direct rainfall at the tunnel portal. A new stormwater drainage system would be provided along President Avenue to accommodate the road widening.	Potential increase in peak flood levels within the section of Scarborough Ponds to the north (upstream) of President Avenue by a maximum of 30 mm. Potential localised increase in peak flood levels by a maximum of 20 mm within the front yards of two residential properties that are located on the northern and southern side of President Avenue, to the east of the new interchange. Potential increase in above-floor inundation and flood damages in the affected properties. Potential impact on a property located on the southern side of President Avenue east of Colson Crescent due to increased flow to the east of the tunnel portals. Potential increase in PMF flood levels across the upper reaches of the Scarborough Ponds and Muddy Creek floodplains. There would be negligible change in PMF levels along the reach of Scarborough Ponds to the south of President Avenue. Potential for localised increases in flow velocities within the section of Scarborough Ponds immediately downstream of the project due to the upgrade of the stormwater drainage system and the relocation of its outlets to accommodate the proposed widening of President Avenue. Impacts to the velocities of discharge and the duration of flooding are assessed in section 6.1.4 of Appendix M (Flooding technical report). The assessment concluded that there will be a significant increase in the rate of flow discharging into Scarborough Ponds at pavement drainage outlets 1 and 2, as well as transverse drainage structure XD01. The total peak flow in Scarborough Ponds downstream of President Avenue will be slightly reduced. This is primarily due to the upgrade of transverse drainage culvert XD01 and the raising of President Avenue which will increase the early release of flow from the section of Scarborough Ponds upstream of President Avenue and prevent the relatively large rate of discharge due to the surcharge of President Avenue that occurs under present day conditions. There would be no change in the duration of flooding within the Scarborough Ponds catchment as a result of the project.

Location	Proposed facilities	Potential impacts on flood behaviour
Bestic Street to England Street shared cycle and pedestrian pathway	As the design for the section of the shared cycle and pedestrian pathway between Bestic Street and Bruce Street is at concept stage, a preliminary assessment of potential flood impacts has been carried out based on an understanding of flooding and drainage patterns under present day conditions and an initial review of the proposed alignment of the shared cycle and pedestrian pathway.	Potential to exacerbate flooding conditions in properties adjacent to sections of the proposed alignment of the shared cycle and pedestrian pathway to the north of the Rockdale Bicentennial Park and between Bruce Street and Bestic Street.
England Street to Civic Avenue shared cycle and pedestrian pathway	A new pedestrian and cyclist path within the proposed shared cycle and pedestrian pathway between England Street and Civic Avenue. A shared cycle and pedestrian bridge would be provided where the shared cycle and pedestrian pathway crosses President Avenue and a section of Scarborough Park North. A series of waterway crossings would be provided where the shared cycle and pedestrian pathway crosses the upper reach of Scarborough Ponds. For the purpose of the assessment these waterway crossings were assumed to comprise raised platform structures. A waterway crossing would also be required where the shared cycle and pedestrian pathway crosses an existing drainage line that discharges into Scarborough Ponds from Civic Avenue. Subject to detailed design, this waterway crossing may be incorporated into an extension to the length of the bridge.	No potential impacts expected.
Princes Highway and President Avenue intersection upgrade	Widening of Princes Highway and the western end of President Avenue to provide additional northbound and southbound turning lanes from the Princes Highway into President Avenue. The existing stormwater drainage system in Princes Highway and President Avenue would be upgraded to accommodate the proposed road widening. Subject to detailed design, the existing stormwater drainage line that runs from the low point in Princes Highway to the north of President Avenue, along Green Lane and West Botany Street to President Avenue, would be upgraded from a 900 mm diameter pipe to a 1200 mm diameter pipe.	Potential impacts on flood behaviour where it discharges into Scarborough Ponds to the south of President Avenue due to the increase in the capacity of the stormwater drainage system.
Permanent power supply	No additional permanent surface works are proposed beyond those that are to be constructed for the permanent power supply.	No potential impacts expected. There would be no impact on long-term flooding and drainage patters would be reinstated to a pre-construction condition at the completion of works.

While measures that are aimed at mitigating the impact of the project on flooding behaviour have been incorporated into the concept design that has formed the basis of the flood assessment for the project, the assessment identifies residual impacts at properties in:

- President Avenue to the east of the new President Avenue intersection
- West Botany Street to the east of the Rockdale motorway operations complex.

Residual impacts at these locations may result in social and economic costs to the community due to property damage, emergency services and potential loss of livelihood. Floor level survey would be required in these areas in order to confirm the extent to which the proposed works would increase above-floor inundation and flood damages in affected properties, and therefore the scope of mitigation measures that may be required.

At President Avenue the assessed increase in 1% AEP flood levels, in properties already affected by inundation, is 20 mm on a depth of inundation that is typically less than 200 mm. Given the minor nature of this increase it would be feasible to mitigate its impact through a combination of the measures listed in Table 8-3 of **Appendix M** (Flooding technical report).

At West Botany Street the assessed increase in peak 1% AEP flood levels is due to the raised level of MOC2, which displaces floodplain storage that is filled by flow that surcharges West Botany Street.

Measures to manage these potential impacts are discussed in **section 18.6**. **Appendix M** (Flooding technical report) also discusses specific measures for each location to be incorporated into the design in order to mitigate potential impacts.

Consultation has occurred with SES Sydney Southern Headquarters (20 March 2018) and Bayside Council (ongoing) (refer to **Chapter 3** (Consultation)). No concerns regarding emergency management arrangements for flooding have been raised.

Consistency with council and state government flood plans and policies

Rockdale Local Environmental Plan 2011 (RCC 2011b) sets out flood related planning controls for land that is located within the flood planning area as shown on *Rockdale Local Environmental Plan 2011 Flood Planning Map*, as well as any other land that is located below the flood planning level.

In accordance with the SEARs, a flood planning area has also been defined by the current assessment through mapping the extent of land which lies below the peak one per cent AEP flood level plus 0.5 metres under present day conditions. The flood planning area shown in **Appendix M** (Flooding Technical Report) is based on main stream flooding along the major rivers, creeks and tributaries that are crossed by the project, as well as the main paths associated with major overland flow. It should be noted that the flood modelling undertaken for the assessment was developed for the specific purpose of assessing the flood risks and impacts associated with the project. It should therefore be taken as preliminary only in terms of defining the flood planning area across the broader extent of flood prone land within the catchments that are crossed by the project.

The findings of the assessment show that the project would have only a minor impact on peak one per cent AEP flood levels. As a result, the project would have no significant impact on the extent of the flood planning area and therefore the area of land to which the flood planning controls set out in RCC 2011b would apply.

Spring Street Drain, Muddy Creek and Scarborough Ponds Floodplain Management Study (WP 2000) contains a draft floodplain management plan that sets out general non-structural and location specific structural measures with varying priority rankings to manage the flood risk associated with development on the floodplains of Spring Street Drain, Muddy Creek and Scarborough Ponds. General non-structural measures include the adoption of flood and stormwater management policies (such as RCC 2011a, RCC 2011b and RCC 2011c), the development of flood warning and response measures (such as SES 2009) and improved management and maintenance of drainage assets. Structural measures relevant to Scarborough Ponds include enlarging the outlet to Botany Bay and the flood proofing of flood liable properties. However WP 2000 notes that the low value of average annual damages within the Scarborough Ponds catchment due to the shallow depth of flooding “makes it difficult to justify any of the structural options on benefit-cost grounds”.

Given the extent of works that are proposed as part of the project and the relatively minor nature of their impact on flood behaviour under present day conditions, the project would not preclude or limit any of the measures identified in the draft floodplain management plan that is contained in WP 2000.

Rockdale City Local Flood Plan (SES 2009) provides a plan for the operation of emergency response to flooding within the Rockdale City Council LGA (now part of Bayside Council), including the catchments of the Cooks River, Spring Street Drain, Muddy Creek and Scarborough Ponds. The plan sets out the preparedness measures, the process for carrying out response operations and the coordination of immediate recovery measures from flooding.

The findings of the assessment show that the project would have only a minor impact on peak one per cent AEP flood levels. Increases in PMF levels, which would occur to a maximum of 60 millimetres on depths of flooding that exceed one metre, are also considered minor in terms of the relative increase in flood hazard. As a result, the project would have no adverse impact on the emergency response arrangements set out in SES 2009. Furthermore, the upgrade of President Avenue would improve its hydrologic standard from less than one exceedance per year under present day conditions to a minimum of one per cent AEP following the construction of the project, thereby having the beneficial effect of improving access across the floodplain during times of flood.

The assessment of flood risks to the project and its impact on the surrounding environment, as well as development of appropriate flood standards and mitigation measures has been carried out in accordance with the *NSW Floodplain Development Manual* (DIPNR, 2005), the requirements of the environmental approvals process and industry guidelines. Features relevant to flooding have been mapped in **Figure 18-2** and **Figure 18-4** in accordance with the *NSW Floodplain Development Manual 2005* (DIPNR, 2005). Refer to **Appendix M** (Flooding Technical Report) for further information regarding the consideration of the *NSW Floodplain Development Manual* (DIPNR, 2005) for the project.

Impact of future climate change on flood behaviour

The following scenarios were adopted as being representative of the likely lower and upper bound estimates of climate change impacts over the design life of the project:

- Scenario 1 – based on an assumed 10 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.4 metres.
- Scenario 2 – based on an assumed 30 per cent increase in currently adopted design rainfall intensities, together with a rise in sea level of 0.9 metres.

The combinations of catchment and coincident storm tide conditions that were used to define the one per cent AEP and PMF design flood envelopes under scenario 1 and 2 climatic conditions are described in **Appendix M** (Flooding technical report).

Potential impacts of future climate change on flood behaviour for a storm with an AEP of one per cent are as follows:

- Arncliffe motorway operations complex – Peak one per cent AEP flood levels could potentially be increased by between 0.6 metres and 1.1 metres under future climate change conditions. The upper bound estimate of the one per cent AEP post-climate change flood level would still be approximately 1.0 metre below the PMF level, which sets the minimum level of the tunnel ancillary facilities
- Rockdale motorway operations complex (north) – Peak one per cent AEP flood levels could potentially be increased by between 0.1 metres and 0.6 metres under future climate change conditions which is primarily due to an increase in rainfall intensities. The upper bound estimate of the one per cent AEP post-climate change flood level would still be approximately 0.7 metres below the PMF level, which sets the minimum level of the tunnel ancillary facilities
- Rockdale motorway operations complex (south) – There could potentially be a minor increase in peak one per cent AEP flood levels of between 0.04 metre and 0.09 metres under future climate change conditions, which would still be around one metre below the PMF level, which sets the minimum level of the tunnel ancillary facilities
- President Avenue tunnel portal - There could potentially be a minor increase in peak one per cent AEP flood levels of between 0.04 metres and 0.09 metres under future climate change conditions, which would still be over one metre below the PMF level which sets the minimum level of the tunnel portal

- President Avenue road upgrade - Peak one per cent AEP flood levels could potentially be increased by between 0.3 metres and 0.7 metres under future climate change conditions. While President Avenue would be inundated to a maximum depth of 0.2 metres under the lower bound estimate, one lane would be accessible to traffic in each direction. Under the upper bound estimate, President Avenue would be inundated across its full width to a maximum depth of 0.6 m
- England Street to Bestic Street shared cycle and pedestrian pathway – Peak one per cent AEP flood levels could potentially be increased by between 0.3 metres and 0.7 metres under future climate change conditions
- Princes Highway and President Avenue intersection upgrade - There would be a minor increase in peak one per cent AEP flood levels at the low point in the Princes Highway to the north of President Avenue of between 0.01 metres and 0.02 metres under future climate change conditions.

The assessment found that peak PMF levels at the tunnel ancillary facilities (Rockdale motorway operations complex (north) and (south)) and the President Avenue tunnel portal would be increased by between 60 mm and 130 mm due to a 0.9 metres rise in sea level (Scenario 2). In order to manage the risk of flooding to the tunnels over the design life of the project, the impact of future sea level rise would need to be taken into consideration when setting the minimum level of entries to the tunnel ancillary facilities and tunnel portal. The concept design of the President Avenue interchange and surface works, includes the road level at the entry to the President Avenue tunnel portal at a level above the PMF, including allowance for an increase in the PMF level under Scenario 2.

Peak flood levels at key locations along the project for current climate conditions, as well as for the assessed climate change scenarios are set out in **Appendix M** (Flooding technical report).

Impact of the project on flood behaviour under future climate change conditions

In accordance with the SEARs, the impact that the project may have on flood behaviour under potential future climate change conditions was based on assessing its effect on present day flood behaviour during a 0.5 per cent and 0.2 per cent AEP event as proxies for assessing the sensitivity to an increase in rainfall intensity on the one per cent AEP event due to future climate change.

The impact of the project on flood behaviour during a 0.5 per cent and 0.2 per cent AEP event, adopted as proxies for assessing the sensitivity to an increase in one per cent AEP design rainfall intensities of between 10 per cent and 30 per cent due to climate change, can be summarised as follows:

- Arncliffe motorway operations complex – Increases in peak 0.5 per cent and 0.2 per cent AEP flood levels are typically 10 mm or less and occur over a significantly smaller area when compared to those during a one per cent AEP event
- Rockdale motorway operations complex (north) – There would be an increase in peak flood levels in two residential properties in West Botany Street of between 100 to 120 millimetres during a 0.5 per cent and 0.2 per cent AEP event, which is similar to those during a one per cent AEP event
- Rockdale motorway operations complex (south) - Peak flood levels in West Botany Street would increase by a maximum of 20 mm during both a 0.5 per cent and 0.2 per cent AEP event, which is similar to those during a one per cent AEP event
- President Avenue interchange and surface works – There would be an increase in peak flood levels within Scarborough Ponds by a maximum of 40 millimetres during both a 0.5 per cent and 0.2 per cent AEP event, which is similar to those during a one per cent AEP event. While increases in peak flood levels during a 0.5 per cent AEP event would be confined to the Rockdale Bicentennial Park reserve, increases in peak flood levels during a 0.2 per cent AEP event would extend into three industrial properties that are located in Bermill Street
- During both a 0.5 per cent and 0.2 per cent AEP event there would be localised increase in peak flood levels by a maximum of 30 mm within the front yards of two residential properties that are located to the north and south of President Avenue, immediately west of O’Connell Street, which is slightly greater than the increases in peak flood levels during a one per cent AEP event

- England Street to Civic Avenue shared cycle and pedestrian pathway – There would be no significant change in peak flood levels during both a 0.5 per cent and 0.2 per cent AEP event, which is consistent with the findings of the assessment for a one per cent AEP event Princes Highway and President Avenue intersection upgrade - The proposed upgrades to the stormwater drainage system would mitigate the impact of the proposed road widening on peak flood levels in adjacent properties during both a 0.5 per cent and 0.2 per cent AEP event, which is consistent with the findings of the assessment for a one per cent AEP event.

Based on the assessment of the impact of future climate change on flood behaviour, no impacts to properties for the one per cent AEP event are anticipated.

18.5 Cumulative impacts

18.5.1 Surface Water

This section presents the findings of an assessment of the potential cumulative impacts on surface water as a result of the construction and operation of the project in combination with other projects in its vicinity. **Table 18-17** summarises the cumulative impacts on surface water.

Table 18-17 Potential Cumulative impacts on surface water

Project	Assessed potential for cumulative impacts on surface water
WestConnex Stage 1 (M4 Widening / M4 East)	The M4 East and M4 widening projects have no common surface water receptors with the project and as such cumulative impacts are unlikely to occur.
WestConnex Stage 2 and 3 (New M5 Motorway and M4-M5 Link)	The Cooks River is a common receptor for the New M5 Motorway and the F6 Extension – Stage 1 projects with Botany Bay being a common sensitive downstream receptor. Whilst there are no common direct surface water receptors for the M4-M5 Link and F6 Extension – Stage 1 projects during construction or operation, the Cooks River is a downstream receptor for the M4-M5 Link project. Construction of the project is likely to overlap with the M4-M5 Link construction over the period 2018 to 2022. Discharges from the M4-M5 Link Campbell Road construction compound in St Peters would be discharged to Alexandra Canal which is upstream of the Cooks River, however the increase in flow is considered to be negligible compared to the mean flow and tidal exchange within the Cooks River. Discharges from construction water treatment plants would also be required to achieve discharge criteria such that releases would be of a suitable quality for discharge to the receiving environment. Therefore, cumulative impacts to water quality and the hydrological regime within the Cooks River due to these two projects would be negligible during construction. During operation of the project, tunnel water would be treated at a new water treatment plant at Arncliffe. Tunnel water from the New M5 Motorway and a small portion of the M4M5 Link project would be pumped to the adjacent New M5 Motorway treatment plant at Arncliffe. This would increase the total flow and pollutant load being discharged. The approved discharge criteria for the New M5 Motorway project would be adopted for the additional flows contributed by the project and therefore the cumulative impacts associated with operational discharges to the Cooks River are considered to pose a minimal impact to water quality within the Cooks River. Runoff volumes to the Kogarah Golf Club drain are likely to increase as a result of additional impervious area associated with the New M5 Motorway Operations Complex 3 and the project operational water treatment plant. This could potentially lead to some minor erosion within unlined sections of the upstream section of the Kogarah Golf Club drain. Given the Cooks River and Botany Bay are large estuarine systems, increases in stormwater runoff volume as a result of the increased imperviousness associated with the New M5 Motorway, M4-M5 Link and the F6 Extension – Stage 1 projects are considered to pose a negligible impact to the Cooks River hydrological regime.

Project	Assessed potential for cumulative impacts on surface water
King Georges Road interchange upgrade	The King Georges Road interchange upgrade project has no common surface water receptors to the project but has two common sensitive downstream receptors, the Cooks River and Botany Bay. Cumulative impacts are unlikely to occur to the sensitive downstream receptors provided the proposed management measures are implemented, maintained and monitored
Sydney Gateway	A surface water impact assessment is not yet available for the Sydney Gateway project therefore the cumulative impact with the project is unable to be fully assessed at this stage. The Cooks River could potentially be a common receptor to both projects, with Botany Bay likely to be a common sensitive downstream receptor. It is assumed that potential surface water impacts for the Sydney Gateway project would be managed in accordance with relevant legislation and guidelines, and that potential cumulative impacts with F6 – Stage 1 would be assessed in any future EIS prepared for that project.
Sydney Metro (Sydenham to Bankstown)	The Sydney Metro City and South West Sydenham to Bankstown upgrade rail corridor would run through the Cooks River catchment, a surface receptor for the project. Potential cumulative surface water impacts could affect the Cooks River and downstream sensitive environments (Cooks River and Botany Bay). The Sydney Metro City and Southwest Sydenham to Bankstown upgrade Environmental Impact Statement (Transport for NSW 2017) states that it is expected that with the appropriate mitigation measures in place, residual surface water impacts during construction and operation of that project are likely to be negligible. Providing the proposed management measures for the project are implemented, maintained and monitored, the cumulative impact to the Cooks River and the downstream sensitive receptor of Botany Bay is likely to be minimal.
F6 Extension (Kogarah to Loftus)	As future stages of the F6 Extension are not yet committed, and no surface water impact assessment has been undertaken for those future stages, potential cumulative impacts with the project is unable to be fully assessed at this time. If the potential future stages of the project go ahead, Scarborough Ponds could potentially be a common receptor and Botany Bay could be a common sensitive downstream receptor. The key potential cumulative impacts are considered to be increases in pollutant loading during construction and post development and increases in runoff volumes during operation. It is assumed that surface water impacts for potential future stages of the F6 Extension would be assessed cumulatively with F6 – Stage 1 and would be managed in accordance with relevant legislation and guidelines. Providing the proposed F6 – Stage 1 and potential future stages of the F6 Extension implement, maintain and monitor appropriate surface water management measures, the cumulative impacts to the common receptors are likely to be minimal, with the potential for some beneficial impacts if opportunities identified as part of the project to improve the water quality of Rockdale wetland are implemented.
Local residential development	Major residential developments proposed within proximity to the F6 – Stage 1 (New M5 Motorway, Arncliffe to President Avenue, Kogarah) project includes the Bayside West Precincts of Arncliffe and Banksia, development at Wolli Creek and also within the Turrella precinct. In terms of common surface water receptors with the project, Cooks River and Botany Bay are downstream of all of these urban developments, and Muddy Creek downstream of the Banksia precinct. The key potential cumulative impacts are considered to be increases in pollutant loading during construction and post development and increases in runoff volumes post development. Whilst environmental assessments have not been prepared for the various urban development projects, it is assumed that local councils would impose development conditions to ensure erosion and sediment controls are implemented during construction in accordance with the principles of the Blue Book (Landcom 2004) and that pollutant load reduction targets in accordance with the BBWQIP would be set for the developed sites. Therefore, with the implementation of the project management measures, the cumulative impacts to water quality with common receiving and downstream receptors are likely to be minimal. Given the common receptors of Muddy Creek and Cooks River are estuarine, anthropogenic environments and given the existing urbanised nature of the development zones, the cumulative increase in runoff volumes associated with the urban development is likely to pose a negligible impact to hydrology or erosion within the waterways.

Project	Assessed potential for cumulative impacts on surface water
Muddy creek naturalisation	Sydney Water has prepared a concept design for the naturalisation of Muddy Creek between West Botany Street and Bestic Street. The concept design proposes replacement of the existing concrete channel with rock banks, planted with native species, a sandstone block low flow channel and replacement of the existing channel base with new concrete. Other potential opportunities shown within the concept design include saltmarsh zones, a wetland for treating stormwater flows and an outdoor education area. The timing of the works is currently unknown. Whilst no environmental assessment has been reviewed for the Muddy Creek naturalisation project, it is assumed that surface water construction impacts would be managed in accordance with relevant legislation and guidelines, particularly to limit potential mobilisation of sediments downstream during earthworks in the channel. Whilst water quality and hydrological benefits of the naturalisation works are likely to be negligible, the works are likely to result in ecological improvements to the waterway. The project shared cycle and pedestrian pathway currently conflicts with sections of salt marsh and riparian restoration proposed as part of the Muddy Creek naturalisation concept design. Providing the proposed project management measures are implemented, maintained and monitored, the cumulative impacts to water quality within Muddy Creek and Cooks River downstream are likely to be negligible. Consultation with Sydney Water would be required during detailed design so that the shared cycle and pedestrian pathway alignment is cognisant of the Muddy Creek naturalisation works.

The projects currently under construction all incorporate surface water management measures during construction and for operation, to prevent adverse impacts to the common receiving receptors and adjoining properties. Other projects that are still in the planning stages would likely be required to implement similar mitigation measures in accordance with legislative requirements to prevent adverse impacts.

Therefore, with due consideration of the proposed management measures to be implemented as discussed in **section 18.6**, minimal adverse cumulative surface water impacts are anticipated. The residual risk to common receptors and sensitive environments downstream would be low, provided the proposed management measures are implemented, maintained and monitored.

18.5.2 Flooding

This section presents the findings of an assessment of the potential cumulative impacts on flood behaviour as a result of the project in combination with other projects in its vicinity. The assessment was based on impacts during the operation of the project only, given the short term nature of exposure to potential flood impacts together with the general requirement to manage adverse impacts on existing development during the construction of the project.

Table 18-18 Potential Cumulative impacts

Project	Assessed potential for cumulative impacts on flood behaviour
WestConnex Stage 1 (M4 Widening / M4 East)	No cumulative impacts on flood behaviour as the M4 Widening / M4 East projects are located in adjacent valleys that are remote from the project.
WestConnex Stage 2 (New M5 Motorway)	The flood model developed of the Cooks River floodplain was used to assess the cumulative impact of the project with the New M5 Motorway project as a result of the proposed extension to the Arncliffe motorway operations complex to accommodate additional tunnel ancillary facility for the project. The cumulative impact of the two projects would result in an increase in peak one per cent AEP flood levels in the Kogarah Golf Course and the road reserve of Marsh Street by a maximum of 30 mm, which is 19 mm greater than the project alone.
WestConnex Stage 3 (M4-M5 Link)	No cumulative impacts on flood behaviour as the M4-M5 Link project are located in adjacent valleys that are remote from the project.
Sydney Gateway	No cumulative impacts on flood behaviour as the Sydney Gateway project are located in adjacent valleys that are remote from the project.

Project	Assessed potential for cumulative impacts on flood behaviour
F6 Extension (Kogarah to Loftus)	Potential future stages of the F6 Extension project would likely involve works on the Scarborough Ponds floodplain that, in combination with the project, have the potential for cumulative impacts on flood behaviour. While subject to future design development and environmental approvals, the potential future stages of the F6 Extension project is likely to include an additional surface connection on the Scarborough Ponds floodplain to the south of the President Avenue interchange. Cumulative impacts would need to be assessed as part of the environmental approvals process for the potential future stages of the F6 Extension project once its details are known. However, given the minor nature of flood impacts associated with the project, it is expected that the cumulative impacts of the multiple stages can be managed through appropriate mitigation measures. Such measures may include, for example, the provision of compensatory floodplain storage within the Scarborough Ponds floodplain.

The assessment found that there would be no cumulative impacts on flood behaviour as a result of the project in combination with other projects that have preceded it.

18.6 Management of impacts

Management measures would be implemented to avoid, minimise or mitigate impacts on surface water and flooding within the study area. These management measures are outlined in **Table 18-19.** Several of the management measures contained in **Chapter 16** (Soils and contamination) would also contribute to management of surface water impacts.

Table 18-20 to **Table 18-22** set out the relevant discharge criteria referred to in the environmental management measures.

Table 18-19 Environmental management measures – surface water and flooding

Impact	Reference	Environmental management measures	Timing
Construction			
Impacts on surface water quality	SWF1	A program to monitor potential surface water quality impacts of the project will be developed and included in a Construction Soil and Water Management Plan (CSWMP). The program will include the water quality monitoring parameters (including pH, turbidity, dissolved oxygen, nitrogen and metals) and the monitoring locations (including Muddy Creek, Rockdale Bicentennial Park, North Scarborough Ponds and Cooks River) identified in Annexure G of Appendix L (Surface water technical report) Continuous surface water level and groundwater level monitoring will be undertaken within Rockdale wetland and surrounding area for at least 12 months prior to the commencement of construction. Monthly groundwater quality would also be undertaken in the surrounding area. The data would be used as a baseline to monitor impacts on surface and groundwater levels and groundwater quality within the Pond during construction. The surface water monitoring program will continue for a minimum of three years following the completion of construction, or until the affected waterways are certified by a suitably qualified and experienced independent expert as being of an equal or better condition than pre construction conditions (or as otherwise required by any project conditions of approval). In the instance that during detailed design it cannot be demonstrated that treated construction wastewater would meet the discharge criteria for Scarborough Ponds, in particular nutrient concentrations, treated construction wastewater from C2 and C3 will be discharged to the Muddy Creek stormwater catchment.	Prior to construction Construction Operation
Impacts on water bodies	SWF2	All works within watercourses or on waterfront land will be managed in accordance with the Controlled Activities on Waterfront Land guidelines (DPI 2012). The following specific measures are required to manage impacts within Rockdale wetland: • Installation of a temporary barrier to isolate the excavation works from the rest of the pond and prevent mobilisation of sediment and pollutants into adjacent areas. Water within the construction zone will be treated by the construction water treatment plant. Sediment mobilised during installation of the barrier will also be managed. • Retention of hydrologic connectivity through Rockdale wetland throughout construction.	Construction
	SWF3	A Water Reuse Strategy for the construction and operational phases of the project will be developed prior to construction. This will outline the construction and operational water requirements and potential water sources to supply the water demand.	Prior to construction

Impact	Reference	Environmental management measures	Timing
Impacts on flood behaviour	SW4	A Flood Management Strategy (FMS) will be prepared prior to construction to demonstrate how flooding risks and behaviours will be mitigated during both the construction and operational phases. The FMS will include floor level survey for identified affected properties. The FMS would be prepared prior to commencement of construction by a suitably qualified and experienced person in consultation with directly affected landowners, Sydney Water, OEH, SES and relevant councils.	Prior to construction
Impacts on flood behaviour	SWF5	Entries to tunnel excavations, including cut and cover sections of tunnel will be protected against flooding, to an appropriate flood standard. The same hydrologic standard will be applied to tunnel ancillary facilities such as tunnel ventilation buildings, operational water treatment plants, emergency facilities and electrical substations. A minimum level of flood immunity of one exceedance per year would be provided to shared cycle and pedestrian pathways within the project footprint.	Detailed design Construction
	SWF6	As a minimum, site facilities are to be located outside high flood hazard areas based on a one per cent AEP flood. For site facilities located within the floodplain, the FMS is to identify how risks to personal safety and damage to construction facilities and equipment will be managed.	Construction
Operation			
Impacts on surface water quality	SWF7	Treatment measures would be implemented within the waterbodies of Scarborough Park North and Rockdale Bicentennial Park disturbed by the project during construction, to reduce algal bloom conditions and contribute to achieving the NSW WQOs over time. Treatments would be considered in consultation with Bayside Council and shall include gross pollutant traps in drainage lines; inclusion of macrophyte zones and bank reshaping of the wetland zones; the use of solar powered devices to aerate the water column.	Detailed design
	SW8	The findings of the pre and post construction water level monitoring and relevant water quality monitoring in Rockdale wetland will be reviewed as part of an investigation by a suitably qualified and experienced independent expert to certify that the Pond has been restored to an equal or better level than pre construction conditions, in terms of its hydrology and water quality, including a review of how water quality within the downstream waters may have been affected by the restoration works.	Operation
	SW9	The project will be designed to manage the potential impacts of future climate change on flooding behaviour in accordance with the procedures set out in *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC, 2007) and in *Australian Rainfall and Runoff* (GA 2016).	Detailed design

Table 18-20 Surface water discharge criteria

Parameter	Discharge criteria
pH	6.5-8.5
Oil and Grease	No visible oil and grease
Total Suspended Solids	<50 mg/L

Table 18-21 Construction Water Treatment Plant – Water Quality Discharge Criteria

Receiving waters	Environment	Toxicants	Nutrients	Oil and grease	pH	Turbidity	EC
Cooks River	Highly disturbed system with significant tidal exchange	Marine Water 80 per cent species protection level	80 per centile of reference sites	No visible oil and grease	Between 20 per centile and 80 per centile of reference site	80 per centile of reference site	NA (estuarine waters)
Muddy Creek	Highly disturbed system with tidal exchange	Marine Water 80 per cent species protection level	80 per centile of reference sites	No visible oil and grease	Between 20 per centile and 80 per centile of reference site	80 per centile of reference site	NA (estuarine waters)
Rockdale wetland	Highly disturbed system Freshwater and limited assimilative capacity for nutrients with high potential for algal blooms	Marine Water slightly to moderately disturbed protection level	Estuarine slightly to moderately disturbed trigger level	No visible oil and grease	Between 20 per centile and 80 per centile of reference site	10 NTU	80 per centile of reference site
Northern Scarborough Pond	Highly disturbed system Limited tidal exchange and limited assimilative capacity for nutrients with high potential for algal blooms	Marine Water slightly to moderately disturbed protection level	Estuarine slightly to moderately disturbed trigger level	No visible oil and grease	Between 20 per centile and 80 per centile of reference site	10 NTU	NA (estuarine waters)

Table 18-22 Operational Water Treatment Plant – Water Quality Discharge Criteria

Receiving waters	Toxicants	Nutrients	pH	Turbidity
Cooks River	ANZECC (2000) 80 per cent species protection level for estuarine waters	80 percentile of reference data as determined by New M5 Motorway project	Range between 20 and 80 percentile of reference data as determined by New M5 Motorway project	80 percentile of reference data as determined by New M5 Motorway project.

18.7 Environmental risk analysis

An environmental risk analysis was undertaken for surface water and flooding and is provided in **Table 18-23** below.

A level of assessment was undertaken commensurate with the potential degree of impact the project may have on that issue. This included an assessment of whether the identified impacts could be avoided or minimised (for example, through design amendments). Where impacts could not be avoided, environmental management measures have been recommended to manage impacts to acceptable levels.

The residual risk is the risk of the environmental impact after the proposed mitigation measures have been implemented. The methodology used for the environmental risk analysis is outlined in **Appendix O** (Methodologies).

Table 18-23 Environmental risk analysis – Surface water and flooding

Summary of impact	Construction/ operation	Management and mitigation reference	Likelihood	Consequence	Residual risk
Impacts on water quality in project catchments due to water discharge, including discharge of treated surface and groundwater.	Construction and Operation	SWF1, SWF2, SWF8, SWF9	Unlikely	Moderate	Low
Impacts to the hydrological and geomorphic processes of receiving water bodies due to increase of baseflow rates	Construction and Operation	SWf2, SWF3, SW9	Unlikely	Moderate	Low
Impacts on surrounding properties due to the potential alterations of flood levels, existing minor drainage paths and overland flows due to construction ancillary facilities and due to new operational facilities.	Construction and Operation	SW5, SW6, SW10	Unlikely	Moderate	Low
Impacts on safety and to project infrastructure due to flooding	Construction and Operation	SW5, SW6, SW7, SW10	Unlikely	Moderate	Low
Impacts on flood levels and behaviour due to sea level rise and potential increase in rainfall intensity due to future climate change	Operation	SW5, SW6, SW10	Unlikely	Moderate	Low

19 Non-Aboriginal heritage

This chapter assesses potential impacts from the project on non-Aboriginal heritage. A Statement of Heritage Impact (SoHI) has been prepared addressing potential impacts to individually listed items and can be found in **Appendix N** (Statement of heritage impact). **Table 19-1** sets out the SEARs relevant to non-Aboriginal heritage and identifies where the requirements have been addressed in this EIS.

Table 19-1 SEARs - Non-Aboriginal heritage

Assessment requirements	Where addressed
1. The Proponent must identify and assess any direct and/or indirect impacts (including cumulative, vibration and visual impacts) to the heritage significance of listed (and nominated) heritage items inclusive of:	Section 20.3 and section 20.4
c) environmental heritage, as defined under the Heritage Act 1977 (including potential items of heritage value, conservation areas, open space heritage landscapes, built heritage landscapes and archaeology);	Section 19.3.1 and section 19.3.2
d) items listed on the State, National and World Heritage lists; and	Section 19.2.2
e) heritage items and conservation areas identified in local and regional planning environmental instruments covering the project area.	Section 19.2.2
2. Where impacts to State or locally significant heritage items or archaeology are identified, the assessment must:	Section 19.3
a) Include a significance assessment and statement of heritage impact for all heritage items (including any unlisted places that are assessed of heritage value);	Section 19.2.3 and Appendix N (Statement of heritage impact)
b) Provide a discussion of alternative locations and design options that have been considered to reduce heritage impacts;	Chapter 5
c) In areas identified as having potential archaeological significance, undertake a comprehensive archaeological assessment and management plan in line with Heritage Council guidelines which includes a methodology and research design to assess the impact of the works on the potential archaeological resource and to guide physical archaeological test excavations and include the results of these excavations. This is to be carried out by a suitably qualified archaeologist and is to discuss the likelihood of significant historical and Aboriginal archaeology on the site, how this may be impacted by the project, and include measures to mitigate any impacts;	Section 19.2.4 Section 19.3
d) Consider impacts to the item of significance caused by, but not limited to, vibration, demolition, archaeological disturbance, altered historical arrangements and access, increased traffic, visual amenity, landscape and vistas, curtilage, subsidence, hydrological changes and architectural noise treatment (as relevant);	Section 19.3
e) Provide a comparative analysis to inform the rarity and representative value of any heritage places proposed for demolition;	Section 19.7
f) Outline mitigation measures to avoid and minimise identified impacts in accordance with the current guidelines; and	Section 19.6
g) Be undertaken by a suitably qualified heritage consultant(s) (note: where archaeological excavations are proposed the relevant consultant must meet the NSW Heritage Council's Excavation Director criteria).	Section 19.1.5

19.1 Assessment methodology

19.1.1 Overview

The methodology for the non-Aboriginal heritage assessment is as follows:

- Identify the study area relevant to non-Aboriginal heritage
- A literature and database review, including a search of relevant heritage registers and schedules to identify heritage items that may be impacted during construction and operation of the project
- Undertake a one day site inspection of the project area to examine the area for both known (previously identified (i.e. properties along Gibbs Street and Farr Street)) and previously unidentified heritage items and archaeological sites
- Record previous unknown heritage items if found during the site inspection
- Assess the heritage significance of heritage items that may be impacted by the project
- Assess the likely level of impact during construction and operation on identified heritage items
- Prepare statements of heritage impact for impacted non-Aboriginal heritage items
- Assess the potential for archaeological deposits within project area according to Heritage Division guidelines and to determine the need for further investigations
- Provide mitigation and management measures, including measures to avoid significant impacts and an evaluation of the effectiveness of the measures.

19.1.2 Relevant legislation and guidelines

The *Heritage Act 1977* is the primary legislation providing for the protection and conservation of non-Indigenous (non-Aboriginal) cultural heritage items. The Heritage Act imposes requirements including:

- Section 32, where places, buildings, works, relics, moveable objects or precincts of heritage significance are protected by listing on the State Heritage Register
- Section 170, which requires that NSW Government agencies, including Roads and Maritime, maintain a register of heritage assets and requires consideration where the assets may be impacted.

The non-Aboriginal heritage assessment was also undertaken in accordance with the following guidelines:

- *Heritage Curtilages* (NSW Heritage Office and NSW Department of Urban Affairs and Planning, 1996)
- *NSW Heritage Manual* (Heritage Office and Department of Urban Affairs and Planning, 1994)
- *Assessing Heritage Significance* (NSW Heritage Office, 2001)
- *Levels of Heritage Significance* (NSW Heritage Office, 2008)
- *Assessing Significance for Historical Archaeological Sites and Relics* (NSW Heritage Branch, 2009)
- *The Burra Charter* (the Australia ICOMOS charter for places of Cultural Significance) (ICOMOS Australia), 2013).

As the Project is being undertaken as a State significant infrastructure (SSI) project, the heritage provisions in Rockdale Local Environmental Plan 2011 (Rockdale LEP) LEP, and the Canterbury Local Environmental Plan 2012 (LEP) for the permanent power supply alignment, do not apply. However as part of identifying known heritage items within the Project corridor, Schedule 5 of the Rockdale LEP and Canterbury LEP was searched for previously listed heritage items.

19.1.3 Study area

The study area was defined by the surface works required above the tunnels, the locations of the construction compounds, the permanent power supply alignment and any other ancillary facilities. The study area also includes those areas immediately adjacent to the surface works as these areas may be subject to direct and/or indirect impacts as a result of construction and operation of the project. Refer to **Figure 1-2** for the project overview.

19.1.4 Literature and database review

A review of archaeological and historical literature and data relevant to the project was undertaken. This review was used to identify any known non-Aboriginal heritage items located in the vicinity of the project footprint. Databases searched include:

- World Heritage List
- Commonwealth Heritage List
- National Heritage List
- NSW State Heritage Register
- NSW State Heritage Inventory
- Roads and Maritime Section 170 Heritage and Conservation Register
- Transport for NSW Section 170 Heritage and Conservation Register
- Sydney Water Section 170 Heritage and Conservation Register
- Sydney Trains Section 170 Heritage and Conservation Register
- Schedule 5 of Rockdale LEP
- Schedule 5 of Canterbury LEP.

Searches of non-statutory databases were also undertaken and included the Register of the National Estate and the Register of the National Trust of Australia.

Additional literature was reviewed for relevant information about the non-Aboriginal heritage in the vicinity of the project, including:

- A review of historical documents, including parish maps and plans, to determine the historical context of the area surrounding the project and to identify any potential for archaeological heritage items
- Archives from the National Library of Australia, State Library of NSW, Land and Property Information's on-line Historical Lands Records Viewer, Trove digitised newspaper collections and relevant local libraries.

Non-Aboriginal Heritage items identified through these searches are summarised in **section 19.2.2**, **Table 19-2** and shown in **Figure 19-2** and **Figure 19-3**.

19.1.5 Field survey

Heritage items identified as having the potential to be either directly or indirectly affected by the project (both surface works and tunnelling) were inspected during a field survey. This sought to establish their specific location and current condition. This survey was carried out by an AECOM Senior Archaeologist and Heritage Specialist (Qualifications: Bachelor of Archaeology (Hons) Flinders University) on 16 January 2018.

The locations of inspections were informed by the results of the desktop assessment. All inspections were undertaken from publicly-accessible locations. Where heritage items were identified as being present they were documented through notes and photos, with relevant features identified.

A summary of the physical description of the areas investigated as part of the field survey as well as photos are provided in **Appendix N** (Statement of heritage impact).

19.1.6 Significance assessment

Where particular non-Aboriginal heritage items were identified in close proximity to the project, assessments were undertaken to determine relative importance ('assessments of significance'). The significance assessment criteria are provided in **Appendix N** (Statement of heritage impact). Assessment of these heritage items evaluated current condition in comparison to historical inspections and the descriptions provided within the heritage listing. Statements of significance were obtained from the respective published registers for each item.

19.1.7 Impact assessment

A detailed description of the project is provided in **Chapter 6** (Project description) and **Chapter 7** (Construction). Impacts as a result of the project have been categorised as follows:

- Direct – where the project footprint is located within the curtilage of the heritage item and/or would involve damage, modification or demolition of that heritage item
- Potentially direct – where impacts to a heritage item may occur subject to the condition of that item (i.e. vibration impacts to sensitive items), the construction methodology employed and/or through the implementation of management measures (i.e. acoustic treatments)
- Indirect – where the project would introduce new visual elements or result in changes to the surrounding landscape context (such as through changes to the ground and /or surface water).

Impacts to heritage items that would affect their value or significance would vary depending on the type of construction work, its duration and the proximity. As a result, a set of impact ratings was established to determine the degree of impact. The heritage impact criteria and Statements of Heritage Impacts for affected non-Aboriginal heritage items are provided in **Appendix N** (Statement of heritage impact), while the comparative assessment is provided in **section 19.7**.

19.2 Existing Environment

19.2.1 Overview

The historical context of the project area around President Avenue is directly related to the settlement along the coastal area along Brighton-Le-Sands and encroachment of early to mid-twentieth century residential development.

The first land grant was awarded in 1803. This first grant was soon followed by a grant to Hanna Laycock of 500 acres called "Kings Grove Farm". The track to her property became the major route south, and by 1830 this route became the main road south of the settlement at Sydney.[1]

The Cooks River was the main factor preventing settlement expanding further to the south. A dam crossing Cooks River was opened in 1839 enabling travellers to cross into what is now the Rockdale area. A direct road to the Illawarra was planned and constructed, and in 1843 the Illawarra Road was opened.

By 1848, most of the occupations were believed to be rural occupations. Most subdivisions, or sales of subdivided land until the 1870s, were aimed at providing sizeable acreages of land, suitable for farms, villas and other large area activities such as market gardens, many of which did not have houses built on them.

Growth and development along the coastal fringe south of the Cooks River was slower. This was mainly due to the gentrification of the area. Given the proximity of the waters of Botany Bay, then in an unpolluted state, the area became the resort of the wealthy and fashionable of Sydney.[2] By the late 1860s more houses were being built along the coastal strip. The more notable land owners, including Thomas Holt, persuaded the government to dedicate low-lying land alongside Scarborough Park for development.[3]

As more people were attracted to the coast, low lying lands that were set back between the coast and the train line were used for market gardens, piggeries and poultry farms. By 1906 pressure for more land for residential needs was increasing. Larger plots of land, including the existing private race courses and tourist resorts were being subdivided from 1910 onwards. This allowed for smaller allotments that allowed modest residential houses to be built. These subdivisions began to encroach on the swamp and low-lying areas, however, the market gardens along Muddy Creek and adjacent to the swamp areas continued to be farmed (Walker and Kass, 1991).

Pressure to reclaim Patmore Swamp began in the 1890s with petitions sent to the government to reclaim the swamp areas to make way for housing (*Daily Telegraph* 19 May 1892). It was noted at the time that the surrounding water run off drained into Patmore Swamp and that filling the swamp would create other greater issues. These plans never eventuated but continuing pressure remained for Rockdale Council to reclaim the swamp. In 1916 the NSW Government proposed buying the swamp area to maintain the wetlands and protect them from development (*Sydney Morning Herald* 1 July 1916). The sale of the swamp to the NSW government does not seem to have eventuated.

---

[1] A.0. Map 5123 in Walker and Kass, 1991
[2] Walker and Kass, 1991
[3] Geeves and Jervis, 1954

Figure 19-1 Portion of West Botany. Note President Avenue has not crossed the swamp at this stage. Rockdale tunnel site and President Avenue outlined in red (Source: Trove https://nla.gov.au/nla.obj-229916244/view)

The health of the swamp area was called into question in 1929 when the Department of Health was called to take water samples of Patmore Swamp. Offensive odours were noted by local residents and samples revealed that the water was found to be "offensive". The cause was deemed to be decomposing vegetation and animals (*St George Call newspaper* 22 March 1929).

Sustained pressure for Rockdale Council to drain and reclaim the swamp areas resulted in Council calling for tenders to reclaim four acres of the swamp and for the potential digging of a channel in the early 1930s (*St George Call* 21 Oct 1932). Details relating to the eventual successful tender are scant however, a description from the opening of the new "Scarborough Park" in November 1934 indicates that extensive reclamation works enabled installation of 15 cricket pitches and a large artificial lake (*St George Call* 30 Nov 1934)(refer **Plate 1**).

Other notable developments in the area include the subdivision and eventual development of the western side of West Botany Street. The allotments appear to have been subdivided for housing sometime between 1890 and 1906. The allotments along what later became West Botany Street appear at this time to be larger and irregularly shaped, and a market garden is located in this area.

The 1943 aerial photo shows there is a shed or possibly a house present in the location of 439 West Botany Street. The remainder of this area consists of what appear to be lightweight sheds and market gardens (**Plate 2**). These allotments were later subdivided in 1969 to create six allotments fronting West Botany Street that become known as Numbers 431 to 439, after which the existing brick warehouses were built. A brick warehouse at 431 West Botany Street was demolished in 2016, however the other brick warehouses remain.

Plate 1 Scarborough Park c1934 (Source: Government Printing Office 1 – 01702)

Between 1970 and the early 1980s there were no development changes to Patmore Swamp on either side of President Avenue. The next phase of changes to the area were in the lead up to the Australian Bicentenary in 1988 when Rockdale Council upgraded the then swamp area north of President Avenue to include a new open grassed field, carpark on the western side of the watercourse, and new playing fields on the eastern side. The redesign included large scale landscaping works that redefined the layout of Patmore Swamp. Once completed the northern side of Patmore Swamp was renamed Bicentennial Park and Memorial Park. A bridge was constructed linking the two parks over the watercourse that remained from the swamp as a result of the works. Smaller additions have since been made to the park, including adding a skate park and playground.

Plate 2 1943 aerial of the Kings Wetland and Patmore Swamp. (Source Six Viewer Online). 439 West Botany Street shown in red.

19.2.2 Listed historic heritage items

A search of relevant heritage registers and databases identified eight listings of heritage items listed in **Table 19-2** within or immediately adjacent to the project footprint which includes the permanent power supply connection route (refer **Figure 19-2**, **Figure 19-3** and **Figure 19-4**). It is noted that some items are listed on more than one register.

Table 19-2 Listed non-Aboriginal heritage items potentially impacted by project

Register	Listed item	Distance from project area
Commonwealth		
World Heritage List	None identified	-
National Heritage List	None identified	-
Commonwealth Heritage List	None identified	-
Register of the National Estate (non-statutory)	None identified	-
State		
State Heritage Register	Arncliffe Market Gardens (SHR 01395)	Above project area
	Dappeto (00638)	275 metres to the East
	Lydham Hall (00477)	355 metres to the West
	Wilsons Farm House (00487)	Above project area
	Rockdale Railway Station (01238)	380 metres to the Southwest
	Western Outfall Main Sewer (SHR 01647)	50 metres to the South
	Alexandra Canal (SHR 01621)	250 metres to the Northeast
	Toomevara Lane Chinese Market Gardens (SHR 01394)	580 metres to the South
State Heritage Inventory	None identified	-
Roads and Maritime S170 Register	None identified	-
TfNSW S170 Register	Banksia Railway Station Group (4801160)	100 metres to the North
	Bardwell Park Railway Station Group (4801896)	Within the project area
Sydney Water S170 Register	None identified	-
Sydney Trains S170 Register	None identified	-
Department of Urban Affairs and Planning S170 Register	Kings Wetland (SHI 3490033)	Within the project area
Conservation areas – permanent power supply connection route		
Register of the National Estate (non-statutory)	Brighton Le Sands Urban Conservation Area (RNE Indicative Place 102111)	Within the project area
Register of the National Estate (non-statutory)	Banksia Urban Conservation Area (RNE Indicative Place 102110)	Within the project area
Register of the National Estate (non-statutory)	Bardwell Park Urban Conservation Area (RNE Indicative Place 102101)	Within the project area
Register of the National Estate (non-statutory)	Clemton Park Urban Conservation Area (RNE Indicative Place 102071)	Within the project area
Register of the National Estate (non-statutory)	Earlwood Urban Conservation Area (RNE Indicative Place 102069)	Within the project area
Local		
Rockdale LEP 2011	• Kings Wetland (I169) • Patmore Swamp (I202) • Brighton-Le-Sands Public School (I167) • Arncliffe Market Gardens (I193)	Within the project area Within the project area Adjacent to the project Above the project area

Register	Listed item		Distance from project area
Rockdale LEP 2011	• Sandstone Federation cottage (I2) • Newstead (I4) • Palm trees (I14) • Californian Bungalow house (I16) • Californian Bungalow house (I17) • Coburra (I28) • Wilga (I29) • Californian Bungalow house (I30) • Dappeto (I62) • Federation house (I63) • Federation house (I65) • Fairview (I66) • House (I67) • Federation house (I68) • Sandstone Victorian cottage (I69) • House (I70) • Sandstone Victorian cottage (I71) • Sandstone Victorian cottage (I72) • Sandstone Victorian cottage (I73) • Part of single-storey terraced cottages known as Jackson's Row (I74) • Part of single-storey terraced cottages known as Jackson's Row (I75) • Stone house (I76) • Stone Victorian house (I77) • Stone house (I78) • Gardiner Park (I79) • Stone cottage (I80) • Stone Federation house (I81) • Californian Bungalow cottage (part of a street precinct) (I82)	• Californian Bungalow cottage (part of a street precinct) (I83) • Californian Bungalow cottage (part of a street precinct) (I84) • Californian Bungalow house (I88) • Brick Californian Bungalow cottage (I89) • Hillsdon's Nursery Cottage (I90) • Stone cottage (I91) • Stone cottage (I92) • Market Gardens (I93) • Girrahween Park gates (I109) • St Andrew's Church (I128) • School building (1916) - Brighton-Le-Sands Public School (I167) • Kings Wetland (I169) • Rock Lynn (I207) • Roslyn Hall (I208) • Sandstone Victorian cottage (I210) • House (I211) • Palm trees on verge (I213) • Jacaranda trees (I214) • Yamba Worra (I215) • Victorian house (I216) • Lydham Hall (I217) • Federation house (I218) • Rockdale Public School (I219) • Rockdale Town Hall (I220) • Brick buildings om platforms, signal box and overhead booking office (I222) • Wilson's Farmhouse (I224) • Wolli Creek Valley (I237)	<400 metres

19.2.3 Significance assessment

Assessment of potential impacts to non-Aboriginal heritage items first requires an understanding of the significance of each heritage item. Assessments of significance provide an understanding of why a heritage item is significant and to appropriately delineate the heritage curtilage. Many of the heritage items within the vicinity of the project already have statements of heritage significance prepared by public authorities, however based on research undertaken as part of the project, statements would be updated if required.

Summaries of the significance of individual non-Aboriginal heritage items within the study area are provided in **Table 19-3**. It is noted that no statements were updated as part of this assessment.

Table 19-3 Summary of the significance of relevant heritage items in the study area

Listing	Summary of heritage significance
Arncliffe Market Gardens (SHR 01395)	The Arncliffe Market Gardens are of high significance for their association with the Chinese community and their demonstration of a continuous pattern of land use since the late nineteenth century. They are one of only three such surviving market gardens in the Inner Sydney region and one of few similar surviving examples in the Sydney Metropolitan Region.
Wilsons Farm House (SHR 00487)	Wilsons Farm House is the last surviving example of the modest pioneer homes built along the banks of Muddy Creek. It demonstrates the early rural and more recent market garden development of Rockdale. It is an extant example of a simple nineteenth-century colonial farmhouse. It is associated with an early small holding settler family, the Wilson's.
Kings Wetland (I169)	The Kings Wetland is an area of regionally significant aquatic plants and demonstrates the geography and vegetation of the area prior to white settlement. The destruction of wetland habitats in the Sydney Metropolitan Region, for the purposes of urban expansion, are of considerable concern and any surviving wetland habitats are considered to be of high significance.
Patmore Swamp (I202)	Patmore Swamp is technically significant for its contribution to the Central Scarborough wetland area which is an integral part of the wetlands corridor. The place also has historical value for its role in the depression era program of public works. The wetland reserve contributes to amenity and character of the area.
Brighton-Le-Sands Public School (I167)	The school is a distinctive Federation style building representative of education in Brighton Le Sands from the early twentieth century and contributing to the history and streetscape of the area.
Bardwell Park Railway Station Group Statement of Significance	Bardwell Park Railway Station has historical significance as a major public work completed as an unemployment relief project during the Great Depression, and as a major transport hub for Bardwell Park since 1931. Bardwell Park Railway Station is of aesthetic significance as an austere 1930s railway building with simple Art Deco detailing and fine brick workmanship that is evocative of the effects of the Depression on building programs for the NSW railways. Bardwell Park Railway Station is representative of the cohesive collection of 10 East Hills line railway stations from Turrella to East Hills.

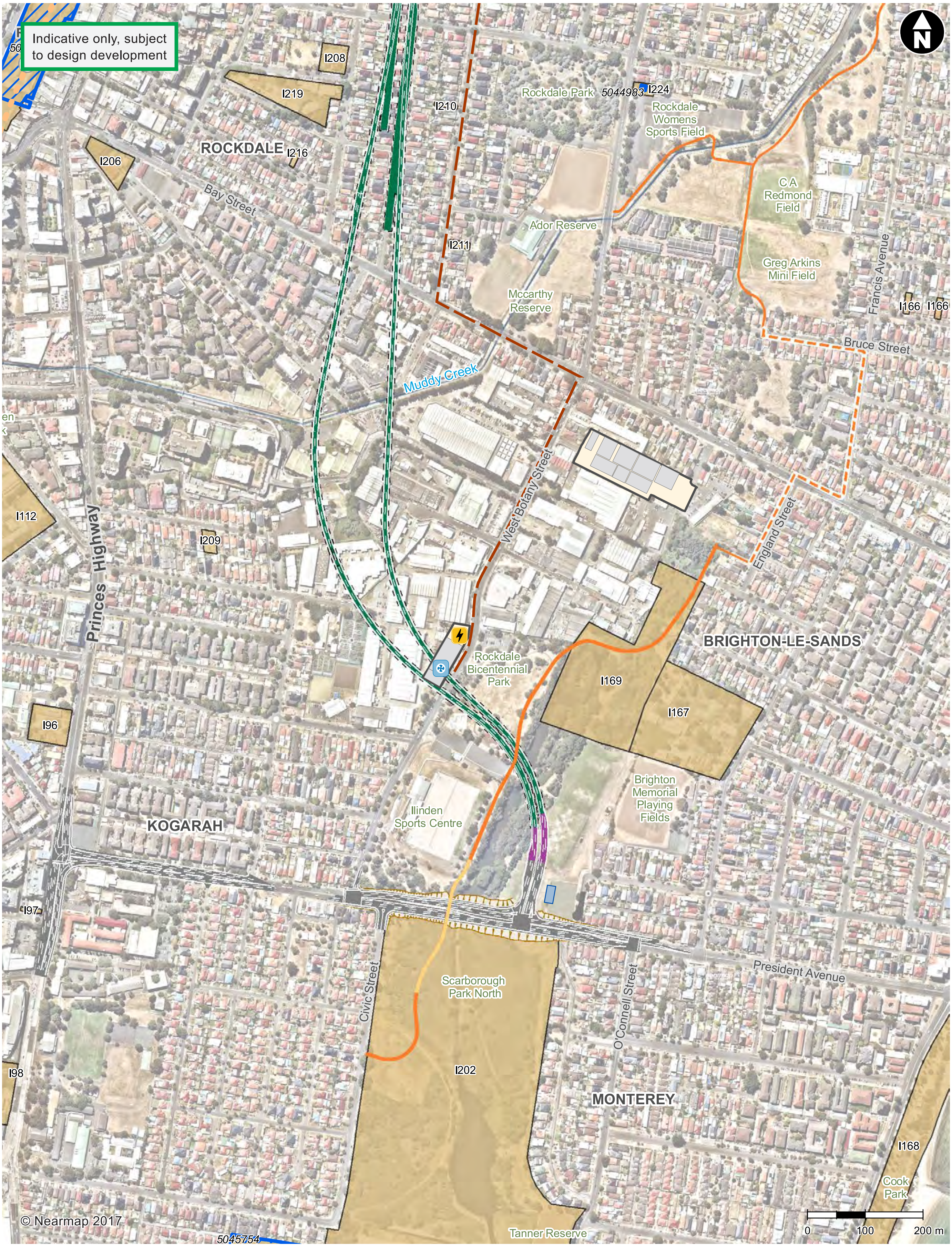
Source: NSW Office of Environment and Heritage

19.2.4 Archaeological Potential

Based on the site inspection and an understanding of the historical land use of the area, predictions about the archaeological potential can be made. Rockdale Bicentennial Park and Memorial Park were largely left as undeveloped swamp lands until the depression era reclamation works between 1932 and 1934. The reclamation works reworked much of the swamp area, building them up and creating a new water course and lake area north of President Avenue.

No areas of archaeological potential have been identified.

Figure 19-2 Non-Aboriginal heritage items within the vicnity of the project



LEGEND

- The project in tunnel
- The project on surface
- The project as an open slot
- Water quality basin
- On-road cycleway
- Shared cycle and pedestrian pathways
- President Avenue shared cycle and pedestrian bridge
- Building
- Embankment
- Water quality basin
- Substation
- Rockdale ventilation facility
- Permanent power supply line
- State Heritage Register
- Rockdale LEP
- Railway station
- Railway line

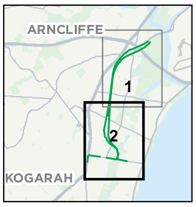


Figure 19-3 Non-Aboriginal heritage items within the vicinity of the project

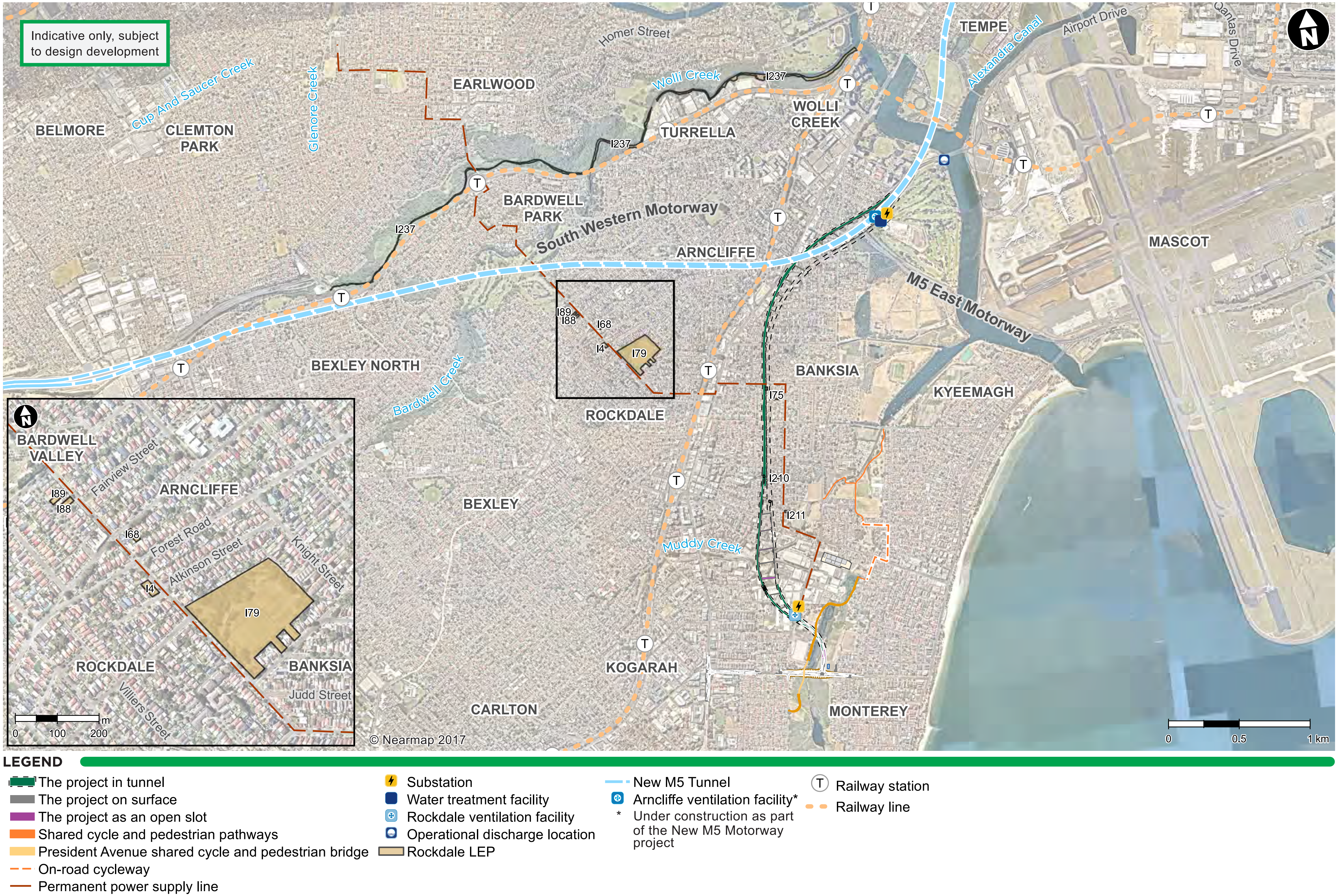


Figure 19-4 Non-Aboriginal heritage items located within the vicinity of the permanent power supply line route

19.3 Potential impacts – construction

The project affects two heritage items listed on the Rockdale LEP with local significance, Kings Wetland (I169) and Patmore Swamp (I202), located to the north and south of President Avenue, respectively.

Impacts to the Kings Wetland site would include clearing of trees located along the eastern boundary of the wetlands adjacent to the Brighton-Le-Sands school. These trees would be removed to allow for the construction of a haul road. The existing trees present along the bank of the wetland are proposed to be retained and would not be disturbed. At the conclusion of construction works, the area would be rehabilitated back to the original state of the wetlands prior to construction. The shared cycle and pedestrian pathways would also cause impacts to the Kings Wetland site. There would be no direct impacts to Brighton-Le-Sands school or to the identified heritage building.

The proposed project footprint in relation to Patmore Swamp is shown on **Figure 19-5**. Impacts to Patmore Swamp include the acquisition of a 30 metre strip along the frontage of President Avenue for the upgrade of President Avenue. A shared cycle and pedestrian bridge would also be constructed over President Avenue. A shared cycle and pedestrian pathway would extend from the shared cycle and pedestrian bridge and continue south through Patmore Swamp and would link up with Civic Avenue near Annette Avenue. This section of the shared cycle and pedestrian pathway would need to be raised above the current ground level of Patmore Swamp. In all, the shared cycle and pedestrian pathway would be approximately 150 metres long and up to six metres at its widest point through the swamp. The construction of the shared pathway would include the removal of the existing vegetation for the network to link President Avenue with Civic Avenue in the vicinity of Annette Avenue.

The permanent power supply route passes through the curtilage of one S170 listed item (Bardwell Park Railway Station Group) and five conservation areas. The proposed works would involve a temporary visual impact to the conservation areas which would be limited to the construction period. The identified heritage values of these conservation areas are vested in the houses and streetscape, therefore no permanent heritage impacts are likely to occur from the powerline. The Bardwell Park Railway Station Group has the potential to be directly impacted and therefore avoidance should be sought as a first preference, with mitigation measures required should the works require egress through the listed curtilage.

19.3.1 Direct impacts

Construction vibration

The safe working distance identified for vibration in the noise and vibration assessment was 25 metres to avoid cosmetic damage to structures, assessed against the maximum rating for plant such as a vibratory roller, hydraulic hammer, vibratory pile driver, pile borer and jack hammer (see section 5.5 in **Appendix G** (Noise and vibration technical report). Analysis of mapped heritage items has identified that the only known heritage item within 25 metres of the proposed surface works with a potential for vibration impacts is the Shop and Residence listed on the Kogarah LEP 2012 as I97 with local significance. No direct impacts are proposed for this item which is located at 111 Princes Highway, adjacent to proposed surface works in that area (approximately seven metres from the closest work area location).

To avoid indirect impacts to this item use of machinery should be limited to a maximum plant use of vibratory roller < 100 kN (Typically 2-4 tonnes), the medium hydraulic hammer (900 kilograms – 12-18 tonne excavator) and the hand-held jack hammer, which the noise and vibration assessment has identified as safe plant to use within a seven metre distance and to avoid cosmetic damage to existing structures.

Ground movement

Ground movement is an expected outcome of tunnelling projects. The ground movement anticipated is predominantly settlement (also termed subsidence). Upward ground movement (also termed heave) may also occur.

The causes of ground movement due to tunnelling can be classified as:

- Consolidation of the soil profile - due to water inflow in to the tunnel resulting in groundwater drawdown in the overlying soil profile. This results in an increase in stress in the soil matrix as water is lost from the soil pores (settlement only)
- Tunnel induced movement - due to the change in stresses in the surrounding rock mass and ground loss caused by the tunnel excavation (settlement or upward heave).

The areas that are most likely to be affected by settlement are usually when tunnelling is closest to the ground surface and around the tunnel portals and entry and exit ramps. The majority of the tunnel is expected to create less than 10 mm of subsidence. It is generally accepted that the risk of damage to surface features is negligible when subjected to total settlements of less than 10 mm (R.J. Mair, R.N.Taylor, J.B. Burland, 1996). For the majority of the tunnel length, the ground settlement is predicted to be less than 10mm due to the depth of the tunnel. Increased levels of settlement (up to around 30mm) may be observed at the southern end of the project, where the tunnel is shallower. **Table 19-4** contains details of the heritage items and heritage conservation areas that directly intersect with the tunnelling alignment.

Table 19-4 Heritage items and Heritage Conservation Areas on Local and State Registers intersecting with the tunnelling alignment

Item Name	Address	Significance	Listing	Depth of Tunnel	Impact Type	Impact Ranking
Rock Lynn	58 Bestic Street, Rockdale	Local	I207	Greater than 60 metres below ground	Unlikely to be impacted	Neutral
Part of singlet-storey terraced cottages known as Jackson's Row	11 Gibbes Street, Banksia	Local	I74	Greater than 60 metres below ground	Unlikely to be impacted	Neutral
Arncliffe Public School and Teluba	168–170 Princes Highway, Arncliffe	Local	I42	Greater than 60 metres below ground	Unlikely to be impacted	Neutral
Sandstone Victorian cottage	15 Kyle Street, Arncliffe	Local	I34	Greater than 60 metres below ground	Unlikely to be impacted	Neutral
House	31 Kyle Street, Arncliffe	Local	I35	Greater than 60 metres below ground	Unlikely to be impacted	Neutral
House	73 West Botany Street	Local	I56	Greater than 60 metres below ground	Unlikely to be impacted	Neutral
Western Outfall Main Sewer (Rockdale to Homebush)	Valda Avenue (off south side of Kogarah Golf Course) Arncliffe	State Area	5053886	Greater than 60 metres below ground	Unlikely to be impacted	Neutral

Statements of heritage impact

There would be the potential for direct impacts to both Kings Wetland and Patmore Swamp from the works associated with this Project. These impacts have been assessed against the significance criterion (as discussed in **section 19.1.6** above). The full heritage impact assessment for both Kings Wetland and Patmore Swamp can be found in **Appendix N** (Statement of heritage impact), while a summary of each is provided below.

The Proposed Works would have an impact to the current heritage listings associated with Patmore Swamp and Kings Wetland only. There are no other historical archaeological or potential built heritage sites that would be affected by the proposed works.

Patmore Swamp

There would be direct construction impacts to Patmore Swamp associated with this project. A 30 metre wide portion of the swamp along the whole of the President Avenue frontage would be acquired and the shared cycle and pedestrian pathways constructed. These works would result in approximately four percent of the Patmore Swamp listed area being impacted (refer **Figure 19-5** for extent of works). This would have a minor impact to the heritage significance of Patmore Swamp. The removal of the portion of the swamp along President Avenue is considered to be a **negative impact**. The construction of the shared cycle and pedestrian pathways proposes associated landscaping works through the swamp. These landscaping works would promote the aesthetic significance of the swamp and have a positive heritage outcome. Overall the negative and positive impacts result in an overall medium residual impact in this area.

LEGEND

- The project on surface
- Shared cycle and pedestrian pathways
- President Avenue shared cycle and pedestrian bridge
- Embankment
- Water quality basin
- State Heritage Register
- Rockdale LEP

Figure 19-5 Project features within Patmore Swamp

Kings Wetland

The project works are likely to have a **moderate impact** to the Kings Wetland heritage listing. Existing vegetation along the eastern boundary of the listed area would be removed to enable construction of a haul road. The existing vegetation along the wetland/creek area would not be impacted. As shown in the historical research and from aerial photography (refer Plate 3 of **Appendix N** (Statement of heritage impact)), the area of Kings Wetland to the north of Kings Road represents the remnant vegetation that can be associated with the pre-1788 environment associated with the wetland. The area to the south of Kings Road within the Kings Wetland heritage listed area has been significantly modified post 1940s and does not represent the pre-1788 natural vegetation landscape associated with a wetland.

Archaeological potential

With the exception of the potential archaeological remnants of market gardens present around the swamp area periphery, the only archaeological potential that may be present is likely to relate to active drains installed as part of the modification and reclamation works at Patmore Swamp. These items, however, are not likely to have any archaeological significance or research potential. Also, former or active drains are not considered to be 'relics' but are 'works' defined by the *Heritage Act 1977*, and therefore no permit is required to impact on these items.

Given the extent of reclamation and modification works, including along the sites of 431 to 439 West Botany Street where a former market garden was present, any archaeological potential associated with former farming practices in this area is likely to be highly disturbed.

It has been assessed that there are no areas of archaeological potential within Rockdale Bicentennial Park, including Memorial Park, or Patmore Swamp.

19.3.2 Indirect impacts

Visual impacts

Impacts to the heritage items as a result of visual impacts of construction are as follows:

- **Kings Wetland** – There would be high-moderate visual impacts experienced in views from the Kings Wetland due to the high level of modification caused by the removal of trees, major earthworks, tunnelling and construction works, and moderate sensitivity of these views
- **Patmore Swamp** – There would be a moderate-low visual impact on views from Patmore Swamp due to the removal of vegetation, earthworks, roadworks and construction of the President Avenue shared cycle and pedestrian bridge resulting in a moderate level of modification to these low sensitivity views
- **Brighton-Le-Sands Public School** - There would be a moderate visual impact on views from the Brighton-Le-Sands school, due to the removal of trees and scale of construction work in proximity to this location.

The visual impacts of the project on non-Aboriginal heritage items and management measures to mitigate impacts are discussed in **Chapter 13** (Landscape and visual).

19.4 Potential impacts – operation

Potential impacts to non-Aboriginal heritage (either direct or indirect) during the operation of the project largely relate to impacts to urban design landscape character and visual amenity. Operational impacts such as increased noise, vibration or air quality are not considered likely to affect any of the known heritage-listed sites, including Kings Wetland or Patmore Swamp.

The design of the project, including post construction landscaping works, would rehabilitate the portion of the Kings Wetland area that would be impacted during construction works. Additionally, through design of the works along the boundary of Patmore Swamp with President Avenue, including the shared cycle and pedestrian pathways through Patmore Swamp, the project has minimised total ground disturbance required for the project.

Visual impacts

Through the preparation of an urban design and landscape strategy, the project aims to blend new infrastructure such as bridges associated with the shared cycle and pedestrian pathways, portals and other facilities into the existing visual surrounds where reasonable and feasible to do so. Furthermore, existing vistas from heritage items would be considered during future design phases and any rehabilitation strategies (for items such as Kings Wetland and Patmore Swamp) in a manner sympathetic with the heritage significance of the item. Specific impacts to each item are as follows:

- Kings Wetland – There would be moderate-low visual impacts from Kings Wetland due to the reinstatement of parkland and introduction of new vegetation, which would in time soften the appearance of views to the tunnel entry and exit lanes, ramps and portal
- Patmore Swamp – There would be a high-moderate impact from Patmore Swamp into the project entry and exit ramps due to the extensive changes to these views which would be transformed from open space to an intersection and tunnel entrance
- Brighton-Le-Sands Public School - There would be a moderate-low visual impact on views from the Brighton-Le-Sands school due to intervening existing and new vegetation.

19.5 Cumulative impacts

The project has been assessed as having an overall minor heritage impact. This has been achieved through:

- Construction in land that was not considered suitable for residential development in the 19th century, and largely reserved for its amenity value in the 20th century
- Minimising impacts to established suburban precincts which may contain heritage items among their building stock
- Design of the extension works to be a tunnel route rather than a surface road route
- Design and refinement of the intersection at President Avenue
- Location of ventilation shaft outlets and co-location of infrastructure with existing compounds and facilities
- The modest overall scale of the project.

Collectively these measures have reduced the likelihood of impact to non-Aboriginal heritage to a minor level.

By comparison, the WestConnex series of projects are located in a far more densely populated part of Sydney, historically occupied throughout the 19th and 20th centuries, where reserved or under-utilised land is limited and less well-placed to minimise impact. The additional impact of the project is relatively minor and does not affect the overall quantum of motorway impacts that have been approved within the past decade.

The future stages of the F6 Extension propose an additional motorway connection from President Avenue south towards Loftus. No detailed design is available at this stage, meaning that any understanding of the cumulative impacts of proposed future works can only be considered in a broader context. As these future works would potentially combine controlled surface infrastructure with underground tunnels, and listed heritage items to the south of President Avenue are known, it should be possible to complete a design that is sensitive to these items and avoids major impacts to heritage. Cumulative impacts can be avoided primarily through avoidance, with underground tunnels an effective method of retaining surface heritage features. Any mitigation measures that are needed would have to be considered when a detailed design is available, should total avoidance of all heritage prove unworkable.

A full description of the cumulative effects of the project can be found in **Appendix N** (Statement of heritage impact).

19.6 Management of impacts

Based on the historical research, site inspection and understanding of the project construction works, the following management and mitigation measures have been prepared. It is noted that management measures relating to non-Aboriginal heritage items have also been addressed in other relevant sections of the EIS, including:

- Vibration resulting from construction in **Chapter 11** (Noise and vibration) and **Appendix G** (Noise and vibration technical report)
- Visual impacts resulting from construction and operation in **Chapter 13** (Landscape and visual) and **Appendix C** (Place making and urban design)
- Urban design and landscape context in **Appendix C** (Place making and urban design).

Table 19-5 Environmental management measures – non-Aboriginal heritage

Impact	Reference	Environmental management measure	Timing
General	NAH1	A Construction Heritage Management Plan will be prepared for the project. The plan will detail measures to minimise impacts on identified heritage features within the project boundary and will also detail procedures to manage unexpected heritage finds.	Prior to construction
	NAH2	Impacts to non-Aboriginal heritage items will, to the greatest extent practicable, be avoided and minimised. Where impacts are unavoidable, works will be undertaken in accordance with the relevant management strategy as defined for the non-Aboriginal heritage item.	Prior to construction Construction
Kings Wetland	NAH3	Consultation will be undertaken with Bayside Council regarding the impacts that would occur to the Kings Wetland (heritage item listed on the Rockdale LEP 2011). Roads and Maritime will provide a copy of the proposed landscape rehabilitation plan to Council to facilitate comment on the proposed impacts and mitigation measures.	Prior to construction
Patmore Swamp	NAH4	Notification and consultation will be undertaken with Bayside Council outlining the impacts that would occur to the Patmore Swamp (heritage items listed on the Rockdale LEP 2011).	Prior to construction
Kings Wetland	NAH5	A protection area will be established either side of the proposed haul road to reduce impacts within the boundaries of the heritage listing. The delineation of the protection area will be maintained throughout the construction period. As part of the detailed design phase, the haul road through the boundaries of the heritage listing will be further optimised with a view to reducing the requirement for the removal of vegetation, as far as is practical. At the conclusion of construction, parts of the area within the boundaries of the heritage listing will be rehabilitated.	Detailed design Construction
Patmore Swamp	NAH6	A protection area will be established as a no-go area during construction along either side of the proposed shared cycle and pedestrian pathways and along the new boundary of President Avenue and Patmore Swamp, to preserve as much of the existing vegetation as is practical within the boundaries of the heritage listing. The delineation of the protection area will be maintained throughout the construction period. A heritage interpretation strategy will be prepared to outline opportunities for heritage interpretation being integrated into the design of the shared cycle and pedestrian pathway through Patmore Swamp.	Construction

Impact	Reference	Environmental management measure	Timing
Bardwell Park Railway Station group	NAH7	The installation of the permanent power supply across the Bardwell Park Railway Station group overbridge would be undertaken to avoid permanent changes to the fabric and visual appearance of the bridge. Should this be unavoidable, further assessment will be undertaken during detailed design.	Prior to construction
Shop and residence	NAH8	Use of machinery should be limited within a seven metre distance to avoid cosmetic damage to existing structures. A visual inspection and assessment should be undertaken by a heritage specialist before works commence to ensure no additional mitigation measures are required.	Pre-Construction and Construction

19.7 Comparative assessment

Based on the impacts the project will have, **Table 19-6** presents a comparative analysis of other heritage wetlands and swamps in the Sydney region.

Table 19-6 Comparative analysis

Item	Heritage Listing	Significance (SHR Criteria)	Comparison to Kings Wetland and Patmore Swamp
Kings Wetland	S170	Criteria A, C, D, E, F & G	N/A
Patmore Swamp	LEP	Criteria A, B, C, E & G	N/A
Botany Water Reserves	SHR, S170, LEP	Criteria A, C, D, E, F & G	Botany Water Reserve is associated with Sydney's water source from 1850 through to 1870s. The listing is 58 ha of wetlands and includes smaller wetland and ponds. The larger po19nds are similar in size to the natural ponds (known as Lachlan Swap) prior to their modification into the current ponds. This listing also includes non-Indigenous heritage items and historical plantings. There are also considered remnant sections of Eastern Suburbs Banksia Scrub present. The Botany Bay Water Reserves are considered to be of higher significance for both its natural and historical cultural values, being associated with Sydney's Water supply than that associated with the Kings Wetland and Patmore Swamp.
Centennial Park, Moore Park, Queens Park	SHR, S170, LEP Nominated to the National heritage list	Criteria A, C, D & E	Centennial Park is historically significant as part of the site of the second Sydney Common and public open (1811); Sydney's second and third water supply, Busby Bore and the Lachlan Water Reserve; and use as a major public event space. The most significant periods in the history of the park are: pre-European, natural environment pre-1788; Lachlan Water Reserve 1811-1887; Centennial Park 1888-1930, 1984-present [1990]. The natural and cultural significance of the site, including both indigenous and non-indigenous heritage, is considered to be unique and exceptional at a State and National level. The natural and cultural significance of the Centennial parklands is considered to be greater than that attributed to Kings Wetland and Patmore Swamp.
Lower Duck River Wetlands	LEP	Criteria C & E	The Lower Duck River Wetlands is located along the foreshore of Duck River and is a representative indigenous vegetation, fauna and fauna habitat and an aesthetic element on the Parramatta River. This heritage listed wetland is listed for its natural heritage values, similar to both Kings Wetland and Patmore Swamp. Both Kings Wetland and Patmore Swamp have been extensively modified culturally, including landscaping and plantings.

Item	Heritage Listing	Significance (SHR Criteria)	Comparison to Kings Wetland and Patmore Swamp
Wolli Creek Wetlands	LEP	Criteria A, B & F	Wolli Creek Wetlands is considered to be an intact mangrove and salt marsh habitat in the Sydney region. The Salt marsh community is rare and poorly conserved in NSW. This area also acts as an important wildlife corridor for migratory Wading Bird Treaty, have been sighted in the area. Compared to both Kings Wetland and Patmore Swamp, this wetland is considered to be of a similar heritage value, however, the Wolli Creek Wetland is listed solely for its natural indigenous heritage values and no cultural heritage values. Both Kings Wetland and Patmore Swamp are both heavily impacted and highly landscaped sites that do not reflect much on their indigenous natural heritage values.

19.8 Environmental risk assessment

An environmental risk assessment was undertaken in three phases as part of the project:

- During the preliminary environmental assessment, carried out as part of the SSI application report to allow for early identification of key non-Aboriginal heritage issues
- Through an assessment of the key issues identified in the SEARs for the project
- During the EIS to confirm the impacts based on the results of detailed investigations.

The assessment process used a likelihood and consequence occurrence risk approach. Likelihood and consequence category descriptions can be found in **Appendix O** (Methodologies)

The risk analysis undertaken for non-Aboriginal heritage identified the following risks:

Table 19-7 Environmental risk analysis – non-Aboriginal heritage

Summary of impact	Construction/ operation	Management and mitigation reference	Likelihood	Consequence	Residual Risk
Potential indirect impacts on features of local heritage significance (e.g. altered viewsheds), including Kings Wetland, Patmore Swamp and Brighton Le Sands Public School	Construction	NAH3, NAH4, NAH5, NAH6	Likely	Moderate	Medium
Direct impacts to local heritage item Patmore Swamp by the proposed surface works to President Avenue	Construction	NAH6	Certain	Minor	Low
Impacts to items of non-Aboriginal heritage which are discovered during demolition or earthworks	Construction	NAH1	Unlikely	Moderate	Low

One medium level residual risk has been identified in this residual risk assessment. Through the detailed design of the project there is further opportunity to:

- Develop effective construction methodologies and planning with the construction contractor to ensure that management and mitigation measures are effectively implemented

- Implement a process of review, correction and audit for the CEMP as detailed in **Chapter 29** (Summary of environmental management measures). This is a process of continuous improvement that would form part of the CEMP and OEMP and allow for management measures to be updated or improved during construction and operational phases where practical.

Impacts identified as having a low residual risk are considered to have already been managed to a reasonable and feasible level.

20 Aboriginal cultural heritage

This chapter assesses the potential impacts of the project on Aboriginal cultural heritage, including cultural and archaeological impact, and how the desired performance outcomes for Aboriginal cultural heritage have been met. **Table 20-1** sets out the SEARs relevant to Aboriginal cultural heritage and where the requirements have been addressed in this EIS.

Table 20-1 SEARs - Aboriginal cultural heritage

SEARs	Where addressed in this EIS
1. The Proponent must identify and assess any direct and/or indirect impacts (including cumulative, vibration and visual impacts) to the heritage significance of listed (and nominated) heritage items inclusive of: a) Aboriginal places and objects, as defined under the *National Parks and Wildlife Act 1974* and in accordance with the principles and methods of assessment identified in the current guidelines; b) Aboriginal places of heritage significance, as defined in the Standard Instrument – Principal Local Environmental Plan;	Direct and/or indirect impacts resulting from construction are presented in **section** 20.3.1, while direct and/or indirect impacts resulting from operation are presented in **section** 20.3.2. There are no Aboriginal places of heritage significance within the project footprint. Cumulative impacts are presented in **section** 20.4.
2. Where impacts to State or locally significant heritage items or archaeology are identified, the assessment must: c) be undertaken by a suitably qualified heritage consultant(s);	Assessment of Aboriginal cultural heritage was undertaken by Dr Darran Jordan, Senior Archaeologist and Heritage Specialist at AECOM. Dr Jordan has over 12 years' experience as a heritage consultant and a doctoral degree from the University of Sydney in Archaeology.
3. The Proponent must identify and describe the Aboriginal cultural heritage values of the area and where this includes archaeological investigations of Aboriginal objects, this must be conducted by a suitably qualified archaeologist, meeting the minimum qualification requirements specified in section 1.6 of the Code of Practice for Archaeological Investigation of Aboriginal Objects in NSW (DECCW 2010).	Aboriginal cultural heritage values are described in **section** 20.2.5.
4. Where impacts to Aboriginal objects and/or places are proposed, or Aboriginal cultural heritage values are identified, consultation must be undertaken with Aboriginal people in accordance with the current guidelines and conservation, management and impact mitigation measures must be identified.	Consultation undertaken as part of the assessment is presented in **section** 20.1.5. Management measures are provided in **section** 20.5.
5. The significance of cultural heritage values for Aboriginal people who have a cultural association with the land must be documented and any Aboriginal objects recorded as part of the assessment must be documented and notified to OEH.	Consultation undertaken as part of the assessment is presented in **section** 20.1.5. Field survey inspection / assessment results are provided in **section** 20.2.4.

20.1 Assessment methodology

20.1.1 Overview

The Aboriginal cultural heritage assessment involved:

- A desktop review of background literature including previous investigations and register searches such as the Aboriginal Heritage Information Management System (AHIMS)
- Consultation with the relevant Local Aboriginal Land Council (LALC)
- An archaeological field inspection conducted on 25 January 2017 attended by an archaeologist and a representative from the Metropolitan Local Aboriginal Land Council (MLALC)
- Identification of mitigation measures to reduce potential impacts to Aboriginal cultural heritage, including Aboriginal archaeological and culturally sensitive sites as well as areas of Potential Archaeological Deposit (PAD).

Assessment of Aboriginal cultural heritage was conducted by a suitably qualified heritage consultant in accordance with the:

- *Aboriginal cultural heritage consultation requirements for proponents 2010* (DECCW,2010)
- *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales* (DECCW 2010)
- *Due Diligence Code of Practice for the Protection of Aboriginal Objects in NSW* (DECCW 2010c)
- *Procedure for Aboriginal Cultural Heritage Consultation and Investigation* (PACHCI) (Roads and Maritime, 2011).

The PACHCI procedure codifies how the *Aboriginal cultural heritage consultation requirements for proponents* and the *Due Diligence Code of Practice* are implemented on Roads and Maritime projects. While the full PACHCI procedure involves four stages, 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. For this project this stage was carried out by a Roads and Maritime Services Aboriginal Cultural Heritage Officer
- Stage 2: Further assessment and site survey with Aboriginal stakeholder involvement and an archaeologist to assess the project's potential to harm 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 (AHIP), if required.

The methodology adopted for this assessment is in accordance with the requirements of Stage 1 and Stage 2 of the PACHCI process. Stage 1 was completed by a Roads and Maritime Aboriginal Cultural Heritage Officer on the 17 January 2018. This report comprises the results of the Stage 2 assessment.

20.1.2 Relevant legislation

National Parks and Wildlife Act 1974 (NSW)

The *National Parks and Wildlife Act 1974* (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.

Aboriginal and Torres Strait Islander Heritage Protection Act 1984 (Commonwealth)

The *Aboriginal and Torres Strait Islander Heritage Protection Act 1984* (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 and Energy, in consultation with the relevant State/Territory minister, may make a declaration to protect an Aboriginal area or object.

20.1.3 Project footprint

For the purposes of both the desktop assessment and field survey, the study area was defined as the project footprint. This includes the main alignment, tunnel portals and surface works as well as the permanent power supply route and the locations of ancillary facilities such as construction compounds, ventilation facilities and motorway operation centres. It also includes the alignment of a route proposed for the construction/installation of a permanent power supply connection from the Ausgrid Canterbury subtransmission substation to the Rockdale Motorway Operations Complex. Refer to **Figure 20-1** for the project footprint.

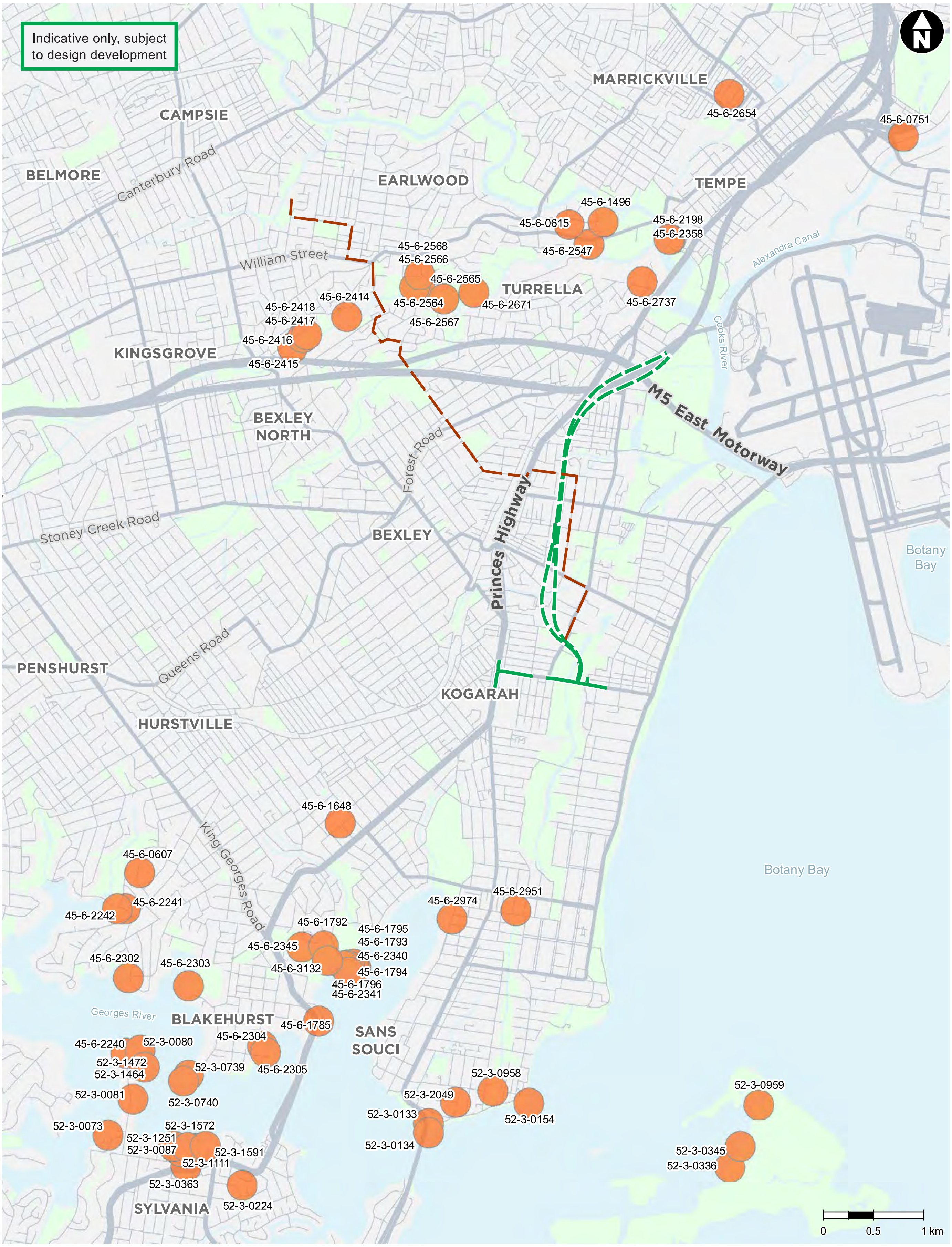
20.1.4 Desktop review

As part of Stage 1 and Stage 2 of the PACHCI process, a desktop review was undertaken. This included a review of background literature and previous investigations, as well as undertaking searches of relevant registers to determine if any known or potential Aboriginal archaeological and culturally sensitive sites were known to be located within the project footprint.

The results of the desktop review are detailed in **section 20.2**.

20.1.5 Consultation

The Stage 1 PACHCI assessment undertaken by Roads and Maritime concluded that the project had the potential to disturb land on which Aboriginal objects or significant cultural values could occur. The Roads and Maritime Officer identified that a Culture and Heritage Officer from the Metropolitan Local Aboriginal Land Council (MLALC) was the appropriate stakeholder and engaged representative Selina Timothy to attend the field inspection. Consultation and a field inspection were undertaken with the MLALC representative as per the Stage 2 PACHCI process. During fieldwork, the MLALC Culture and Heritage Officer was consulted for any relevant cultural information pertaining to the project footprint. The results of the field inspection and consultation are detailed in **section 20.2.4**.



LEGEND

- The project in tunnel
- The project on surface
- Permanent power supply line
- AHIMS
- Road
- Waterway
- Waterbody

Figure 20-1 AHIMS Sites within the project vicinity

20.2 Existing Environment

In this section the existing environment for Aboriginal cultural heritage addresses:

- Occupation of the land (pre-European settlement)
- Aboriginal occupation within the landscape context of the area
- AHIMS register records
- Any previous Aboriginal cultural heritage investigations
- Results and discussion of the Stage 2 PACHCI field investigation.

20.2.1 Overview

The project footprint falls within the Aboriginal language group of the Eora, according to the boundaries identified on the AIATSIS Map of Indigenous Australia[1]. The Eora area is predominantly coastal and ranges from Port Jackson in the north down to La Perouse in the south. The AIATSIS Map defines the surrounding language groups as Kuring-gai to the north, Tharawal to the south and Dharug to the west[2].

Early usage of the term Eora was not in relation to the description of any particular tribal group, but rather was a more general reference to Aboriginal people. As the name Eora was only introduced in later sources and not contained in the earliest ethnographic recordings, it suggests that the Eora area was either part of the Kuring-Gai area or the Dharug area. Some studies have argued that the Dharug territory extended to the coastline between Port Jackson and Botany Bay, based on the ethnographic observations of explorers and settlers, while other texts, such as the writings of Threlkeld, suggest the Kuring-Gai area may have extended further south along the coast[3].

The Dharug language group (comprised of two coastal and hinterland dialects) is known to have 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. Some sources indicate that the coastal dialect of the Dharug language was spoken on the Sydney peninsula and the country to the north of Port Jackson, and a hinterland dialect, spoken on the Cumberland Plain from Appin in the south to the Hawkesbury River in the north[4].

The primary unit of social organisation amongst the Dharug was the clan, with each clan, or 'tribe', consisting of around 50 to 60 people and taking its name from the place where its members resided[5]. Unlike many Australian Aboriginal groups, social organisation amongst the Dharug did not comprise a class system based on moieties or sections but rather was based on clan membership attained through patrilineal descent.

As to the name of the Dharug clan occupying land within the project corridor at contact, available sources suggest that this may have been the *Gameygal* clan (also spelt *Kameygal*). Attenbrow (2010) has suggested that the Gameygal likely occupied land around Botany Bay.

Available historic records indicate that a wide range of marine, freshwater, terrestrial and avian fauna were exploited by Dharug-speaking peoples for food. In coastal areas, an emphasis on the exploitation of marine resources, principally fish and shellfish, is attested in the writings of several early observers[6]. The plant food resources of coastal and hinterland Dharug-speaking peoples are poorly represented in the writings of early colonial observers. Nonetheless, available descriptions suggest that plants formed a regular part of the diets of groups in both areas[7].

---

[1] Horton, D. R. (1996). Aboriginal Australia. Canberra, ACT: Aboriginal Studies Press.
[2] State Library of NSW. (2006). *EORA: Mapping Aboriginal Sydney 1770-1850*. (K. V. Smith & T. Willsteed, Eds.). Sydney: State Library of New South Wales.
[3] Threlkeld, L. E. (1827). Specimens of a Dialect of the Aborigines of New South Wales; Being the First Attempt to Form Their Speech Into a Written Language. Sydney: Monitor Office.
[4] Attenbrow, V. (2010). Sydney's Aboriginal Past: Investigating the Archaeological and Historical Records. Sydney: University of New South Wales Press.
[5] Kohen, J. (1993). *Darug and their Neighbours: The Traditional Aboriginal Owners of the Sydney Region*. Sydney: Darug Link in association with Blacktown and District Historical Society.
[6] Collins, D. (1798). *An Account of the English Colony in New South Wales. Vol. 1.* (B. H. Fletcher, Ed.). London: T. Cadell Jun. & W. Davie
[7] Attenbrow, V. (2010). Sydney's Aboriginal Past: Investigating the Archaeological and Historical Records. Sydney: University of New South Wales Press.

Evidence from European documentation identifies such practices as fishing from bark canoes, utilising grass tree stems for spear shaft manufacture, wrapping hair in paperbark strips for decoration and partaking in a variety of art activities occurring in this area. Early observations in this area describe fishing and the collection of oysters, mussels and cockles as primary contributions to the diet of Aboriginal people. Associated implements included bark canoes, spears, hooks and lines. Other items of material culture that were recorded in observations of the area include shields and spear throwers. Stone tools have also been identified in the archaeological record of the region[8].

Two major forms of shelter appear to have been utilised by Dharug speaking peoples at the time of European contact: rockshelters and small huts built from sheets of bark, branches and bushes[9,10]. In keeping with the linguistic division of the Dharug language into coastal and hinterland dialects, differences in the nature of huts built along the coast and in the hinterland are attested in early colonial writings, with the former reportedly larger and “formed of pieces of bark from several trees put together in the form of an oven with an entrance…large enough to hold six to eight people”. Regarding settlement duration, “there is little direct historical evidence for the length of time people stayed at any one campsite (be it a rockshelter or bark hut), how often they moved, or what motivated them to move to another campsite”.

With the spread of European settlement across the Sydney region there came numerous acts of Aboriginal resistance. One of the best known is the guerrilla war waged by Pemulwuy, a *Bidjigal* man from the George’s River area. Between 1791 and his death in 1802, Pemulwuy is believed to have organised numerous raids on settler farms and to have speared many travellers around Botany Bay and the Georges River[11]. As he operated in the larger region, it has been suggested that he is likely to have hidden in swampy areas when active around Botany Bay.[12] Widely known and respected in his community due to his various acts of resistance and evasion, many Aboriginal people believed Pemulwuy to be invincible. After his eventual death, Governor King acknowledged Pemulwuy as “an active, daring leader of his people” and “brave and independent character”.

In 1896 an Aboriginal site was identified during construction of the Alexandra Canal. It was comprised of dugong bones and axe heads located within a layer of dark bluish grey sandy clay with marine shells. The finds were considered significant at the time as they showed evidence of transverse and oblique curved cuts and scars that appeared to have been produced by a blunt-edged instrument. The axe heads were located approximately 500 metres from the dugong bones, within the same stratigraphic layer. The excavated material was collected and retained by the Australian Museum and in 2009 the dugong bones were radiocarbon dated, producing a date of 5,520±70 years[13].

---

[8] Navin Officer Heritage Consultants. (2003). Cultural Heritage Assessment of the Proposed Port Botany Expansion.
[9] Barrington, G. (1802). *The History of New South Wales, including Botany Bay, Port Jackson, Parramatta, Sydney and all its Dependents*. London: Paternoster Row.
[10] Collins, D. (1802). *An Account of the English Colony in New South Wales. Vol. 2.* (J. Collier, Ed.). London: T. Cadell Jun. & W. Davies [Reproduced 1971 by the Libraries Board of South Australia. Australiana Facsimile Editions No. 76] Sydney].
[11] Flynn, M. (1995). *Place of Eels: Parramatta and the Aboriginal Clans of the Sydney Region: 1788-1845*. Unpublished report for Parramatta City Council.
[12] Madeline Hourihan from Bayside Council has run a contemporary wetlands tour, with local zoologist Dr Arthur White taking the tour to Patmore Swamp and using it as a touchstone to discuss the Pemulwuy story, noting that he could have hidden in swampy areas in the vicinity when active in the Botany Bay area (St George and Sutherland Shire Leader, 2013).
[13] Lindbergh, J. (2009). AMBS celebrates National Archaeology Week - Australian Museum. Retrieved October 15, 2012, from http://australianmuseum.net.au/BlogPost/Science-Bytes/AMBS-celebrates-National-Archaeology-Week

Plate 1 Dugong bones and stone tools excavated at Sheas Creek in 1896; Australian Museum curator Robert Etheridge at centre[14]

20.2.2 Landscape context

The project is located across the Botany Lowlands physiographic region, characterised by deep sand dunes and patches of swampland surrounding Botany Bay. Surface geology comprises a mixture of Quaternary alluvium and sands associated with watercourses. Additional information regarding the geology surrounding the project is described in **Chapter 16** (Soils and contamination).

The project footprint originally consisted of flat swampy land. While the swamp itself was not utilised, the area around Botany Bay and Cooks River was used for farming, lime extraction, textile manufacturing and flour milling. In 1812 a section of the project footprint located in Scarborough Park was granted to Patrick Moore (Patmore Swamp). In the 1930s the government drained Patmore Swamp, creating artificial lakes through the area, with the modified landscape renamed Scarborough Park[15].

In the 1890s, the search for new permanent clean water sources resulted in the diversion of Sheas Creek and excavation of Alexandra Canal immediately to the north of the project area. Major expansions at Sydney Airport included large scale disturbance works such as the diversion of Cooks River and reclamation of the mangrove and saltmarsh basin located at its mouth[16]. Today, the modified wetlands consist of a system of tidal and freshwater swamps that drain into Botany Bay.

20.2.3 Aboriginal Heritage Information Management System

The AHIMS register provides records of Aboriginal objects reported in accordance with section 89A of the NPW Act. It 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 register was undertaken on 16 January 2018. The search area measured 10 kilometres by 11 kilometres, being larger than and centred on the project footprint. A total of 63 sites were listed in the search results. These are described in **Table 20-2** and shown on **Figure 20-1**. One restricted site was identified, being a site that has been deemed by the recorder to be culturally sensitive, with information about it restricted to an approved list of people. In the case of this restricted site (#52-3-1114), AHIMS administrator Eva Day confirmed on 22 January 2018 that it was located outside the bounds of the project footprint and would not be affected by the proposed works. This site is well away from the project, located within the bounds of the Kamay Botany Bay National Park (north and south) and Towra Point Nature Reserve (SHR 01918).

[14] Lindbergh, J. 2009. *AMBS celebrates National Archaeology Week - Australian Museum*. Retrieved from http://australianmuseum.net.au/BlogPost/Science-Bytes/AMBS-celebrates-National-Archaeology-Week
[15] NSW Office of Environment & Heritage. (2017). NSW State Heritage Register. Retrieved from http://www.environment.nsw.gov.au/heritage/listings/stateheritageregister.htm
[16] Sydney Airport Corporation Limited. (2009). *Sydney Airport Environment Strategy 2010-2015*.

The AHIMS search results also contained two sites listed as 'Not a Site' (#45-6-1496 and #45-6-2951). This designation refers to a site recording that, following further investigation after its initial recording, has been determined to not be of Aboriginal origin. One site in the search results was listed as 'Deleted', #45-6-2358 being a duplicated entry of #45-6-2198. A further site (#45-6-0751) was listed as 'Destroyed', being the location of the Aboriginal stone axes and cut dugong bones (refer **section 20.2.1**) **that** were identified during excavation works for the Alexandra Canal in 1896.

In addition, one Aboriginal Place was identified in the AHIMS search results, the Kamay Botany Bay National Park (north and south) and Towra Point Nature Reserve (SHR 01918). This Aboriginal Place is located approximately 5.5 kilometres to the south-east of the proposed disturbance area and would not be affected directly or indirectly by the proposed works.

The AHIMS data also contains multiple inaccuracies. It is possible that some of the artefact scatter sites may be isolated artefacts, as information on the number of artefacts located in site areas is not present for all of those identified in the search results. Coordinate inaccuracy for AHIMS data is also known from past assessments to be an issue, often the result of errors translating coordinates from one datum to another when updating the register. The given coordinates only represent a centroid, not the full extent of a site's area. Consideration of these limitations was kept in mind during this assessment. Site card recordings are the most accurate representation of the available site data and are treated as the primary source for any relevant AHIMS sites.

Table 20-2 AHIMS sites identified within the extensive search area

Site Type	Number of Sites	Percentage of Sites
Rockshelter (being natural rock overhangs containing evidence of Aboriginal use / occupation)	22	34.9%
Midden (comprising deposits of shells / other materials)	19	30.1%
Art Site	6	9.5%
Artefact Scatter	6	9.5%
Resource and Gathering	2	3.2%
Not a Site	2	3.2%
Burial	1	1.6%
Restricted Site	1	1.6%
Isolated Artefact	1	1.6%
Potential Archaeological Deposit (PAD)	1	1.6%
Deleted	1	1.6%
Destroyed	1	1.6%
TOTAL	63	100%

None of the sites identified in the AHIMS search results were within the project footprint, including the footprint for the permanent power supply. The closest registered site centre point to the project footprint was approximately 710 metres to the north of its northern-most extent (AHIMS #45-6-2737 – a partially destroyed artefact scatter with associated Potential Archaeological Deposit (PAD) at Tempe House, 8 Brodie Spark Drive, Wolli Creek). The closest site coordinate to the permanent power supply route was approximately 290 metres to the west of the footprint (AHIMS #45-6-2414 – a rockshelter located on Wolli Creek approximately 50 metres to the south of Bray Avenue, Earlwood). Based on an assessment of the available AHIMS data, no previously recorded Aboriginal sites would be affected by the proposed works.

Based on aerial images, areas that had been subject to lower levels of past disturbance were assessed for archaeological potential including reserves and parks, particularly if located in proximity to water sources and/or known sites. Public park areas within the project footprint included Patmore Swamp, Illinden Sports Centre, Memorial Fields, Rockdale Bicentennial Park, Rockdale Skate Park and Civic Avenue Reserve with its associated dog park. These areas were assessed through background research and as part of the field inspection and were found to be highly disturbed and unlikely to contain in situ cultural deposits (see **section 20.2.4**).

Possible areas of low disturbance associated with the permanent power supply footprint were not subject to field inspection or MLALC consultation. Aerials indicated that areas with the potential for sensitivity included McCarthy Reserve, Rockdale Park, Gardiner Park, Bardwell Valley Golf Club, Charles Daly Reserve, the Wolli Creek reserve corridor, Earlwood Oval and Hughes Park. Of these areas, the Wolli Creek reserve corridor was identified as having archaeological potential due to low levels of past disturbance. Aboriginal sites have previously been identified along its extent, outside of the project footprint to the east and west of where the permanent power supply footprint would cross the creek alignment. As previously recorded sites follow the course of Wolli Creek, it suggests that further sites may be present in both surface and subsurface contexts.

Available archaeological reports focussed on the areas of recorded AHIMS sites, which were all outside the project footprint. One report noted that Aboriginal skeletal material had been identified in the vicinity of Kogarah. The remains were transferred to the Australian Museum in 1983 and were later examined by anatomist Dr Denise Donlan in 1994 and Professor Richard Wright in 1996. The remains were from a mineral rich layer within an old sand dune located parallel to the coast. It was noted in the report that the sand dunes in this area had high levels of acidity, with bone unlikely to remain extant more than a few hundred years.[17] As there are no intact in situ sand dune deposits in the project footprint, it is highly unlikely that any burials would be present.

Patmore Swamp is listed for its natural and landscape values as part of the wetlands corridor, and has also been noted as having historical value due to the public works program that reshaped its landscape during the depression era. It is listed on the *Rockdale Local Environmental Plan* 2011 as Item 202 (including the Scarborough Park Lakes within its bounds). Despite the high levels of past impact in this area, the retention of sections of (now modified) wetland within the project footprint allows for an opportunity to recognise the prior presence of Aboriginal people by highlighting resource zones they may have used in the past.

20.2.4 Archaeological field inspection

The archaeological field inspection included:

- The identification and recording of existing surface evidence of past Aboriginal activity
- Identification of areas with the potential for subsurface archaeology
- Investigation and development of strategies for avoiding and/or mitigating potential impacts to Aboriginal cultural heritage.

The archaeological survey was carried out on the 25 January 2018, attended by an AECOM senior archaeologist and a MLALC representative in accordance with the *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales*[18] and the PACHCI[19].

The inspection was conducted on foot and by vehicle of both the above-ground sections of the project as well as areas above the proposed tunnels, during which details of the ground surface visibility and land condition were observed. Relevant information was recorded on a hand-held GPS and photographs were taken.

No Aboriginal archaeological sites or objects or areas of Potential Archaeological Deposit (PAD) were identified during the survey. No specific cultural values were identified by the MLALC representative during the survey, although it was noted that this area would have been utilised in the Aboriginal past, having had swamp resources and being close to coastal resources at that time.

[17] Wright, R. 1997. *Report on Human Skeletal Remains from Kogarah in New South Wales (No. E.85991)*.
[18] Department of Environment, Climate Change and Water (2010) *Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales*
[19] NSW Roads and Maritime Services. (2011). *Procedure for Aboriginal Cultural Heritage Consultation and Investigation*

The project footprint has been subject to high levels of disturbance in the recent past, meaning that if any Aboriginal sites were previously present, they are likely to have been destroyed. Impacts noted during the survey included earthworks associated with swamp reclamation and artificial channel construction, dating to the 1930s depression relief program that drained Patmore Swamp and created artificial lakes. In addition there was evidence of road construction, park landscaping, the creation of pathways, parks, residential development and industrial business development as well as ovals, playing fields and other recreational areas and facilities (including Illinden Sports Centre, Memorial Fields, Rockdale Bicentennial Park, Rockdale Skate Park, Civic Avenue Reserve and the associated dog park). Due to the change in landscape from swamp to raised areas for parks and other development, the area has been subjected to high levels of disturbance. Given these past impacts, it is unlikely that any intact in situ deposits would be present within the project footprint. No surface expression of artefacts were noted during the survey and no mature vegetation with the potential for cultural modification was identified. Photographs of areas of disturbance taken during the survey of the project footprint are included below (see **Plate 2** to **Plate 15**).

Plate 2 Civic Avenue Reserve pathway, view north

Plate 3 Civic Avenue Reserve park area, view northwest

Plate 4 President Avenue, view west towards Princes Highway

Plate 5 Park area on the northern side of President Avenue, view east

Plate 6 Illinden Sports Centre, view east

Plate 7 Rockdale Bicentennial Park, view northeast

Plate 8 Waterway between Rockdale Bicentennial Park and Memorial Fields, view north

Plate 9 Memorial Fields, view north

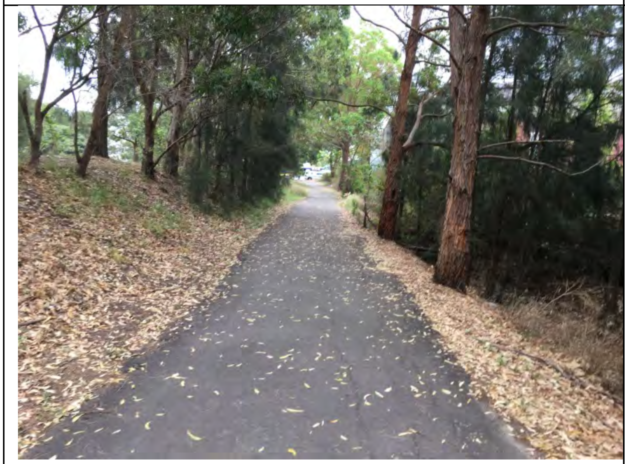


Plate 10 Rockdale Bicentennial Park walkway, view west towards West Botany Street

Plate 11 Industrial businesses adjacent to Rockdale Bicentennial Park, view north

Plate 12 Industrial businesses adjacent to Rockdale Bicentennial Park, view northwest

Plate 13 Car park area off West Botany Street, view northeast

Plate 14 Corner of Marsh Street and M5 East, view northeast

Plate 15 Corner of Marsh Street and M5 East, view northeast

20.2.5 Aboriginal cultural heritage values

MLALC representative Selina Timothy provided a separate report specifically discussing the Aboriginal cultural heritage values of the project footprint. It stated that MLALC "has no objection to the proposed development of this site", but highlighted the likelihood of Aboriginal use of the general area in the past.

The report describes the general area as "a significant spiritual and social area" based on the past water resources that would have been at the original pre-disturbance swamp location likely being "very suitable as hunting and breeding grounds for Aboriginal people due to the abundance of bird and fish life, native food, fresh drinking water and swimming areas".

The report further describes some of the resources that would have been available, including water fowl, fish, different species of frogs, wallabies and other mammals, shellfish, yams, berries and lilies, concluding that: "this area was quite lush and sustainable for the Ancestors who lived off this land".

The MLALC report is included in full in **Appendix N** (Statement of heritage impact).

20.3 Potential impacts

20.3.1 Construction

Impacts on Aboriginal cultural heritage as a result of the project can be either direct or indirect. Direct impacts include physical damage or destruction of Aboriginal sites, while indirect impacts largely relate to vibration from machinery/blasting or subsidence/ground settlement from tunnelling. Indirect impacts could also include activities taking place in culturally significant locations construing a visual impact, or which provide a more generalised sense of harm or loss to Aboriginal cultural heritage values.

Based on the assessment of the project footprint and proposed works with relation to Aboriginal cultural heritage, construction of the project is not likely to result in direct or indirect impacts upon Aboriginal cultural heritage.

The permanent power supply connection would generally be located within the existing road reserve with the exception of where it would cross Bardwell Valley Golf Course, where it would be installed using a horizontal under boring method. It is unlikely that impacts on Aboriginal cultural heritage artefacts or deposits would occur. This would need to be confirmed through field investigation including consultation with MLALC once the final alignment is verified with particular reference to impacts (if any) to Bardwell Valley Golf Course.

20.3.2 Operation

Potential impacts to Aboriginal cultural heritage (either direct or indirect) during operation of the project largely relate to associated impacts such as landscape character and visual amenity. Operational impacts such as increased noise, vibration or air quality are not considered likely to affect Aboriginal cultural heritage given the lack of identified sites within close proximity of the project. Through consideration in design, the project has minimised the surface works to more closely integrate with the existing surrounding infrastructure and to be sympathetic to the surrounding landscape context. This is a prudent measure for the avoidance of Aboriginal cultural heritage sites and values, although in this case the assessment has shown there were no known sites or values in the vicinity that require avoidance.

20.4 Cumulative impacts

The project physically overlaps with the New M5 Motorway project in the vicinity of the Kogarah Golf Course including the colocation of the motorway operations centre, ventilation facilities and the New M5 stub tunnels. As noted within the EIS for the New M5 Motorway, no exiting AHIMS sites nor impacts to Aboriginal cultural heritage were identified within the vicinity of Kogarah Golf Course.

The project has also included the use of the existing construction compound associated with the New M5 Motorway to avoid further disturbance within the vicinity of Kogarah Golf Course, minimising the potential for unexpected finds.

Furthermore, as it has been determined that the project is currently not likely to result in residual impacts upon any known Aboriginal cultural heritage sites, areas of sensitivity or areas identified as having cultural heritage value, it is considered that the project would not contribute to cumulative impacts in this context. As such, no further cumulative impact assessment has been undertaken.

20.5 Management of impacts

In order to reduce the risk of potential impacts to unexpected Aboriginal cultural heritage, environmental management measures are to be implemented during construction are provided in **Table 20-3**. Operational management measures are not considered warranted.

Table 20-3 Environmental management measures – Aboriginal cultural heritage

Impact	Reference	Environmental management measure	Timing
Unexpected discovery of Aboriginal objects	AH1	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).	Construction
Unexpected discovery of human remains	AH2	If human remains are discovered during construction, they would be managed in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime Services, 2015).	Construction
Recognising the prior presence of Aboriginal people	AH3	The project would recognise the prior presence of Aboriginal people by highlighting resource zones they may have used. This could be undertaken through the implementation of interpretive signage and incorporated in to the Place Making and Urban Design Strategy. Should this be pursued, it will be undertaken in consultation with the MLALC.	Construction

This assessment has concluded that the construction and operation of the project is currently unlikely to result in direct or indirect impacts upon Aboriginal cultural values.

The results of this assessment have identified that further investigations (as per PACHCI Stage 3 and Stage 4) are not warranted.

20.6 Environmental risk assessment

An environmental risk assessment was undertaken in three phases as part of the project:

- During the preliminary environmental assessment, carried out as part of the SSI application report to allow for early identification of key Aboriginal cultural heritage issues
- Through an assessment of the key issues identified in the SEARs for the project
- During the EIS to confirm the impacts based on the results of detailed investigations.

The assessment process used a likelihood and consequence occurrence risk approach. Likelihood and consequence category descriptions can be found in **Appendix O** (Methodologies).

The risk analysis undertaken for Aboriginal cultural heritage is summarised in **Table 20-4**.

Table 20-4 Environmental management measures – Aboriginal cultural heritage

Summary of key impact	Construction / operation	Management / mitigation measure	Likelihood	Consequence	Residual Risk
Potential impact on previously unidentified Aboriginal cultural heritage items	Construction	AH1, AH2	Unlikely	Moderate	Low
Potential impact on previously unidentified Aboriginal cultural heritage places or values	Construction	AH1, AH2	Unlikely	Moderate	Low

Impacts identified as having a low residual risk are considered to have already been managed to a reasonable and feasible level. Despite the low risk rating however, review and continual improvement would be undertaken where relevant during detailed design and would be detailed in the Construction Environmental Management Plan and the Operational Environmental Management Plan.

(blank page)

21 Waste management

This chapter outlines the proposed waste management for the project. **Table 21-1** sets out the SEARs relevant to waste management and identifies where the requirements have been addressed in this EIS.

Table 21-1 SEARs – Waste

Assessment requirements	Where addressed
Waste	
1. The Proponent must assess predicted waste generated from the project during construction and operation, including:	Section 21.3 and section 21.4
(a) classification of the waste in accordance with the current guidelines;	Section 21.3
(b) estimates/ details of the quantity of each classification of waste to be generated during the construction of the project, including bulk earthworks and spoil balance;	Section 21.3
(c) handling of waste including measures to facilitate segregation and prevent cross contamination;	Section 21.3
(d) management of waste including estimated location and volume of stockpiles;	Section 21.3
(e) waste minimisation and reuse;	Section 21.3
(f) lawful disposal or recycling locations for each type of waste; and	Section 21.3
(g) contingencies for the above, including managing unexpected waste volumes.	Section 21.5
2. The Proponent must assess potential environmental impacts from the excavation, handling, storage on site and transport of the waste particularly with relation to sediment/leachate control, noise and dust.	Section 21.3.6 and section 21.4.3

21.1 Assessment approach

A desktop assessment was carried out to consider the potential waste streams likely to be generated as part of the construction and operational stages of the project. Indicative quantities and types of waste that would be generated from the project have been estimated through a review of the indicative scale and extent of the project as outlined in **Chapter 6** (Project description), the construction methodology described in **Chapter 7** (Construction) and review of construction waste quantities for similar projects.

Management and mitigation measures were then developed with respect to the relevant legislation and guidelines as outlined below.

21.2 Legislative framework

The key legislative instruments which manage waste in NSW are:

- *Waste Avoidance and Resource Recovery Act 2001* (NSW) (WARR Act)
- *Protection of the Environment Operations Act 1997* (POEO Act)
- *Protection of the Environment Operations (Waste) Regulation 2014* (NSW) (POEO Regulation).

Other guidelines which have been considered for this assessment include:

- Waste Classification Guidelines: Part 1 Classifying Waste (NSW EPA 2014)
- Waste Classification Guidelines: Part 4 Acid sulfate soils (NSW EPA 2014)
- Technical Guide – Management of road construction and maintenance wastes (NSW Roads and Maritime Services (Roads and Maritime) 2016).

21.3 Construction waste management

All wastes generated during construction of the project would be managed using the waste hierarchy approach of avoidance and re-use before consideration of waste disposal. All wastes would be managed in accordance with the waste provisions contained within the POEO Act and, where reused off site, would comply with relevant NSW EPA resource recovery exemptions.

Should waste be found to be unsuitable for reuse or recycling, disposal methods would be selected based on the classification of the waste material in accordance with the Waste Classification Guidelines: Part 1 Classifying Waste (NSW EPA 2014). The Waste Classification Guidelines provide direction on the classification of waste, specifying requirements for management, transportation and disposal of each waste category.

Resource recovery will be applied to the management of construction waste and will include:

- Recovery of resources for reuse - reusable materials generated by the project will be segregated for reuse on site, or off site where possible, including the reuse of the major waste streams (VENM)
- Recovery of resources for recycling - recyclable resources (such as metals, plastics and other recyclable materials) generated during construction and demolition will be segregated for recycling and sent to an appropriate recycling facility for processing
- Recovery of resources for reprocessing - cleared vegetation will be mulched or chipped on-site and used for landscaping, in the absence of a higher beneficial use being identified.

21.3.1 Waste streams

Waste streams generated during construction of the project and their expected classification are outlined in **Table 21-2**.

Table 21-2 Anticipated construction waste types

Activity	Waste streams produced	Expected classification	Waste management strategy
Site establishment and enabling works	Vegetation waste from the removal of trees, shrubs and ground cover that are unable to be mulched and reused within the project.	General solid waste (putrescible)	Minimise areas of vegetation to be cleared by the project.
Demolition of existing structures	Demolition wastes including concrete, bricks, tiles, timber (untreated and treated), metals, plasterboard, carpets, electrical and plumbing fittings and furnishings (doors, windows). May also include asbestos and lead paint.	General solid waste (non-putrescible), Special waste and/or Hazardous waste	Concrete and bricks to be demolished using low impact blasting techniques so as to maintain the structure of the material, and thus its reusability. All other materials are to be disassembled and removed carefully to maximise the potential for reuse and recycling. Hazardous waste is to be removed by a qualified handler for recycling or recovery of energy where possible.
Operation of construction machinery	Waste from operation and maintenance of construction vehicles and machinery including adhesives, lubricants, waste fuels and oils, engine coolant, batteries, hoses and tyres.	Hazardous waste, Special waste and Liquid waste	Liquid waste to be collected and transferred to a dedicated recycling facility where possible, to ensure diversion from landfill. Batteries are to be collected and recycled by a qualified handler.
Tunnelling and earthworks	Excavated wastes (spoil), such as soil and rock, primarily from tunnelling and cutting including virgin excavated natural material (VENM).	General solid waste (non-putrescible)	Minimise excavation and tunnelling through alignment design, cross section of tunnel and construction techniques (i.e. use road headers instead of tunnel boring machines to excavate tunnel).

Activity	Waste streams produced	Expected classification	Waste management strategy
Tunnelling and earthworks	Asbestos and hazardous waste (including contaminated spoil).	Hazardous waste and/or special waste	Disposed of offsite.
Construction of permanent operational infrastructure	General construction waste such as timber formwork, scrap metal, steel, concrete, plasterboards and packaging material (crates, pallets, cartons, plastics and wrapping materials).	General solid waste (non-putrescible)	All materials that are potentially recyclable and should be disassembled and removed carefully to maximise further reuse and recycling. To ensure diversion from landfill, waste materials should be clearly separated and stored on-site, monitored and maintained by the site's environment/waste manager.
Construction of permanent operational infrastructure	Surplus construction material and general site reinstatement waste such as fencing, sediment, concrete, steel, formwork and sand bags.	General solid waste (non-putrescible)	As a priority, surplus construction materials may be transferred to other sites for use, or stored by the contractor for future use. In the second instance, surplus construction materials may be recycled where possible. Surplus materials should avoid being sent to landfill.
Drainage and water management infrastructure	Sediment laden/ potentially contaminated wastewater.	Liquid waste	The contractor may consult with Sydney Water regarding the disposal of potentially contaminated wastewater to the sewer for treatment.
Activities at site offices	General wastes from site offices such as putrescibles, paper, cardboard, plastics, glass and printer cartridges.	General solid waste (non-putrescible) and General solid waste (putrescible)	All waste and recycling generated by the site offices should be source-separated into the following dedicated bins: • General waste • Co-mingled recycling • Paper/cardboard • Toner/cartridges The segregation of recyclables from the general waste stream will maximise resource recovery and minimise materials sent to landfill. All bins should be clearly labelled and coloured to reflect the correct stream. All staff should be trained about the internal office waste management system to ensure adequate understanding across all employees.
Construction of the permanent power supply route	Surplus construction material and general site reinstatement waste such as demarcation fencing, sediment, concrete, formwork and sand bags. Vegetation waste from the removal of ground cover that is unable to be reused within the project.	General solid waste (putrescible)	As a priority, surplus construction materials may be transferred to other sites for use, or stored by the contractor for future use. In the second instance, surplus construction materials may be recycled where possible. Surplus materials should avoid being sent to landfill. Vegetation waste may be collected and transferred to a dedicated green waste recycling facility for garden and food organics to ensure diversion from landfill.

Notes:
1 Classified in accordance with the Waste Classification Guidelines: Part 1 Classifying Waste (NSW EPA, 2014).

21.3.2 Waste disposal locations

There are a number of options for recycling and disposal of construction and operation waste generated by the project. A large number or waste facilities in Sydney are licensed to accept general solid waste (putrescible) and general solid waste (non-putrescible). Specific facilities and collection contractors for the disposal of putrescible and non-putrescible general solid waste would be selected during the later stages of the project and documented in the construction waste management plan.

Recyclables generated during construction and operation of the project would be collected by an authorised contractor for off-site recycling. There are a number of resource recovery facilities in Sydney. Recycling facilities for the project would be determined by the contractor engaged to collect the material.

Special and hazardous wastes would be disposed of at appropriately licensed waste management facilities to be selected during the later stages of the project and documented in the construction waste management plan.

Wastewater generated as a result of construction activities is considered to be ‘construction wastewater’. Construction wastewater would be tested and treated at a construction water treatment plant (if required) and then reused on site wherever feasible, or discharged into the local stormwater system in accordance with the requirements of the POEO Act (refer to **Chapter 18** (Surface water and flooding)).

21.3.3 Spoil management

Spoil generation and management

The most significant waste stream associated with the project is spoil generated from the excavation of the tunnels that is in excess of project requirements. Smaller quantities of spoil would be generated by excavation required for surface components of the project. Anticipated spoil volumes generated from tunnelling and surface works are outlined in **Table 21-3**. Around 1,098,242 cubic metres of spoil would be generated during construction of the project.

Table 21-3 Anticipated spoil types

Waste type	Expected classification	Estimated Spoil Volume (m^3)[1]
Clean spoil (suitable for reuse on site)	General solid waste (non-putrescible)	965,044
Contaminated material for landfill from cut-and-cover excavation at President Avenue	General solid waste (non-putrescible), Restricted waste, Hazardous waste and/or Special waste[2]	77,519
Unsuitable material (alluvium spoil which is not suitable for reuse on site)	General solid waste (non-putrescible)	3,463
Acid sulfate soils	N/A	110,434
Construction and demolition waste (from President Avenue surface works)	General solid waste (non-putrescible) and Special waste[2]	1450
Total		1,098,242

Notes:

1 Classified in accordance with the Waste Classification Guidelines: Part 1 Classifying Waste (NSW EPA, 2014).

2 Spoil would be classified in accordance with the Waste Classification Guidelines: Part 1 Classifying Waste (NSW EPA, 2014) prior to disposal.

Around 191,416 m^3 of general solid waste (non-putrescible) is estimated to be generated during the construction of the project. The volumes of the other classifications of waste (identified in **Table 21-2**) to be generated during the construction of the project were not able to be estimated at this stage.

A contamination assessment has been carried out as part of this EIS (refer to **Chapter 16** (Soils and contamination)). This assessment identified existing contamination issues primarily related to historical land uses which have adversely impacted the quality of soil, fill, groundwater, ground gas and surface water within the project footprint.

Spoil management hierarchy

The project design has considered the principles of the resource management hierarchy as defined in the WARR Act, including minimising excess spoil generation as far as practical. Where possible and fit for purpose, spoil would be beneficially reused as part of the project before alternative spoil disposal options are pursued. Excess spoil which cannot be reused or recycled would be disposed of at a suitably licensed waste management facility.

The project would target a 95 per cent beneficial re-use of the usable spoil, either within the project or at other locations. Spoil reuse would be prioritised in accordance with the spoil management hierarchy outlined below.

- Minimisation of spoil generation through design and management
- Reuse of spoil within the project
- Beneficial reuse of spoil outside the project
- Where reuse is not possible, disposal of spoil would be the last resort.

The spoil reuse opportunities identified for the project have been outlined in order of preference in **Table 21-4** below.

Table 21-4 Spoil reuse options

Option	Potential options for reuse of spoil
Reuse within the project site	• The use of tunnel spoil for the backfill of cut-and-cover tunnels and the infill of temporary access shafts and declines • The use of tunnel spoil as fill to raise President Avenue above the flood level.
Beneficial reuse of spoil outside the project for environmental benefit	• Reuse of spoil for environmental restoration projects (e.g. flood mitigation and coastal protection projects).
Reuse of spoil outside the project on other projects	• Reuse of spoil as fill on other development projects with consideration of financial feasibility and traffic impacts • Reuse of spoil for land reclamation or remediation projects with consideration of financial feasibility and traffic impacts.
Reuse of spoil outside the project for land restoration	• Reuse of spoil for fill on land restoration projects (e.g. to rehabilitate disused mines or quarries) with consideration of financial feasibility and traffic impacts.
Reuse of spoil outside the project for other purposes	• Reuse of spoil for land management purposes (e.g. capping or covering of landfill waste) with consideration of financial feasibility and traffic impacts.

Spoil that is in excess of project requirements and that meets the classification of VENM would be preferentially/ beneficially re-used in other projects that require engineered fill. **Table 21-6** shows the potential spoil management and disposal sites.

The construction traffic and transport assessment has taken into account heavy vehicle movements associated with spoil management. **Chapter 8** (Traffic and transport) provides a summary of heavy vehicle movements including spoil related haulage.

Stockpile management

Stockpiles would be located at the following construction ancillary facilities:

- Arncliffe construction ancillary facility (C1)
- Rockdale construction ancillary facility (C2)
- President Avenue construction ancillary facility (C3)
- Shared cycle and pedestrian pathways construction ancillary facilities (C4/C5).

The estimated stockpile volumes at these construction ancillary facilities are provided in **Table 21-5**. Stockpile material at the Arncliffe construction ancillary facility (C1) would consist primarily of spoil, while stockpile material at the Rockdale construction ancillary facility (C2) and President Avenue construction ancillary facility (C3) would consist of spoil and excavated infrastructure.

Stockpile material at the shared cycle and pedestrian pathways construction ancillary facilities (C4/C5) construction ancillary facilities would consist of topsoil stripping material from where topsoil stripping has been undertaken and the stripping material cannot be moved off site during construction.

The Princes Highway construction ancillary facility (C6) would not be used for stockpiling spoil material. This facility would primarily be used for the laydown of construction equipment and parking of construction vehicles required for the construction of the President Avenue and Princes Highway intersection upgrade. The site would also include some offices, amenities and workshops.

Table 21-5 Estimated stockpile volumes

Stockpile location	Estimated stockpile volume (m^3)
Arncliffe construction ancillary facility (C1)	2,500
Rockdale construction ancillary facility (C2)	5,500
President Avenue construction ancillary facility (C3)	2,500
Shared cycle and pedestrian pathways construction ancillary facilities (C4/C5)	300

Spoil stockpiles would be located away from adjacent sensitive receptors where possible and contained within tunnels at Rockdale construction ancillary facility (C2) or cut-and-cover tunnel structures at President Avenue construction ancillary facility (C3). Spoil stockpiles would be contained within spoil sheds. Where excavations are carried out prior to the construction of tunnel structures, spoil would be stored on the surface or loaded into trucks directly from excavation areas.

Stockpile management procedures for segregating spoil, preventing cross-contamination of clean spoil with contaminated spoil and odour management would be included in the Construction Environmental Management Plan (CEMP). Potential impacts from runoff and sedimentation would be further minimised through the implementation of the environmental management measures described in **Chapter 16** (Soils and contamination) and **Chapter 18** (Surface Water and flooding).

Potential impacts related to dust and noise and vibration associated with the management of stockpiles are discussed in **Chapter 9** (Air quality) and **Chapter 11** (Noise and vibration) respectively.

Spoil reuse and disposal sites

Excess spoil that cannot be reused within the project would require off-site reuse/disposal. Around 95 per cent of uncontaminated spoil would be beneficially reused in accordance with the project spoil management hierarchy.

Eight potential sites have been identified for receiving excess spoil from the project, as summarised in **Table 21-6**. Negotiations for the final destinations for excess spoil would be carried out during detailed design and may include the sites listed in **Table 21-6** or other alternative sites.

Table 21-6 Potential spoil management and disposal sites

Site	Location	Distance from the project (kilometres_	Capacity
Horsley Park (manufacturing facility)	Wallgrove Road at Horsley Park	About 40	250,000
Blacktown Waste Services (landfill)	920 Richmond Road at Marsden Park	About 70	250,000
Sakkara Development (industrial estate)	Riverstone Parade at Riverstone	About 45	3,500,000
Kurnell Landfill	330 Captain Cook Drive at Kurnell	About 20	5,000,000
Lenore Drive, Erskine Park	Lenore Drive, Erskine Park	About 50	250,000
Development sites within North West Growth Area	Marsden Park, Hollinsworth Road	About 70	1,000,000 - 3,000,000
Development sites within South West Growth Area	Oran Park Drive, Bringelly	About 50	1,000,000 - 3,000,000
Badgerys Creek	Badgerys Creek Road, Badgerys Creek	About 50	1,000,000 - 3,000,000

Spoil would be delivered to the spoil management sites in accordance with the conditions of approval and environment protection licences governing those sites. The spoil reuse and disposal sites identified above are based on the current existing availability of spoil receiving locations (including projects with a fill deficit) across the Sydney area. Construction of the project would occur over a four year period, with spoil generation peaking in year two.

The following criteria would be applied to determine the priority given to the identified spoil reuse and disposal sites, including how much spoil would be sent to each site, and to evaluate any additional spoil reuse or disposal options that emerge during construction:

- Environmental benefit - preference for the material to be reused for environmental works (e.g. coastal protection works), clean fill on other projects, or land restoration
- Traffic impacts – with a preference for haulage routes that keep to major arterial roads and minimise total haulage requirements as far as possible
- Approvals – any receiving location would need to be approved to receive the applicable type and volume of spoil
- Economic feasibility – feasibility of transporting the spoil compared to the options already identified, including consideration of the distances to be travelled.

Spoil would be hauled using heavy vehicles to spoil reuse and disposal sites. The anticipated spoil haulage routes are outlined in **Chapter 7** (Construction). Additional disposal/reuse sites would be determined based on need at the time spoil is generated and additional sites not listed above may be used. Further details regarding spoil generation and management are provided in **Chapter 7** (Construction) and in **Chapter 8** (Traffic and transport).

Contaminated spoil

A contamination assessment completed as part of this EIS identified areas of potential and confirmed contamination as outlined in **section 21.3.3**.

If previously unidentified contaminated material is discovered during construction, the contaminated material would be managed in accordance with an unexpected contaminated lands discovery procedure, as outlined in the Guideline for the Management of Contamination (Roads and Maritime 2013).

Spoil, including contaminated spoil, would be classified in accordance with the Waste Classification Guidelines: Part 1 Classifying Waste (NSW EPA 2014). Depending on the extent of contamination, spoil would be considered for reuse on the project site or, where reuse is not possible, disposed of lawfully at an appropriately licensed facility.

Suitable areas would be identified to allow for contingency management of unexpected waste materials, including contaminated materials. Suitable hardstand or lined areas would be required that are appropriately stabilised and bunded, with sufficient area for stockpile storage and segregation.

Material that is identified as contaminated would be segregated from uncontaminated material on site to prevent cross-contamination. A detailed sub-plan to the CEMP for the project would describe methodologies and strategies to prevent cross-contamination.

A number of waste facilities in Sydney are licensed to accept contaminated waste. Specific facilities would be selected during the later stages of the project and documented in the construction waste management plan.

21.3.4 Special wastes

Acid sulfate soils

There is the potential for acid sulfate soils to be present within the project footprint. High risk areas include:

- An area surrounding the drainage line running south and perpendicular to Spring Street into Muddy Creek
- The low lying areas along Muddy Creek and in the industrial area at Rockdale
- The low lying areas surrounding Scarborough Ponds including Rockdale Bicentennial Park and Memorial Fields.

Procedures to manage acid sulfate soils would be included in a Construction Soil and Water Management Plan that would be prepared as part of the CEMP.

Identified acid sulfate soil material would be stored temporarily in a bunded area and treated on site before being transported 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[1].

Asbestos

Asbestos has been identified within fill at the Arncliffe construction ancillary facility (C1) and President Avenue construction ancillary facility (C3) and is likely to be present at other locations within the project footprint. The excavation, handling, storage, movement and disposal of ACM would be undertaken in accordance with procedures detailed in an Asbestos Management Plan.

A number of waste facilities in Sydney are licenced to accept asbestos. Specific facilities and collection contractors for the disposal of asbestos waste would be selected during the later stages of the project and documented in the construction waste management plan.

Heavy metals

Heavy metals have been identified within groundwater in locations along the tunnel alignment and within groundwater and soils at the President Avenue construction ancillary facility and are likely to be present at other locations within the project footprint.

[1] Roads and Traffic Authority (2005) *Guidelines for the Management of Acid Sulfate Materials.*

The excavation, handling, storage, movement and disposal of waste material that is identified as being contaminated with heavy metals would be undertaken in strict accordance with the procedures detailed in the CEMP and the Work Health and Safety Regulation 2011 (NSW). A number of waste facilities in Sydney are licenced to accept contaminated spoil. Specific facilities and collection contractors for the disposal of contaminated spoil would be selected during the later stages of the project and documented in the construction waste management plan.

21.3.5 Wastewater

Wastewater would be generated predominantly during tunnel construction. Tunnel construction would result in significant volumes of groundwater inflow which would require collection, treatment and disposal. Volumes generated would vary depending on construction activity, tunnel groundwater infiltration rate and excavated tunnel length. Other sources of wastewater during construction include dust suppression, washdown areas and stormwater runoff from construction ancillary facilities. Indicative total wastewater volumes generated over the duration of the construction period are identified in **Table 21-7**.

Construction water would be reused on site wherever feasible, or discharged into the local stormwater system in accordance with the requirements of the POEO Act. The reuse of treated water would be considered in preference to discharge to the stormwater system or the Cooks River. Preference would be given to reusing as much water as feasible before discharging.

Further information is provided in **Chapter 18** (Surface water and flooding) including potential impacts associated with construction stormwater runoff.

Table 21-7 Indicative wastewater volumes

Construction ancillary facility	Estimated daily discharge (kilolitres)	Discharge point
Arncliffe construction ancillary facility (C1)	500	Cooks River
Rockdale construction ancillary facility (C2)	200	Muddy Creek
President Avenue construction ancillary facility (C3)	Variable – 400 typical, up to 1600 short term rate	Muddy Creek
Shared cycle and pedestrian pathways east construction ancillary facility (C4)	2.5	Discharges from C4 and C5 would be minor only due to their relatively small footprint, with negligible hydrologic impact.
Shared cycle and pedestrian pathways west construction ancillary facility (C5)	1.7	
Princes Highway construction ancillary facility (C6)	4.9	Muddy Creek

Water treatment plants would be located at each of the construction ancillary facilities that would support tunnelling. These would receive water pumped from the low point of each tunnel and temporary sumps would treat the water so that it is suitable for reuse during tunnelling and construction generally, or for appropriate discharge or disposal

Details of water treatment methods, proposed discharge locations, the existing water quality of potential receiving waterways and proposed discharge criteria and volumes are in **Chapter 18** (Surface water and flooding). Discharge criteria for the project would be further developed during detailed design and subsequently documented in relevant management plans.

21.3.6 Potential impacts

Potential impacts associated with construction waste for the project include:

- Large volumes of spoil directed to landfill due to inadequate recycling and reuse
- Large volumes of waste being directed to landfill due to inadequate collection, classification and disposal of waste
- Contamination of soil, surface and/or groundwater from the inappropriate excavation, storage, transport and disposal of liquid and solid waste
- Risks to human health from the handling, storage, transport and disposal of contaminated waste (including asbestos) generated by the project
- Dust impacts due to incorrect storage, handling, transport and disposal of spoil (refer to **Chapter 9** (Air quality))
- Noise impacts associated with waste disposal (refer to **Chapter 11** (Noise and vibration))
- Traffic impacts associated with transport of spoil and waste (refer to **Chapter 8** (Traffic and transport)).

Construction waste management activities would not pose a significant risk to the environment or human health, with the implementation of the management measures provided in **section 21.5**. A Construction Waste Management Plan would be prepared and implemented as part of the CEMP for the project. A Sustainability Management Plan would also be developed outlining ways to optimise resource efficiency and waste management during construction and operation of the project. These plans would take into account construction staging and specific conditions of approval that may be applied to the project.

21.3.7 Cumulative impacts

Cumulative impacts could occur if the disposal of large volumes of spoil is required at the same time as other tunnelling projects in Sydney. No other cumulative impacts are anticipated as a result of construction waste management for the project.

Construction of the project would occur at the same time as other tunnelling projects in Sydney, including:

- Westconnex (M4-M5 Link, New M5 Motorway, M4 East)
- Sydney Metro City and Southwest.

The tunnelling projects listed above would also require the management and disposal of large volumes of spoil. Cumulative impacts would arise if the spoil management sites identified for the project reach capacity as a result of receiving spoil from other tunnelling projects. Cumulative impacts may also arise where multiple tunnelling projects use the same spoil management sites and/or haulage routes.

Estimated spoil volumes and potential spoil management sites for the project and for other tunnelling projects (as identified in their respective environmental assessments) are outlined in **Table 21-8**.

Spoil management site options would continue to be investigated during detailed design. Internal coordination with the proponents of the tunnelling projects identified in **Table 21-8** would be undertaken to encourage cooperative approaches to spoil management.

Table 21-8 Estimated spoil volumes and spoil management site capacities for Sydney tunnelling projects

Project	Estimated spoil volume (m^3)	Spoil Management Sites (capacity in cubic metres)
F6 Extension Stage 1	1,098,242	• Excess spoil would be transported to spoil management sites within the Sydney Metropolitan area, where feasible.
M4-M5 Link Project	4,000,000	• Horsley Park (4,000,000) • Blacktown Waste Services (250,000) • Sakkara Development, Riverstone (3,500,000) • Kurnell Landfill (7,000,000) • Moorebank Intermodal Terminal Precinct (2,500,000) • Western Sydney Airport (Capacity unknown)
New M5 Motorway project	3,200,000	• Boral-CSR Brick Pit, Schofields (550,000) • Quakers Hill (500,000) • Horsley Park (3,000,000) • Sakkara Development, Riverstone (3,500,000) • Kurnell Landfill (7,000,000)
M4 East project	2,400,000	• Sakkara Development, Riverstone (3,500,000) • Quakers Hill (600,000) • Marsden Park (360,000) • Horsley Park (2,400,000)
Sydney Metro City and Southwest	2,400,000	• CSR Quarry, Schofields (1,100,000) • Horsley Park (No. 2 and No. 3 Plants only) (600,000) • CSR Quarry, Schofields (1,100,000) • CSR Quarry, Horsley Park (2,000,000) • Hornsby Quarry (1,800,000) • Gosford Quarry (2,500,000)

Considering the combined capacity of the spoil management sites, it is unlikely that any one spoil management site would reach capacity and it is highly unlikely that all the sites would reach capacity at the same time.

21.4 Operational waste management

All wastes generated during operation of the project would be managed in accordance with relevant legislation and government policies. Waste streams generated during operation of the project would include maintenance waste and wastewater.

21.4.1 Maintenance waste

Wastes would be generated during routine maintenance and repair activities required during operation of the project. The type and volume of wastes generated would depend on the nature of the activity, but would predominantly consist of minor volumes of oil and road materials, as well as contaminated waste resulting from potential fuel spills and leaks.

The volumes and types of waste would be typical of motorway operations and could be accommodated by existing metropolitan waste management facilities. Maintenance and repair activities would be subject to separate assessment processes, which would include the assessment of waste impacts associated with these activities.

With the implementation of standard work practices during routine maintenance and repair activities (which would be assessed separately from the project), the overall impact of operational waste streams would be minimal.

21.4.2 Wastewater

The mainline tunnel would include a drainage system to capture stormwater ingress, groundwater seepage, tunnel maintenance wash-down water, fire system operations, accidental ruptures of fire mains or hydrants, accidental spills by vehicles using the tunnel and fire system testing.

Captured water would be reused on site where feasible, discharged to the local stormwater system in accordance with POEO act requirements or treated and discharged to the Cooks River.

The New M5 Motorway operational water treatment facility at Arncliffe Motorway Operations Complex would be utilised to treat tunnel water and intermittent flows of other water sources (e.g. wash down water). Groundwater ingress for Stage 1 is expected to be up to around eight litres per second. Treated water would be preferentially reused on site for example for the irrigation of landscaped areas. Water which could not be beneficially reused on site would be discharged to the Cooks River or receiving stormwater systems.

Further information is provided in **Chapter 18** (Surface water and flooding) including potential impacts associated with operational stormwater runoff.

21.4.3 Potential impacts

The following waste management related impacts have the potential to occur as a result of the operation of the project:

- Contamination of soil, surface and/or groundwater due to the inappropriate transport, storage and disposal of waste and wastewater during operation of the project
- Impacts on the Cooks River due to wastewater discharge.

With the implementation of the management measures outlined in **section 21.5** and standard work practices during routine maintenance and repair activities, the overall impact of operational waste for the project would be minimal. The Sustainability Management Plan to be developed as part of the project would outline ways to optimise resource efficiency and waste management during construction and operation of the project and take into account construction staging and specific conditions of approval that may be applied to the project.

21.4.4 Cumulative impacts

The operation of other nearby road projects including the New M5 Motorway would require the treatment and discharge of wastewater to the Cooks River. There is the potential for cumulative impacts related to increased wastewater discharged to the Cooks River. The cumulative impact of wastewater discharge on the Cooks River has been assessed in **Chapter 18** (Surface water and flooding).

21.5 Management of impacts

Contingency management of waste

Contingency measures would be implemented to manage unexpected waste volumes and types of waste materials generated from the construction and operation of the project. Suitable areas would be identified to allow for contingency management of unexpected waste materials, including contaminated materials. These areas would be hardstand or lined areas that are appropriately stabilised and bunded, with sufficient area for stockpile storage and segregation.

Excess spoil would be deposited to spoil management sites within the Sydney Metropolitan area, where feasible. The spoil management sites would have adequate capacity to accept spoil from the project and there is capacity at these sites to accept additional unexpected spoil volumes if required.

In the event of discovery of previously unidentified contaminated material, all relevant work would cease in the vicinity of the discovery and the unidentified contaminated material would be managed in accordance with an unexpected contaminated lands discovery procedure, as outlined in the Guideline for the Management of Contamination[2].

---

[2] Guideline for the Management of Contamination (Roads and Maritime 2013)

The environmental management measures outlined in **Table 21-9** would be consistently implemented in the event of unexpected waste volumes and materials generated from the construction and operation of the project, along with adherence to all waste principles and relevant legislation and regulations.

Environmental management measures

Waste can be managed and mitigated through the development of construction and operational management plans and implementation of standard approaches to waste management. Measures to avoid, minimise or manage waste streams generated as a result of the project are detailed in **Table 21-9** and would ensure that all wastes generated during the construction and operation of the project are effectively stored, handled, treated, reused, recycled and/or disposed of in accordance with applicable legislation and guidelines, and in a manner that protects human health and environmental values.

Table 21-9 Environmental management measures - waste

Impact	Reference	Environmental Management Measures	Timing
Waste generation and disposal	W1	A Construction Waste Management Plan will be prepared for the project prior to construction and will detail appropriate waste management procedures. The CWMP will: • Document expected waste types and volumes for the project • Describe procedures for managing office and project waste materials including separation, treatment and disposal in accordance with relevant guidelines • Detail waste reporting requirements including the implementation of a waste register • Detail the process for identifying waste re-use sites including approval requirements.	Prior to construction
	W2	A Spoil Management Plan will be prepared for the project. The plan will detail spoil management measures including spoil haulage routes and spoil disposal sites.	Prior to construction
Large volumes of spoil directed to landfill due to inadequate recycling and reuse	W3	The project will target the reuse or recycling of 95 percent of uncontaminated spoil generated for beneficial purposes in accordance with the project spoil management hierarchy.	Construction
Unexpected waste volumes and types during construction	W4	Suitable areas will be identified to allow for contingency management of unexpected waste materials, including contaminated materials. Suitable areas will be required to be hardstand or lined areas that are appropriately stabilised and bunded, with sufficient area for stockpile storage.	Construction

21.6 Environmental risk analysis

An Environmental risk analysis was undertaken for waste management (refer to **Table 21-10**).

A level of assessment was undertaken commensurate with the potential degree of impact the project may have on that issue. This included an assessment of whether the identified impacts could be avoided or minimised (for example, through design amendments). Where impacts could not be avoided, environmental management measures have been recommended to manage impacts to acceptable levels.

The residual risk is the risk of the environmental impact after the proposed mitigation measures have been implemented. The methodology used for the environmental risk analysis is outlined in **Appendix O** (Methodologies).

Table 21-10 Environmental risk analysis – waste

Summary of impact	Construction/ operation	Management and mitigation references	Likelihood	Consequence	Residual risk
Generation of large quantities of excess spoil due to tunnelling that cannot be reused in the project or adjacent projects	Construction	W1, W2, W3	Certain	Minor	Medium. These level items would be further reviewed during the detailed design development and where necessary additional measures implemented to ensure these risks are suitably mitigated.
Impacts associated with poor waste management during construction	Construction	W1	Likely	Moderate	Low
Impacts associated with unexpected waste volumes or types during construction	Construction	W1	Unlikely	Minor	Low

22 Climate change and greenhouse gas

This chapter outlines the climate change risk assessment undertaken for the project, the adaptation measures adopted as part of the project, and how the desired performance outcomes have been met. **Table 22-1** sets out the assessment requirements as provided in the SEARs relevant to climate change risk and identifies where the requirements have been addressed in this environmental impact statement (EIS).

Table 22-1 SEARs – Climate change risk

Assessment requirements	Where addressed
1. The Proponent must assess the risk and vulnerability of the project to climate change in accordance with the current guidelines.	This chapter presents a climate change risk assessment for the project in accordance with current guidelines as listed in section 22.1.
2. The Proponent must quantify specific climate change risks with reference to the NSW Government's climate projections at a 10km resolution (or lesser resolution if 10km projections are not available) and incorporate specific adaptation actions in the design.	Climate change risks to the project are identified in section 22.3 and section 22.4. Climate change projections used to inform the risk assessment are discussed in section 22.2.2 and Appendix O (Methodologies).

The project SEARs for flooding, addressed in **Chapter 18** (Surface water and flooding), also identify the need to consider changes in rainfall intensity and sea level rise due to climate change. **Section 22.5** includes discussion of how climate change has been incorporated in flood modelling and drainage design for the project.

The assessment set out in this chapter considers the impact of climate change on the project, as well as the project's contribution to future climate change through the assessment of greenhouse gas (GHG) emissions generated from the construction and operation of the project.

22.1 Assessment methodology

22.1.1 Climate change risk assessment

The climate change risk assessment follows the approach set out in the draft *Technical Guide: Climate Change Adaptation for the Road Network*[1] (Technical Guide). Use of the Technical Guide ensures consistency with Roads and Maritime's planned approach to climate change adaptation across the road network.

In addition to the Technical Guide, the climate change risk assessment has been conducted 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
- AS 5334-2013 Climate change adaptation for settlements and infrastructure – A risk based approach, which follows ISO 31000:2009 Risk Management – Principles and guidelines
- *Australian Government, Climate Change Impacts & Risk Management – A Guide for Business and Government*, Australian Government (2006)
- *Guideline for Climate Change Adaptation*, Revision 2.1, Australian Green Infrastructure Council (2011)
- *Guidelines for Risk Management* (Roads and Maritime 2014).

The climate change risk assessment approach is shown in **Figure 22-1**.

These steps, and the risk assessment criteria used to assess risks to the project, are described in detail in **Appendix O** (Methodologies).

[1] Roads and Maritime Services (2015) draft *Technical Guide: Climate Change Adaptation for the Road Network*

As part of the screening process, a multidisciplinary workshop was held with key members of the project design and planning team to identify and validate climate change risks specific to the project. The climate change risk screening for the project is provided in **Appendix O** (Methodologies).

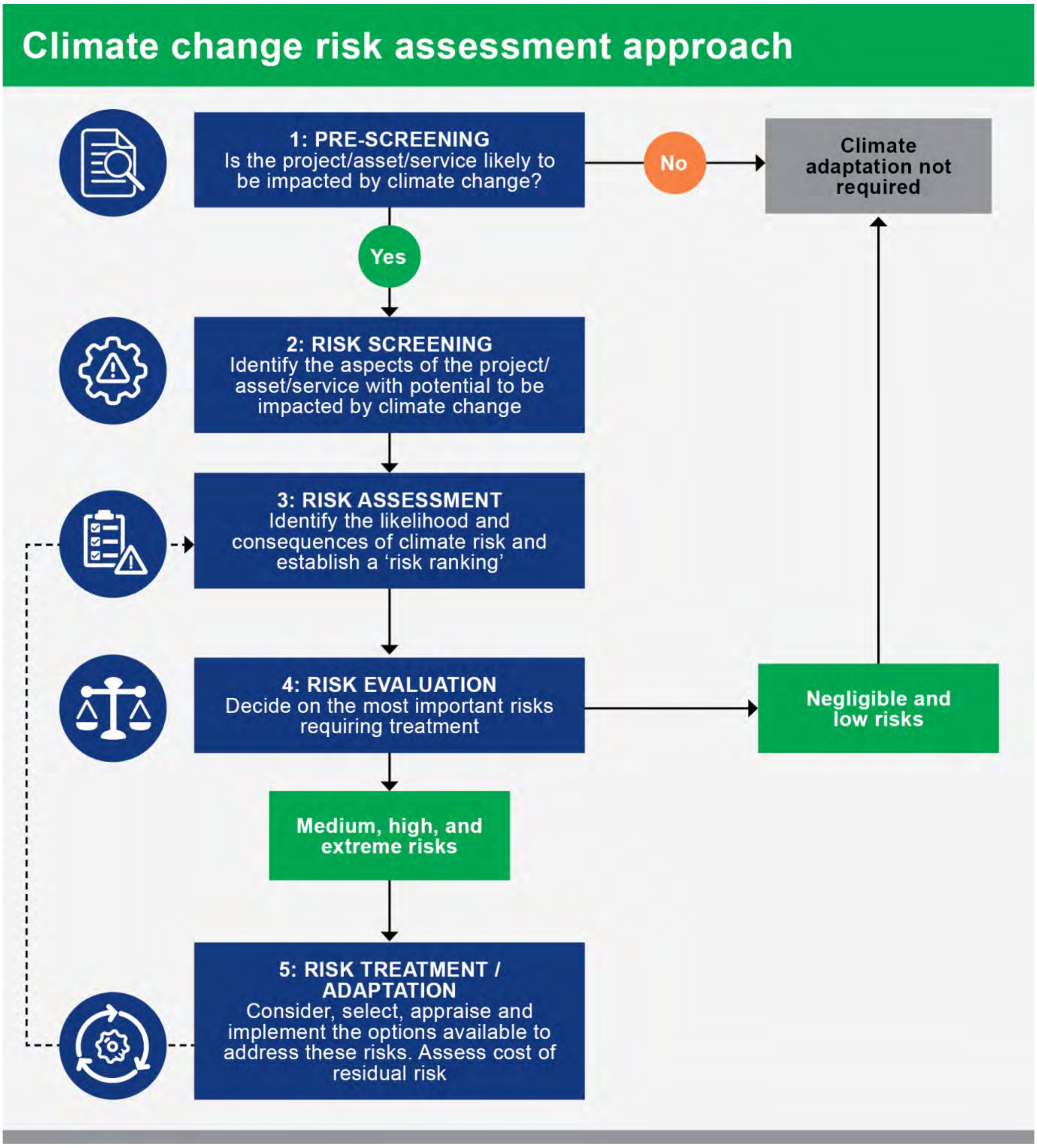


Figure 22-1 Climate change risk assessment approach

22.1.2 Greenhouse gas assessment

The GHG assessment methodology is based on relevant GHG 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 July 2017)
- *Greenhouse Gas Assessment Workbook for Road Projects* (the TAGG Workbook) (Transport Authorities Greenhouse Group (TAGG) 2013).

The TAGG was formed by Australian state road authorities, including NSW Roads and Maritime Services, and the New Zealand Transport Agency as a collaborative effort to share information regarding the estimation, reporting and minimisation of GHG emissions. The TAGG Workbook provides a consistent methodology for estimating the GHG 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.

To calculate the potential GHG emissions associated with the project, the following steps were followed:

1. Define the assessment boundary and identify potential sources of GHG emissions associated with the project
2. Determine the quantity of each emission source (fuel and electricity consumed, vegetation cleared, construction materials used and waste produced)
3. Quantify the potential GHG emissions associated with each GHG source, using equations and emission factors specified in the NGA Factors and the TAGG Workbook
4. Present the potential GHG emissions associated with the project.

Appendix O (Methodologies) provides a detailed description of the GHG assessment methodology, including the emissions factors used for all emission sources, and detailed calculation methods used to estimate the GHG emissions from fuel combustion, electricity consumption, vegetation removed, materials use and waste.

GHG emissions are reported in this assessment as tonnes of carbon dioxide equivalent (t CO_2-e).

22.2 Existing environment

GHGs 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 GHGs into the atmosphere are caused by both natural processes (e.g. bushfires) and human activities (e.g. burning of fossil fuels).

Since the industrial revolution there has been an increase in the amount of GHGs emitted from human activities, which has increased the global concentration of GHGs in the atmosphere. This has led to an increase in the Earth's average surface temperature[2].

The NSW Government has acknowledged that despite efforts to reduce GHG emissions, some climate change is now inevitable. Adapting to these changes is necessary to minimise the impacts of climate change on the natural and built environments and the NSW communities and economy.

[2] Intergovernmental Panel on Climate Change (IPCC) (2013) *Fifth Assessment Report*

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC)[2] states with high confidence that Australia is already experiencing impacts from 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, increases in bushfire weather conditions, ocean warming, ocean acidification and sea level rise.

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[3]. This recent assessment confirms the long-term warming trend, showing that in Australia, the average surface air temperature has increased by 0.9°C since records began in 1910, with most of the warming occurring since 1950. Australia's warmest year since 1910 was 2013[3].

22.2.1 Climate change and greenhouse gas policy setting

National policy

In 2015 the Australian Government announced its commitment to a target of reducing GHG 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 Australian Government submitted this new target as its intended nationally determined contribution to the United Nations Framework Convention on Climate Change (UNFCCC) for negotiation at the 21st Conference of the Parties (COP21) held in Paris in December 2015. The Australian Government ratified its commitment to the Paris Agreement on 9 November 2016.

The Australian Government's Direct Action Plan sets out how the 2030 emissions reduction target will be achieved. The Emissions Reduction Fund, as part of the Direct Action Plan, aims to reduce Australia's GHG emissions by creating positive incentives to adopt better technologies and practices to reduce emissions.

In 2015, the Australian Government released the *National Climate Resilience and Adaptation Strategy*, which recognises Australia's vulnerability to climate change and provides a set of principles to guide effective adaptation and build the resilience of Australia's communities, economy and environment. The guiding principles include priorities for:

- Shared responsibility and collaboration among stakeholders
- Climate risk factored into decision making
- A risk management approach based on the best available scientific data
- Assisting the vulnerable
- Monitoring decisions and outcomes over time.

The Strategy identifies the need to consider future climate and extreme weather events in the design and construction of infrastructure, and references the Australian Government's *Critical Infrastructure Resilience Strategy: Policy Statement* (2015), which aims for the continued operation of critical infrastructure and essential services in the face of all hazards.

In 2017 the Australian Government completed a review of national climate change policies[4] and reported that Australia is on track to meet its 2030 emissions reduction target, while maintaining economic and population growth.

State policy

In 2016, the NSW Government released a new *Climate Change Policy Framework*, which aims to maximise the economic, social and environmental wellbeing of NSW in the context of a changing climate, including the development and implementation of a *Draft Climate Change Fund Strategic Plan 2017–2022* and *a Draft Plan to Save NSW Energy and Money*.

---

[3] CSIRO & BoM (2015) *Climate Change in Australia*

[4] Australian Government Department of the Environment and Energy (2017) *2017 Review of Climate Change Policies*

The *Draft Climate Change Fund Strategic Plan 2017–2022* sets out priority investment areas for funding over the next five years, including funding for actions to prepare NSW for a changing climate. As part of this priority investment area, the Plan identifies actions for reducing the costs to public and private assets arising from climate change, reducing the impacts of climate change on health and wellbeing, particularly for vulnerable communities, and managing the impacts of climate change on natural resources, natural ecosystems and communities.

The *Draft Plan to Save NSW Energy and Money* is proposed to meet the NSW Government's energy efficiency target of 16,000 gigawatt hours of annual energy savings by 2020 and contribute to the Climate Change Policy Framework's aspirational target of NSW achieving net-zero emissions by 2050. The draft plan summarises the preferred options for achieving the State's energy savings target, which include opportunities for implementing energy standards for State significant developments and major infrastructure projects such as road tunnels.

Further discussion of the policy setting for climate change mitigation and GHG emissions reduction is summarised in **Chapter 23** (Sustainability).

22.2.2 Impacts of climate change on road infrastructure

The main impacts relevant to road network and infrastructure assets are associated with an increase in the intensity of extreme rainfall (which can increase the risk of flooding or landslides and exacerbate damage to pavements), and sea level rise (which is likely to exacerbate coastal erosion, cause an increase in storm surges and coastal flooding and may eventually lead to long-term inundation and loss of land). The largest impacts are likely to be borne by surface roads in low-lying areas or those with steep gradients, and by coastal infrastructure in areas exposed to coastal erosion and storm surges.

The nature of the project, primarily comprising underground tunnel infrastructure, is likely to offer protection from a number of climate impacts (e.g. solar radiation, rainfall, storm events, urban heat island), however the associated surface infrastructure including tunnel interchanges and project buildings are likely to be susceptible to these impacts.

22.2.3 Climate change projections

An assessment of the risk of climate change requires an understanding of the current climate using historical data for comparison with future climate scenarios. In order to assess the risk to the project posed by climate change, the current climate science and model projections have been investigated using information published by CSIRO and BoM in 2015, available through their *Climate Change in Australia* portal (https://www.climatechangeinaustralia.gov.au). Further detail regarding the selection of climate change projections for the project is provided in **Appendix O** (Methodologies).

Future timescales

Given the expected design life of the infrastructure, proposed project construction timeframe and the available climate data, the time periods selected for assessment were 2030 (an average of the period 2020–2039) and 2090 (an average of the period 2080–2100). Climate change projections for 2030 were identified as appropriate for assessment of short term impacts of climate change, while projections for 2090 are relevant to the longer term operation and maintenance stages of the project.

Emissions scenarios

Projections are presented for two emission scenarios or possible pathways, referred to as 'representative concentration pathways' (RCPs), each reflecting a different concentration of global greenhouse gas emissions. The two RCPs reported here are moderate emissions (RCP4.5) and high emissions (RCP8.5).

A summary of projections for 2090, for the high emissions scenario, is provided in **Figure 22-2**.

Figure 22-2 Key climate change projections relevant to the project

22.3 Potential impacts – construction

22.3.1 Climate change risk evaluation

Climate change projections for the near future (2030) are considered relevant to the project's proposed construction timeframes, planned for the period between 2020 and 2024.

Table 22-2 identifies potential climate change risks to project construction, with a risk rating of medium or higher. A total of four risks were identified, three of which were high risks and one medium.

Table 22-2 Climate change risks to project construction (2030) prior to mitigation

Risk scenario	Likelihood	Consequence	Risk rating
Extreme rainfall			
Increase in the intensity and frequency of extreme rainfall, combined with sea level rise, leads to localised flooding of project construction sites and ancillary facilities resulting in delays to project program.	Medium	High	High
Storm events			
Increase in the intensity and frequency of storm events leads to unsuitable conditions for undertaking construction works, requiring stop work procedures to be implemented for the safety of construction personnel, resulting in delays to project program.	Medium	High	High
Extreme heat			
Increase in frequency and intensity of extreme heat events increases the risk of heat stress conditions for construction personnel, resulting in increased work health and safety risks and potential delays to project program.	Medium	High	High
Increase in frequency and intensity of extreme heat events with increased risk to the quality of the concrete pouring process, resulting in program delays.	Medium	Medium	Medium

22.3.2 Greenhouse gas emissions

Emission sources are categorised into the following three 'scopes':

- Scope 1 – direct emissions: GHG emissions generated by sources owned or controlled by the project, for example emissions generated by the use of diesel fuel in project-owned construction plant, equipment or vehicles
- Scope 2 – indirect emissions: GHG emissions from the consumption of purchased electricity in project-owned or controlled equipment or operations. These GHG emissions are generated outside the project's boundaries, for example the use of electricity purchased from the grid
- Scope 3 – indirect upstream/downstream emissions: GHG 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 GHG emissions associated with the mining, production and transport of materials used in construction (referred to as the embodied energy of a material).

It is estimated that the project would generate about 535,000 t CO_{2}-e during construction. The breakdown of emissions by scope is shown in **Figure 22-3** and summarised (with numbers rounded to the nearest thousand tonnes) as:

- 85,000 t CO_{2}-e of Scope 1 (direct) GHG emissions
- 63,000 t CO_{2}-e of Scope 2 (indirect) GHG emissions
- 387,000 t CO_{2}-e of Scope 3 (indirect) GHG emissions.

Key emissions sources during project construction are shown in **Table 22-4** and **Figure 22-3**.

Table 22-3 Construction GHG emissions

Emissions source	GHG emissions (t CO2 e)				
	Scope 1	Scope 2	Scope 3	Total	% of total
Fuel use					
Diesel – mobile plant and equipment	57,155	-	2,918	60,074	11.2%
Diesel – transport of materials, spoil and waste to/from site	24,660	-	1,259	25,919	4.8%
Petrol – project light vehicles and transport of construction workforce to/from site	3,111	-	166	3,277	0.6%
Electricity					
Electricity consumption	-	62,563	9,045	71,609	13.4%
Construction materials					
Concrete	-	-	70,207	70,172	13.1%
Steel	-	-	105,221	105,221	19.7%
Aggregate	-	-	385	385	0.1%
Asphalt	-	-	870	870	0.2%
Copper	-	-	1,545	1,545	0.3%
Plastic (PVC)	-	-	145	145	0.0%
Land use change					
Vegetation removal	321	-	-	321	0.1%
Waste					
General Solid Waste	-	-	194,740	194,740	36.4%
Construction and demolition waste	-	-	580	580	0.1%
Total	85,247	62,563	387,081	534,891	100%
% of total	15.9%	11.7%	72.4%	100%	

Notes:
1 Results may not add up to totals due to rounding of emissions to the nearest whole number.

The results demonstrate that the majority of GHG emissions associated with the construction of the project are attributed to indirect Scope 3 emissions (72.4 per cent), followed by direct Scope 1 emissions (15.9 per cent).

As shown on **Figure 22-3**, emissions associated with the decomposition of waste contributes the largest proportion of indirect Scope 3 emissions, accounting for around 36.5 per cent of these emissions. This is due to the cut and cover excavation through areas of existing landfill, which will require quantities of general solid waste to be transported to landfill. The embodied energy associated with the offsite mining, production and transport of construction materials that would be used for the project also contributes a high proportion of indirect Scope 3 emissions, accounting for around 33.4 per cent of these emissions. The use of concrete and steel would contribute significantly to Scope 3 emissions. 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. The cut and cover excavation and diaphragm walls for project construction require additional quantities of steel reinforcement, compared with other recent tunnelling projects in Sydney.

Figure 22-3 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 onsite contributes the largest proportion of Scope 1 emissions (67 per cent), followed by the consumption of fuel for heavy vehicle movements for the haulage of spoil, construction materials and waste (29 per cent). Indirect Scope 2 emissions from the use of electricity are estimated to account for around 11.7 per cent of total emissions during construction.

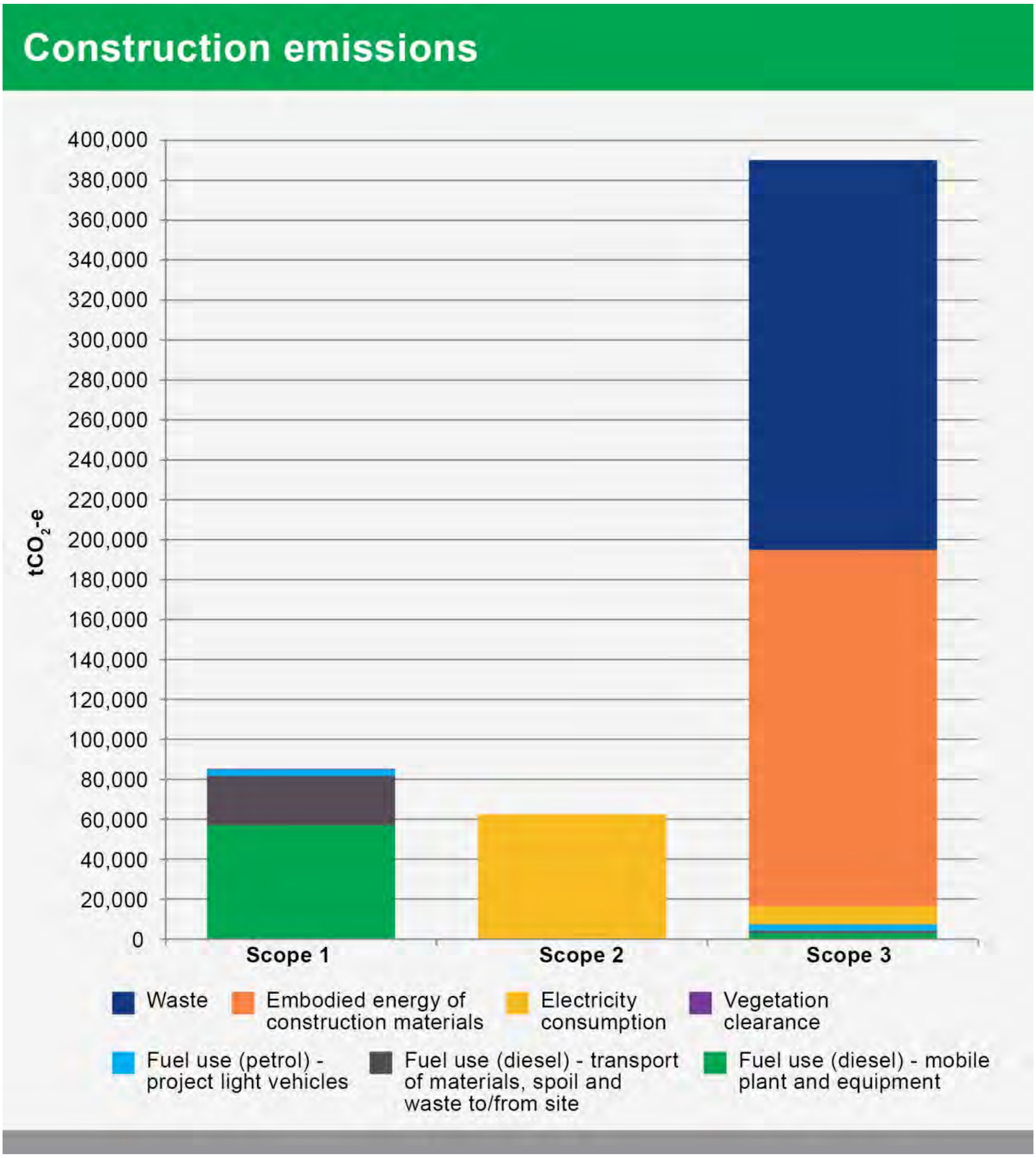


Figure 22-3 Construction GHG emissions by scope and emissions source

22.3.3 Cumulative construction impacts

The nature of the project, primarily comprising underground tunnel infrastructure, is likely to offer protection from a number climate impacts (e.g. solar radiation, rainfall, storm events, urban heat island), however, the construction of surface infrastructure, including tunnel interchanges, surface road upgrades and project buildings, and the project's construction compounds are likely to be susceptible to such impacts.

The vulnerability and exposure of project infrastructure would be specific to the location of each surface element. As a result, the cumulative climate change risks are considered to occur at locations where project construction would overlap with construction of other major infrastructure projects, namely the New M5 Motorway construction compound at Arncliffe. Cumulative climate change risks would be associated with an increase in extreme climate events and delays to respective construction programs, resulting in a cumulative increase in the duration of construction periods.

Climate change risk assessments undertaken for each project would address risks specific to each project respectively.

The project would contribute to the cumulative generation of GHG emissions from construction of major infrastructure projects and would contribute to NSW and Australian GHG emissions inventories. Construction emissions estimated to be generated by the project would represent around 0.10 per cent of the Australian national inventory for the year September 2016 to September 2017[5], and around 0.41 per cent of the NSW inventory for 2016[6]. Mitigation and management measures would be implemented during each project to minimise GHG emissions during construction.

22.4 Potential impacts – operation

22.4.1 Climate change risk evaluation

The climate change risk assessment identified a total of 27 direct and indirect risks to the project. Of these risks, seven high and six medium risks were identified, as summarised in **Table 22-4**. Risks in **Table 22-4** are assessed prior to consideration of adaptation measures, which are detailed in **section 22.5**. A residual risk assessment is presented in **section 22.6**.

Table 22-4 Climate change risks to project operation (2030 to 2090) prior to mitigation

Risk scenario	Likelihood	Consequence	Risk rating
Extreme rainfall, sea level rise and storm events			
Exacerbated local flood risk to the President Avenue portal exits and surface facilities as a result of the increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges).	High	Medium	High
Reduced performance of the surface drainage system at President Avenue interchange due to increased runoff causing localised flooding and inundation as a result of an increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges).	Medium	High	High
Reduced performance of the tunnel drainage system due to an increase in groundwater filtration, leading to reduced capacity of sumps and the pumping system resulting in localised flooding as a result of an increase in the intensity and frequency of extreme rainfall.	Medium	Medium	Medium
Reduced performance and/or failure of the water treatment system (particularly the submerged discharge infrastructure into Cooks River and Botany Bay) due to saline intrusion and deterioration as a result of sea level rise.	Medium	Medium	Medium
Inundation / flooding of landscaped areas, particularly throughout Rockdale Bicentennial Park and the Scarborough Ponds, due to an increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges).	Medium	Low	Low
Safety risk to users of the shared cycle and pedestrian pathways due to flooding as a result of an increase in the intensity and frequency of extreme rainfall, combined with sea level rise.	Medium	Medium	Medium
Power outages impacting electrical systems (such as pumping stations) resulting from increased flooding as a result of an increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges).	Medium	Medium	Medium

[5] Australian Government Department of the Environment and Energy (2018) *Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2017*
[6] Australian Government Department of the Environment and Energy (2018) *State and Territory Greenhouse Gas Inventories 2016* (the most recently available emissions inventory for Australia's States and Territories)

Risk scenario	Likelihood	Consequence	Risk rating
Failure of the water treatment plant due to water inflow exceeding capacity as a result of increased intensity and frequency of extreme rainfall.	Medium	Medium	Medium
Increased road incidents and safety risk to operational personnel and road users as a result of an increase in the intensity and frequency of extreme rainfall.	Low	High	Medium
Mean rainfall and mean temperature			
Adverse impacts to landscaped areas, such as the reinstated parklands, as a result of a decrease in mean rainfall and increase in mean surface temperature and the intensity and frequency of extreme heat events.	Low	Low	Negligible
Increased risk of reduced tunnel ventilation system performance due to increased occurrence and risk of dust storms as a result of a decrease in mean rainfall combined with an increase in mean surface temperature and the frequency and intensity of extreme heat events.	Low	Medium	Low
Extreme heat			
Increased risk of vehicle breakdown within the tunnel (due to vehicle overheating) as a result of the increase in the frequency and intensity of extreme heat.	Low	Low	Negligible
Increased risk of heat stress for operational personnel due to an increase in the frequency and intensity of extreme heat events.	Medium	High	High
Increased risk of heat stress for users (pedestrians and bicyclists) using the shared cycle and pedestrian pathways as a result of the increase in frequency and intensity of extreme heat events.	Medium	High	High
Accelerated deterioration of road pavement due to an increase in the frequency and intensity of extreme heat events.	Low	Low	Negligible
Bushfire			
Reduced performance of the tunnel ventilation system (impacting road users) due to smoke pollution as a result of increased frequency and intensity of bushfire events.	Medium	Low	Low
Atmospheric CO_2			
Accelerated deterioration of ventilation facilities due to corrosion and thermal expansion of steel and concrete structures as a result of increased atmospheric CO_2 and the frequency and intensity of extreme heat events.	Low	Low	Negligible
Accelerated deterioration of bridge structures (shared pedestrian and cyclist bridge) and surface pavement (President Avenue) due to corrosion and thermal expansion of steel and concrete structures and protective coatings as a result of increased atmospheric CO_2 and the frequency and intensity of extreme heat events.	Low	Low	Negligible
Accelerated deterioration of the surface drainage system due to corrosion and thermal expansion of steel and concrete structures as a result of increased atmospheric CO_2 and the frequency and intensity of extreme heat events.	Low	Low	Negligible
Accelerated deterioration of tunnel drainage system due to corrosion of steel and concrete structures as a result of increased atmospheric CO_2 and the frequency and intensity of extreme heat events.	Low	Low	Negligible

Risk scenario	Likelihood	Consequence	Risk rating
Wind speed			
Structural stability concerns of elevated bridge structures along the shared cycle and pedestrian pathways being adversely affected by changes in wind speed.	Negligible	Low	Negligible
Tunnel ventilation facility experiencing adverse performance impacts due to changes in wind speed.	Negligible	Negligible	Negligible
Indirect risks			
Failure of power supply infrastructure due to fire damage to the electricity network as a result of increased frequency and intensity of bushfires, with associated risk of power outages for the project.	Medium	High	High
Extreme heat leading to increased power demand and/or faults/failure of power infrastructure resulting in interruptions to power supply with increased frequency and duration of power outages.	Medium	High	High
Storm events leading to damage to power supply infrastructure or a need to cut supply resulting in interruptions to power supply with increased frequency and duration of power outages.	Medium	High	High
Failure of the communications network due to direct fire risk as a result of increased frequency and intensity of bushfire events.	Medium	Low	Low
Extreme heat leading to decreased efficiency and outages of telecommunications systems, resulting in loss of communications for the facility.	Medium	Low	Low

22.4.2 Greenhouse gas emissions

Activities that would generate GHG emissions during operation and maintenance of the project include:

- Road infrastructure operation: the use of electricity for powering tunnel lighting and ventilation, operation of ventilation facilities, the operations and maintenance facility, water treatment, substation cooling, street lighting, 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 project during operation: use of the F6 Extension Stage 1 (New M5 Motorway, Arncliffe to President Avenue, Kogarah) tunnels during operation and the change in traffic volumes and traffic performance on alternative routes within the GHG assessment study area.

The GHG assessment results are presented in the following sections. The emission source data, and any assumptions used to estimate the GHG emissions associated with operation and maintenance of the project, are provided in **Appendix O** (Methodologies).

Operation and maintenance emissions

Annual operational emissions and emissions from major maintenance are estimated in **Table 22-5**.

.

Table 22-5 Operation and maintenance GHG emissions

Emission source		GHG Emissions			
		Scope 1	Scope 2	Scope 3	Total
Annual operation emissions (t CO_2-e per year)					
Electricity consumption		-	24,900	3,600	28,500
Total maintenance emissions (50 year major maintenance) (t CO_2-e)					
Fuel use (diesel) – mobile plant and equipment		224	-	17	241
Maintenance materials	Cement	-	-	2	2
	Steel	-	-	169	169
	Aggregate	-	-	1,056	1,056
	Bitumen	-	-	29	29
Total maintenance emissions		224	-	1,273	1,497

Emission estimates for the use of fuel and materials for the maintenance of the road pavement are based on one major rehabilitation of asphalt pavement with the top 150 millimetres replaced and five per cent of pavement replaced for patching/repair every 50 years, and five per cent of concrete pavement replaced with only the top layer requiring replacement every 50 years (in accordance with 'typical' maintenance activities given in the TAGG Workbook[7]).

Emissions from vehicles during operation

GHG emissions generated from the operation and maintenance of road infrastructure are relatively small in comparison with the indirect emissions associated with the fuel consumed by vehicles using the proposed road network within the study area.

To assess the Scope 3 (indirect) emissions associated with fuel consumed by vehicles using the project and proposed road network within the study area, and to evaluate any potential GHG emissions savings as a result of the project, the following operational scenarios, as presented in **Table 22-6**, were considered. The scenarios were modelled by combining future year demands with future networks. 2026 was adopted as the project opening case for the project. The scenarios listed in **Table 22-6** shows which projects were aligned with each scenario. Further description of these scenarios is presented in **Chapter 8** (Traffic and transport).

Table 22-6 Traffic modelling scenarios

Scenario	Year	Existing road network	F6 Extension		NorthConnex	WestConnex program of works	Sydney Gateway	Western Harbour Tunnel	Beaches Link
			Stage 1	Kogarah to Loftus					
Operation - 'Do minimum'	2026	✓			✓	✓	✓		
Operation - 'Do something'	2026	✓	✓		✓	✓	✓		
Operation - 'Do minimum'	2036	✓							
Operation - 'Do something'	2036	✓	✓		✓	✓	✓		
Operation - 'Cumulative'	2036	✓	✓	✓	✓	✓	✓	✓	✓

[7] Transport Authorities Greenhouse Group (TAGG) (2013) *Greenhouse Gas Assessment Workbook for Road Projects*

The GHG assessment for operational road use involved calculation of the following inputs, using the Roads and Maritime strategic traffic model outputs, industry default factors, current vehicle statistics and fuel intensity projections as detailed in **Appendix O** (Methodologies):

- Average speed for each road link
- VKT for both light and heavy vehicles
- Rate of fuel consumption
- Total fuel quantity
- Fuel quantity by fuel type (e.g. petrol, diesel, liquid petroleum gas (LPG)).

These inputs were then used to estimate the GHG emissions associated with changes in traffic volumes on the road network within the study area as a result of the project, under different future timeframes and project scenarios as identified in **Table 22-6**. Further detail regarding the calculation of fuel use and GHG emissions is presented in **Appendix O** (Methodologies).

Table 22-7 shows the difference between the total GHG emissions generated in the 'do minimum' (without project) and 'do something' (with project) 2026 and 2036 scenarios, and the difference between the total GHG emissions generated in the 'do minimum' (without project) and the 'cumulative' 2036 scenarios.

Table 22-7 Road use GHG emissions

GHG Study Area	GHG emissions (t CO2 e)					Difference between scenarios (t CO2 e)		
	Do Minimum (without project)		Do Something (with project)		Cumulative	Do Something Do Minimum		Cumulative Do Minimum
	2026	2036	2026	2036	2036	2026	2036	2036
Existing road network[8]	8,901,497	10,726,679	8,777,628	10,576,627	10,340,756	-123,869	-150,052	-385,922
F6 Extension	0	0	9,134	11,323	25,170	9,134	11,323	25,170
Totals	8,901,497	10,726,679	8,786,762	10,587,949	10,365,926	-114,735	-138,729	-360,753

Note: negative numbers indicate emissions savings

The results demonstrate the benefits of road tunnel usage in urban areas, where travel along a more direct route at higher average speeds results in fewer GHG emissions being generated by road users, as reduced congestion and stop-start driving reduces the fuel used by vehicles. Despite increases to overall daily VKT on motorways and a reduction in performance of some non-motorway roads (as discussed in **Chapter 8** (Traffic and transport)), a reduction in GHG emissions is estimated as a result of the project compared with the 'do minimum' scenario.

The predicted reduction in GHG emissions as a result of the project would be due to an improvement in vehicle fuel efficiency for some links within the study area as well as the operational efficiency of the project tunnels. Vehicle fuel efficiency is anticipated to improve as part of the project based on:

- An overall increase in daily VKT and a reduction in daily vehicle hours travelled (VHT) on the road network, with more trips able to be made on the network in a shorter time, primarily associated with traffic using the new motorway tunnels
- A decrease in VKT and VHT on key alternative routes and non-motorway roads
- Increased average speeds as a result of the operational efficiency of the project tunnels, with reduced number of intersections and frequency of stopping
- Increased average speeds on key alternative routes (non-motorway roads) within the study area due to reduced congestion.

[8] Within the study area

Emissions estimated to be generated during construction would result in a nett increase of emissions generated for the project. However, annual operation and maintenance emissions estimated to be generated would be offset against emissions savings for the 'with project' and 'cumulative' scenarios in 2026 and 2036, as a result of improved road performance within the study area boundary.

Emissions were not able to be extrapolated beyond the operational traffic scenarios modelled for the project, which were assessed up to 2036. It is expected that the savings in emissions from improved road performance attributed to the project would reduce over time as traffic volumes increase. However, improvements in fuel efficiency of the vehicle fleet and increased uptake of electric vehicles and autonomous vehicles in future[9] are anticipated to reduce the dependence of vehicles on fossil fuels, thereby reducing GHG emissions from road use.

Mitigation and management measures, including efficiencies incorporated into the project design to reduce energy and resource requirements, are provided in **section 22.5**.

22.4.3 Cumulative operational impacts

Cumulative impacts associated with climate change risk would primarily occur as a result of interdependencies between the project and the upstream and downstream environment. These impacts may occur where the introduction of the project exacerbates climate change risks for receiving environments. Examples of interdependencies for the project, which may be susceptible to climate change risks, include:

- Increased overland flow and changes to drainage lines associated with the project resulting in increased risk of localized flooding and/or increased flows to receiving environments.
- The project would contribute to a cumulative increase in impervious surfaces, however given that the majority of project infrastructure would be below the surface in tunnels, this increase is not anticipated to result in significant cumulative impacts.
- Project infrastructure at surface locations would interact with existing drainage systems. The design for project drainage infrastructure has been undertaken to account for the capacity of these existing drainage systems, such that project drainage infrastructure has been designed to meet or improve current drainage flows.
- Induced demand associated with the project resulting in an increase in users through high flood risk areas, such as President Avenue, with implications for emergency management during extreme events.
- Introduction of additional infrastructure as part of the project, contributing to the "urban heat island effect" and an increase in local average temperatures. However given that the majority of project infrastructure would be below the surface in tunnels, this increase is not anticipated to result in significant cumulative impacts.

Adaptation measures identified in **section 22.5** would improve the project's resilience to climate change and reduce potential interdependencies and cumulative climate change risks. The implementation of adaptation measures to address climate change risks provides opportunities to improve the resilience of infrastructure within the Sydney region as a whole.

The transport sector contributes about 18 per cent of Australia's total GHG emissions[10]. Around 90 per cent of these emissions are considered to be attributed to the combustion of fuel for road transport[11]. Reducing the contribution of emissions from road transport would therefore have a significant impact on emissions reduction for the transport sector, and for Australia's overall emissions profile.

An assessment of GHG emissions for the cumulative 2036 scenario is included in **section 22.4.2**. The magnitude of GHG emissions savings for the cumulative scenario is attributed to, not only an increase in average speeds, but an increase in the number of vehicles shifting off non-motorway roads within the study area as alternative routes become available through the completion of projects such as the proposed future Sydney Gateway, Western Harbour Tunnel, Beaches Link and the F6 Extension between Kogarah and Loftus.

[9] Uptake of electric vehicles and autonomous vehicles was not considered (refer to Appendix O (Methodologies))
[10] Australian Government Department of the Environment and Energy (2018) *Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2017*
[11] Climate Change Authority (2014); Maddocks et al. (2010)

22.5 Management of impacts

This section presents adaptation measures that have been incorporated into the project's design at the time of preparation of the EIS, as well as additional adaptation options for further consideration during the project's detailed design.

22.5.1 Adaptation to climate change

As part of the project's design development, consideration has been given to avoiding, minimising or managing risks from future climate change, where possible.

As discussed in **section 22.4.1**, climate change risks identified as high for the project are associated with an increase in the intensity of extreme rainfall and sea level rise. In order to assess the impact of climate change on flood behaviour, sensitivity analyses were undertaken for increases in extreme rainfall and sea level rise, with design refinements made to manage potential flood risks exacerbated by climate change. Adaptation options incorporated into the design of the project include:

Construction

- The indicative layouts of the temporary construction ancillary facilities have taken into consideration the flood risk posed to the land, including increased flood risk due to climate change. This includes identifying opportunities to provide setback from areas at risk of flooding, locating uses considered more vulnerable to flooding – such as stockpile areas, chemical storage areas, tunnel dives and deep excavations – away from areas of highest risk, and allowing controlled flooding of suitable areas such as car parks, where feasible.

Operation

- As discussed in **Chapter 18** (Surface water and flooding), a Flood Management Strategy (FMS) would be prepared to demonstrate how the risk of flooding to the project, as well as the impact it would have on flooding behaviour under present day conditions would be mitigated during both the construction and operational phases.
- The design of the operational sites has taken into consideration the flood risk posed to the sites and how to manage these risks, as appropriate. The process for establishing flood risk for the project is outlined in **Chapter 18** (Surface water and flooding). This has meant that mitigation measures are already included as a consequence of the evolution of the project design.
- Tunnel portals have been designed to ensure immunity from the greater of the PMF or 100 year Average Recurrence Interval (ARI) event plus 0.5 metre freeboard. Where the portals lie within the PMF extent, this would be achieved by appropriate flood protection measures. Refer to management measures in **Chapter 18** (Surface water and flooding) and **Appendix M** (Flooding technical report) for further detail.
- To accommodate increased flows as a result of the project, the design includes upgrade of existing drainage infrastructure on President Avenue between O'Connell Street and Oakdale Avenue.
- Consideration has been given to flood risks to cyclists and pedestrians and the shared cycle and pedestrian pathways have been designed with a minimum of one exceedance per year level of flood immunity.
- The project corridor and design of portals and surface ancillary facilities have been refined to minimise impacts on the Rockdale Recreation Corridor and associated green space.
- Consideration of increased extreme heat events has been incorporated into the urban design of project surface infrastructure and areas of open space created by the project, including provision of areas of respite and drinking fountains, where possible.
- Landscaping has been designed to include consideration of users of the shared cycle and pedestrian pathways and the increasing need for shading and areas of respite during extreme heat events.
- The design reduces power consumption associated with tunnel ventilation by locating the ventilation facilities close to the mainline tunnel portals, thereby optimising the piston effect generated by vehicles.
- Backup power and other redundancy measures have been built in, to ensure temporary continuity of powered infrastructure in the event of a power outage.

- Project infrastructure has been designed for long term performance and durability of structures, increasing asset design lives and reducing the frequency of maintenance activities.

22.5.2 Adaptation options for consideration during detailed design

Table 22-8 Environmental management measures – climate change adaptation

No.	Environmental management measures	Timing
CC1	A review of the climate change risk assessment will be undertaken during detailed design, with adaptation actions implemented to address extreme and high risks. Adaptation measures for medium risks will be considered and implemented where reasonable and feasible.	Detailed design
CC2	The increased potential for heat stress among construction personnel will be considered when refining construction Work Health and Safety Management Plans. Measures will be implemented to create greater awareness and education of personnel around health and wellbeing during periods of extreme heat.	Construction
CC3	The projected increase in the intensity and frequency of extreme rainfall, which may lead to exacerbated risk of road incidents, will be considered during detailed design.	Detailed design
CC4	Implementation of operational procedures will be considered for surface connections to increase safety during extreme rainfall events, including the potential use of variable speed signs and reduced speed limits.	Detailed design
CC5	Emergency management planning will include consultation and collaboration with other key agencies to enable a coordinated response.	Detailed design
CC6	Emergency management procedures will consider worst case scenarios with multiple events (e.g. evacuation of the tunnel required during a storm/ flash flood event).	Detailed design
CC7	The upgrade of bus stop facilities on President Avenue in proximity to the tunnel portals to incorporate shading/ areas of respite for commuters will be considered during detailed design.	Detailed design
CC8	Roads and Maritime will consider the possibility of using treated water, normally discharged to waterways to irrigate green space (if feasible) in proximity to the project to provide cooling, particularly during periods of extreme heat. This approach will depend on suitability and salinity of water and potential for reuse.	Detailed design

Notes:
1 During the consideration of any of the above management measures, analysis of costs and benefits should be undertaken.

22.5.3 Reducing greenhouse gas emissions

Reducing emissions through design

The design of the project has been optimised such that measures to reduce energy and resource requirements, and therefore GHG emissions, are inherent in the design. Design development has been optimised, as discussed in **Chapter 5** (Project alternatives and options) and would include:

- Refinement and revision of the alignment of the mainline tunnels, thereby reducing construction risk and costs, the volume of spoil generated, materials used, and emissions generated from operational road use by vehicles.
- Reduced energy and resource consumption, and spoil generation, during tunnel excavation, through selection of roadheaders and drill and blast for excavation, as opposed to the use of a tunnel boring machine. The latter option consumes more electricity, potable water and concrete, and generates more spoil.
- Optimal tunnel ventilation power consumption by locating the ventilation facilities close to the main alignment tunnel portals, thereby optimising the piston generated vehicle effect
- Optimal vertical alignment and grade of project tunnels and portals to allow consistent vehicle speeds to be maintained, thereby improving vehicle fuel efficiency.
- Mainline tunnels and the associated surface road network designed for long term performance and durability of materials, increasing asset design lives and reducing the frequency of maintenance activities.

- Improvements to pedestrian and cyclist paths with provision of new shared cycle and pedestrian pathways, linking existing active transport networks and reducing the need for reliance on road transport between these communities.

Greenhouse gas management measures

Table 22-9 provides a list of mitigation measures to be incorporated during the construction and operation of the project, to further reduce the GHG emissions generated by the project.

Table 22-9 Environmental management measures – climate change adaptation

No.	Environmental management measures	Timing
GG1	Targets to reduce GHG emissions, including the use of GreenPower and/or other renewable energy sources, will be included as part of the project's Sustainability Management Plan to assist in achieving 'Design' and 'As Built' ratings of Excellent under the Infrastructure Sustainability Council of Australia infrastructure rating tool.	Detailed design
GG2	An updated GHG assessment based on detailed design will be undertaken for ongoing monitoring and review of emissions during construction.	Detailed design
GG3	Energy efficiency will be considered during the design of mechanical and electrical systems such as the tunnel ventilation system, tunnel lighting, water treatment systems and electronic toll and surveillance systems. Energy efficient systems will be installed where reasonable and practicable. The installation and use of solar power on operational infrastructure will be considered as part of detailed design, in order to improve the operational energy efficiency of the project.	Detailed design
GG4	Opportunities to use low emission construction materials, such as recycled aggregates in road pavement and surfacing, and cement replacement materials will be investigated and incorporated where feasible and cost-effective.	Construction
GG5	Construction site layouts will be designed to reduce travel distances and double handling of materials so as to reduce fuel usage and emission generation.	Construction
GG6	Construction plant and equipment will be well maintained to allow for optimal fuel efficiency.	Construction
GG7	Raw materials will be managed to reduce energy requirements for their processing. For example, stockpiled materials will be covered or provided undercover storage where possible to reduce moisture content of materials, and therefore the process and handling requirements.	Construction
GG8	Locally produced goods and services will be procured where feasible and cost effective to reduce transport fuel emissions	Construction

22.6 Residual risk assessment

In line with volume.1.2 of the ISCA IS Rating Scheme Cli-2 criteria, adaptation options for all high and extreme risks and a percentage of medium priority risks are identified with appropriate measures implemented. Specifically, to comply with Cli-2 level 2 requirements between 25 – 50% of medium risks must be treated. To comply with Cli-2 level 3 requirements at least 50% of medium priority risks must be treated and the optimal scale and timing be addressed.

A residual risk assessment was undertaken to consider climate change risks to the project post-mitigation, following the implementation of adaptation measures identified in **section 22.5.1** and **section 22.5.2**. Adaptation measures identified as part of this climate change risk assessment would increase the project's resilience to climate change, thereby reducing the consequence of potential impacts and lowering residual risks.

Of the three high risks and one medium risk identified for project construction, proposed adaptation measures have resulted in a residual risk rating of two medium risks and two low risks.

For project operation, proposed adaptation measures have resulted in all high risks lowered to a residual risk rating of medium or low.

Table 22-10 Residual risk to project construction (2030) after mitigation

Risk scenario	Original risk rating	Adaptation / mitigation options	Likelihood	Consequence	Residual risk rating
Extreme rainfall					
Increase in the intensity and frequency of extreme rainfall combined with sea level rise leads to localised flooding of project construction sites and ancillary facilities, resulting in delays to project program.	High	The indicative layouts of the temporary construction ancillary facilities have taken into consideration the flood risk posed to the land, including increased flood risk due to climate change. This includes identifying opportunities to provide setback from areas at risk of flooding, locating uses considered more vulnerable to flooding – such as stockpile areas, chemical storage areas, tunnel dives and deep excavations – away from areas of highest risk, and allowing controlled flooding of suitable areas such as car parks, where feasible.	Medium	Medium	Medium
Storm events					
Increase in the intensity and frequency of storm events leads to unsuitable conditions for undertaking construction works, requiring stop work procedures to be implemented for the safety of construction personnel, resulting in delays to project program.	High	The indicative layouts of the temporary construction ancillary facilities have taken into consideration the flood risk posed to the land, including increased flood risk due to climate change. This includes identifying opportunities to provide setback from areas at risk of flooding, locating uses considered more vulnerable to flooding – such as stockpile areas, chemical storage areas, tunnel dives and deep excavations – away from areas of highest risk, and allowing controlled flooding of suitable areas such as car parks, where feasible.	Medium	Medium	Medium
Extreme heat					
Increase in frequency and intensity of extreme heat events increases the risk of heat stress conditions for construction personnel, resulting in increased work health and safety risks and potential delays to project program.	High	Consider the increased potential for heat stress among construction personnel when refining construction Work Health and Safety Management Plans. Implement measures for greater awareness and education of personnel around health and wellbeing during periods of extreme heat.	Medium	Low	Low
Increase in frequency and intensity of extreme heat events increases the risk to the quality of the concrete pouring process, resulting in program delays.	Medium	Construction contractor to consider appropriate level of contingency in construction program planning to account for increases in extreme heat events.	Medium	Low	Low

Table 22-11 Residual risk to project operation (2030 to 2090) after mitigation

Risk scenario	Original risk rating	Adaptation / mitigation options	Likelihood	Consequence	Residual risk rating
Extreme rainfall, sea level rise and storm events					
Exacerbated local flood risk to the President Avenue portal exits and surface facilities as a result of the increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges).	High	Tunnel portals have been designed to ensure immunity from the greater of the PMF or 100 year Average Recurrence Interval (ARI) event plus 0.5 metre freeboard. Where the portals lie within the PMF extent, this would be achieved by appropriate flood protection measures.	High	Low	Medium
Reduced performance of the surface drainage system at President Avenue interchange due to increased runoff causing localised flooding and inundation as a result of an increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges).	High	To accommodate increased flows as a result of the project, the design includes upgrade of existing drainage infrastructure on President Avenue.	Medium	Medium	Medium
Reduced performance of the tunnel drainage system due to an increase in groundwater filtration, leading to reduced capacity of sumps and the pumping system resulting in localised flooding as a result of an increase in the intensity and frequency of extreme rainfall.	Medium	The project corridor and design of portals and surface ancillary facilities have been refined to minimise impacts on the Rockdale Recreation Corridor and associated green space to help minimise groundwater filtration.	Medium	Medium	Medium
Reduced performance and/or failure of the water treatment system (particularly the submerged discharge infrastructure into Cooks River and Botany Bay) due to saline intrusion and deterioration as a result of sea level rise.	Medium	Water treatment plant operational treatment and drainage infrastructure to be designed with consideration to the effects of potential sea level rise.	Medium	Low	Low
Safety risk to users of the shared cycle and pedestrian pathways due to flooding as a result of an increase in the intensity and frequency of extreme rainfall, combined with sea level rise.	Medium	The design of the operational sites has taken into consideration the flood risk posed to the shared cycle and pedestrian pathways and how to manage these risks, as appropriate.	Medium	Low	Low

Risk scenario	Original risk rating	Adaptation / mitigation options	Likelihood	Consequence	Residual risk rating
Power outages impacting electrical systems (such as pumping stations) resulting from increased flooding as a result of an increase in the intensity and frequency of extreme rainfall, combined with sea level rise (and increased extreme sea levels during storm surges).	Medium	Backup power and other redundancy measures have been built in, to ensure temporary continuity of powered infrastructure in the event of a power outage.	Medium	Low	Low
Failure of the water treatment plant due to water inflow exceeding capacity as a result of increased intensity and frequency of extreme rainfall.	Medium	Construction contractor to consider use of solar powered surface water treatment options as a backup power source.	Medium	Low	Low
Increased road incidents and safety risk to operational personnel and road users as a result of an increase in the intensity and frequency of extreme rainfall.	Medium	The design of the operational sites has taken into consideration the flood risk posed to the sites and how to manage these risks, as appropriate, including raising the base road level to account for flooding.	Low	Medium	Medium
Extreme heat					
Increased risk of heat stress for operational personnel due to an increase in the frequency and intensity of extreme heat events.	High	Consider the increased potential for heat stress among construction personnel when refining construction Work Health and Safety Management Plans. Implement measures for greater awareness and education of personnel around health and wellbeing during periods of extreme heat.	Medium	Medium	Medium
Increased risk of heat stress for users (pedestrians and bicyclists) using the shared cycle and pedestrian pathways as a result of the increase in frequency and intensity of extreme heat events.	High	Consideration of increased extreme heat events has been incorporated into the urban design of project surface infrastructure and areas of open space created by the project, including landscaped areas to increase shading and areas of respite and reduce the absorption of heat by infrastructure, where possible. Landscaping has been designed to include consideration of users of the shared cycle and pedestrian pathways and the increasing need for shading and areas of respite during extreme heat events.	Medium	Medium	Medium

Risk scenario	Original risk rating	Adaptation / mitigation options	Likelihood	Consequence	Residual risk rating
Indirect risks					
Failure of power supply infrastructure due to fire damage to the electricity network as a result of increased frequency and intensity of bushfires, with associated risk of power outages for the project.	High	Backup power and other redundancy measures have been built in, to ensure temporary continuity of powered infrastructure in the event of a power outage.	Medium	Medium	Medium
Extreme heat leading to increased power demand and/or faults/failure of power infrastructure resulting in interruptions to power supply with increased frequency and duration of power outages.	High	Backup power and other redundancy measures have been built in, to ensure temporary continuity of powered infrastructure in the event of a power outage.	Medium	Medium	Medium
Storm events leading to damage to power supply infrastructure or a need to cut supply resulting in interruptions to power supply with increased frequency and duration of power outages.	High	Backup power and other redundancy measures have been built in, to ensure temporary continuity of powered infrastructure in the event of a power outage.	Medium	Medium	Medium

(blank page)

23 Sustainability

This chapter assesses the project against the principles of sustainability and provides an overview of how sustainability has been integrated into the project's design.

Table 23-1 sets out the SEARs relevant to sustainability, alongside the desired performance outcomes of the project, and identifies where the requirements have been addressed in this EIS.

Table 23-1 SEARs - Sustainability

SEARs	Where addressed in this EIS
1. The Proponent must assess the sustainability of the project in accordance with the Infrastructure Sustainability Council of Australia (ISCA) Infrastructure Sustainability Rating Tool and recommend an appropriate target rating for the project.	Assessment of the sustainability of the project in accordance with the ISCA *Infrastructure Sustainability Rating Tool* is discussed in section 23.2.
2. The Proponent must assess the project against the current guidelines including targets and strategies to improve Government efficiency in use of water, energy and transport.	Assessment of the project against current guidelines is provided in section 23.1. Sustainable use of water, energy and transport are discussed in sections 23.1 and 23.3.

23.1 Overview of sustainability

Sustainable development is referred to as 'development which meets the needs of the present, without compromising the ability of future generations to meet their own needs'[1]. In 2016, 17 Sustainable Development Goals of the United Nations (UN) 2030 Agenda for Sustainable Development officially came into force. These goals encourage all countries to take steps to achieving each of these goals. The project would contribute to the three goals shown below in **Figure 23-1**.

Figure 23-1 Project relevant Sustainable Development Goals

The Australian 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'[2].

The provision of properly functioning infrastructure is essential for sustained economic growth, international competitiveness, public health and overall quality of life[3]. 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'[4].

[1] Brundtland Commission (1987) *Our Common Future*
[2] Australian Government Department of the Environment (1992) *National Strategy for Ecologically Sustainable Development*
[3] Mirza S. (2006) *Durability and sustainability of infrastructure — a state-of-the-art report. Canadian Journal of Civil Engineering, 33(6): 639–649.*
[4] Infrastructure Sustainability Council of Australia (ISCA) (2012) *What is infrastructure sustainability?*

23.1.1 Sustainability policy framework

The sustainability policy framework relevant to the project, including NSW Government targets and strategies to improve efficiency in the use of water, energy and transport, is made up of the following documents:

- Future Transport Strategy 2056 (NSW Government 2018)
- A Metropolis of Three Cities – the Greater Sydney Region Plan (Greater Sydney Commission 2018)
- South District Plan (Greater Sydney Commission2018) and Eastern City District Plan (Greater Sydney Commission2018)
- Roads and Maritime Environmental Sustainability Strategy 2015–2019 (NSW Roads and Maritime 2016)
- NSW Sustainable Design Guidelines Version 4.0 (Transport for NSW 2017)
- NSW Freight and Ports Strategy (Transport for NSW 2013)
- NSW Climate Change Policy Framework (NSW Office of Environment and Heritage (OEH) November 2016)
- NSW Government Resource Efficiency Policy (OEH 2014)
- NSW Waste Avoidance and Resource Recovery Strategy 2014-21 (NSW Environment Protection Authority (NSW EPA) 2014).

Together, these documents provide the sustainability principles that inform the design of the project. An overview of relevant strategic plans and how the project relates to these plans is provided in **Chapter 4** (Strategic context and project need), **Chapter 5** (Project alternatives and options), **Chapter 21** (Waste management) and **Chapter 22** (Climate change and greenhouse gas). Specific aims and objectives in relation to sustainability for each of the documents are provided below.

23.1.2 Future Transport Strategy 2056

The *Future Transport Strategy 2056* is a 40-year vision to use transport to contribute to long-term economic, social and environmental outcomes as well as contribute to the NSW Government's aspirational target to achieve net-zero emissions by 2050.

The Strategy recognises that transport related activities account for just over 40 per cent of NSW's energy consumption with a growing share of total public infrastructure investment. Given this level of energy consumption and subsequent emission of greenhouse gases, transport has a responsibility to operate in a more sustainable way to limit environmental and societal impacts.

While it is recognised that a growing transport investment is critical to the wellbeing of communities, doing so in an unsustainable way risks the government's ability to respond to community needs. As a result, the sixth vision of the Strategy specifically relates to Sustainability including a series objectives including:

- Moving towards sustainability
- Sustainable and equitable transport funding
- Striking the balance between user contributions and taxpayer subsidies
- A continued focus on spending efficiency
- Transport's role in working towards environmental sustainability
- Securing energy reliability and affordability
- Managing a resilient transport system.

23.1.3 A Metropolis of Three Cities – the Greater Sydney Region Plan

A Metropolis of Three Cities serves as the vision for Sydney where the three cities; Western Parkland, Central River and Eastern Harbour, serve to allow residents to live within 30 minutes of their jobs, education, health facilities and services. This vision aims to utilise land use and transport patterns to boost Sydney's liveability, productivity and sustainability through a series of Ten Directions.

The Plan sets out a series of objectives to support each of the Ten Directions. Objectives supporting sustainability of relevance to the project and the location they are addressed in the EIS, include:

- Objective 25: The coast and waterways are protected and healthier - **Chapter 18** (Surface water and flooding)
- Objective 27: Biodiversity is protected, urban bushland and remnant vegetation is enhanced - **Chapter 12** (Biodiversity)
- Objective 28: Scenic and cultural landscapes are protected - **Chapter 13** (Landscape and visual) and **Chapter 20** (Aboriginal heritage)
- Objective 31: Public open space is accessible, protected and enhanced - **Chapter 15** (Social and economic)
- Objective 32: The Green Grid links parks, open spaces, bushland and walking and cycling paths - **Chapter 8** (Traffic and transport), **Chapter 15** (Social and economic) and **Appendix C** (Place making and urban design).
- Objective 34: Energy and water flows are captured, used and re-used - **Chapter 17** (Groundwater and geology), **Chapter 18** (Surface water and flooding) and **Chapter 22** (Climate change and greenhouse gas).
- Objective 35: More waste is re-used and recycled to support the development of a circular economy - **Chapter 21** (Waste management)
- Objective 36: People and places adapt to climate change and future shocks and stresses - **Chapter 22** (Climate change and greenhouse gas)
- Objective 37: Exposure to natural and urban hazards is reduced - **Chapter 22** (Climate change and greenhouse gas)
- Objective 38: Heatwaves and extreme heat are managed - **Chapter 22** (Climate change and greenhouse gas).

23.1.4 South District Plan and Eastern City District Plan

The *South District Plan* and *Eastern City District Plan* both provide a 20-year action plan to help manage growth and contribute towards achieving the 40 year vision as set out in the Greater Sydney Region Plan. The intent of the plan is to serve as a bridge between regional and local planning.

Specific to Sustainability, the *South District Plan* sets out a series of Planning Priorities to support implementation. The priorities relevant to the project are as follows:

- Planning Priority S1: Protecting and improving the health and enjoyment of the District's waterways **Chapter 18** (Surface water and flooding)
- Planning Priority S2: Protecting and enhancing bushland, biodiversity and scenic and cultural landscapes and better managing rural areas **Chapter 12** (Biodiversity), **Chapter 13** (Landscape and Visual) and **Chapter 20** (Aboriginal heritage)
- Planning Priority S5: Reducing carbon emissions and managing energy, water and waste efficiently **Chapter 18** (Surface water and flooding), **Chapter 21** (Waste management) and **Chapter 22** (Climate change and greenhouse gas)
- Planning Priority S6: Adapting to the impacts of urban and natural hazards and climate change **Chapter 22** (Climate change and greenhouse gas).

Specific to Sustainability, the *Eastern City District Plan* sets out a series of Planning Priorities to support implementation. The priorities relevant to the project, including where they have been addressed in the EIS are as follows:

- Planning Priority E14: Protecting and improving the health and enjoyment of Sydney Harbour and the District's waterways **Chapter 18** (Surface water and flooding)
- Planning Priority E15: Protecting and enhancing bushland and biodiversity **Chapter 12** (Biodiversity) and **Chapter 20** (Aboriginal heritage)
- Planning Priority E16: Protecting and enhancing scenic and cultural landscapes **Chapter 13** (Landscape and visual)
- Planning Priority E19: Reducing carbon emissions and managing energy, water and waste efficiently **Chapter 18** (Surface water and flooding), **Chapter 21** (Waste management) and **Chapter 22** (Climate change and greenhouse gas)
- Planning Priority E20: Adapting to the impacts of urban and natural hazards and climate change **Chapter 22** (Climate change and greenhouse gas).

23.1.5 NSW sustainable Design Guidelines

The *NSW Sustainable Design Guidelines Version 4.0*[5] provide guidance to embed sustainability initiatives into the design and construction of transport infrastructure projects and are aimed at projects being delivered by Transport for NSW, namely rail infrastructure projects.

While these guidelines and the corresponding checklist are not specifically applicable to road projects, the sustainability initiatives outlined in the guidelines are consistent with sustainability objectives identified by Roads and Maritime (see **section 23.1.5**). The compulsory sustainability initiatives identified in the guidelines address the following sustainability themes:

- Energy and greenhouse gases
- Climate resilience
- Materials and waste
- Biodiversity and heritage
- Water
- Pollution control
- Community benefit.

Discussion of how the project would meet each of these themes, in line with the corresponding Roads and Maritime focus areas is provided in **section 23.1.6**).

23.1.6 Roads and Maritime Services Environmental Sustainability Strategy

The design has aimed to adopt the approach as outlined in the Roads and Maritime *Environmental Sustainability Strategy 2015-2019*[6]*,* which outlines nine sustainability focus areas for integrating sustainability into Roads and Maritime operations and services, and aligns with NSW Government targets and strategies as listed in **section 23.1.1**.

Table 23-2 presents the Roads and Maritime sustainability focus areas and outlines how the project is consistent with these.

---

[5] Transport for NSW (2017) *NSW Sustainable Design Guidelines Version 4.0*
[6] Roads and Maritime Services (2016) *Roads and Maritime Environmental Sustainability Strategy 2015–2019*

Table 23-2 Project consistency with Roads and Maritime sustainability focus areas

Sustainability focus area	Project consistency
Energy and carbon management	The project's Sustainability Management Plan Outline, identifies initiatives to be implemented during design and construction of the project to reduce carbon emissions, energy use and embodied life cycle impacts. These include minimising travel distances between ancillary facilities and minimising transport of materials and staff around the site, and optimising plant operations and efficiency.
Climate change resilience	A climate change risk assessment has been prepared as part of this EIS to identify risks and adaptation opportunities to improve the project's resilience to future climate change. Refer to Chapter 22 (Climate change and greenhouse gas).
Air quality	The project 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 9 (Air quality).
Resource use and waste management	During construction of the project, unnecessary resource consumption would be avoided by making accurate predictions of the required quantities of resources such as construction materials. The management of construction waste would include reuse and recycling of waste, where possible. Further details are provided in Chapter 21 (Waste management).
Pollution control	An acoustic impact assessment has been prepared for the project to identify and mitigate potential noise impacts (refer to Chapter 11 (Noise and vibration)). An assessment has also been prepared for the project to identify and mitigate potential air quality impacts (refer to Chapter 9 (Air quality)). The EIS includes an assessment of the project's potential impact on soil and groundwater and is provided in Chapter 16 (Soils and contamination). The project would also include measures for the abatement, avoidance and/or containment of pollution and waste.
Biodiversity	A biodiversity assessment has been prepared for the project to identify and consider measures to avoid and minimise potential impacts on biodiversity. Project impacts would be managed in accordance with the Roads and Maritime Biodiversity Guidelines. Additional detail is provided in Chapter 12 (Biodiversity).
Heritage	Items of non-Aboriginal heritage significance were identified early in the project design and assessment. Impacts on these items have been minimised, avoided and mitigated where practicable and management measures to be implemented throughout construction of the project have been provided. Refer to Chapter 19 (Non-Aboriginal heritage). No items of Aboriginal heritage significance were identified however management measures are proposed to reduce the risk of potential impacts on unexpected Aboriginal heritage in Chapter 20 (Aboriginal heritage).
Liveable communities	The project would contribute to reducing congestion on the existing road network and improve connectivity across Sydney (refer to Chapter 8 (Traffic and transport)). The project would provide and facilitate improvements in pedestrian and cyclist connections, creating new shared cycle and pedestrian pathways and linking existing active transport networks with new connections. The project would also improve the amenity of streetscapes, and would investigate a 'net improvement in public recreation' policy whereby the project results in an overall improvement in terms of public recreation facilities. Additional detail is provided in Chapter 13 (Landscape and visual impact assessment) and Chapter 14 (Property and land use).
Sustainable procurement	The Sustainability Management Plan Outline guides the implementation of sustainability throughout the project's design and construction phases and facilitates the achievement of the project's ISCA Infrastructure Sustainability (IS) target rating. Refer to section 23.2 for discussion of the IS rating scheme and the project's target rating.

23.1.7 NSW Freight and Ports Strategy

The *NSW Freight and Ports Strategy*[7] outlines two main objectives: to deliver a freight network that efficiently supports the projected growth of the NSW economy, and to balance freight needs with those of the broader community and the environment.

Chapter 4 (Strategic context and project need) outlines the potential benefits of the project in improving efficiency of the freight network.

23.1.8 NSW Climate Change Policy Framework

The *NSW Climate Change Policy Framework*[8] aims to maximise the economic, social and environmental wellbeing of NSW in the context of a changing climate. The framework outlines policy directions for implementing the government's long-term objectives of achieving net zero emissions by 2050, and improving the resilience of NSW to a changing climate.

As part of the implementation of this framework, two additional draft plans have been released for public consultation:

- *Climate Change Fund Draft Strategic Plan 2017–2022*[9]
- *A Draft Plan to Save NSW Energy and Money*[10].

The *Draft Climate Change Fund Strategic Plan 2017–2022* sets out priority investment areas for funding over the next five years, including the provision of up to $100 million in new funding for actions to prepare NSW for a changing climate. As part of this priority investment area, the draft plan identifies actions for reducing the costs to public and private assets arising from climate change; reducing the impacts of climate change on health and wellbeing, particularly for vulnerable communities; and managing the impacts of climate change on natural resources, natural ecosystems and communities. **Chapter 22** (Climate change and greenhouse gas) identifies climate change risks to the project and the adaptation measures implemented during design to improve the resilience of the project to climate change.

The *Draft Plan to Save NSW Energy and Money* is proposed to meet the NSW Government's energy efficiency target of 16,000 gigawatt hours of annual energy savings by 2020, and contribute to achieving net zero emissions by 2050. The draft plan summarises the preferred options for achieving the state's energy savings target, which include opportunities for implementing energy standards for State significant developments and major infrastructure projects such as road tunnels. **Chapter 22** (Climate change and greenhouse gas) and **Chapter 21** (Waste management) outline the proposed energy efficiency measures to reduce the project's energy consumption and contribution to greenhouse gas emissions.

23.1.9 NSW Government Resource Efficiency Policy

The *NSW Government Resource Efficiency Policy*[11] aims to drive resource efficiency, with a focus on energy, water and waste, and a reduction in 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** (Climate change and greenhouse gas) and **Chapter 21** (Waste management) for information regarding how the project aligns with the policy.

---

[7] Transport for NSW (2013) NSW Freight and Ports Strategy
[8] OEH (2016) *NSW Climate Change Policy Framework*
[9] OEH (2016) *Climate Change Fund Draft Strategic Plan 2017-2022*
[10] OEH (2016) *A Draft Plan to Save NSW Energy and Money*
[11] NSW Government (2014) *NSW Government Resource Efficiency Policy*

23.1.10 NSW Waste Avoidance and Resource Recovery Strategy 2014-21

The *NSW Waste Avoidance and Resource Recovery Strategy 2014-21*[12] provides a framework for waste management.

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.

In line with the *NSW Waste Avoidance and Resource Recovery Strategy 2014-21*, measures to avoid, minimise or manage waste streams generated as a result of the project are detailed in **Chapter 21** (Waste management). The management of contaminated waste, including contaminated spoil is discussed in **Chapter 16** (Soils and contamination) and **Chapter 21** (Waste management), along with mitigation measures, including the ways in which disposal of contaminated waste would be managed.

23.2 Infrastructure Sustainability Rating Scheme

Sustainability of the project will be assessed in accordance with the ISCA Rating Tool to determine and set an appropriate target rating for the project, in accordance with the SEARs.

In August 2018, ISCA released the new Planning, Design and As-Built Infrastructure Sustainability (IS) Version 2.0 ratings. This update provides a number of improved and additional categories and credits to further enhance the sustainability performance of major infrastructure projects. Roads and Maritime have registered for Design and As-Built IS Version 1.2 for the project prior to the release of Version 2.0. Therefore, Version 1.2 would continue to be used for the remainder of the project and options to selectively apply Version 2.0 criteria would be considered where beneficial to achieving sustainable project outcomes.

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, as shown in **Figure 23-2**. For Version 1.2 the three types of ratings as part of the IS rating scheme are Design, As Built and Operation.

The project is seeking a minimum IS ‘Design’ and ‘As-Built’ rating of ‘Excellent’.

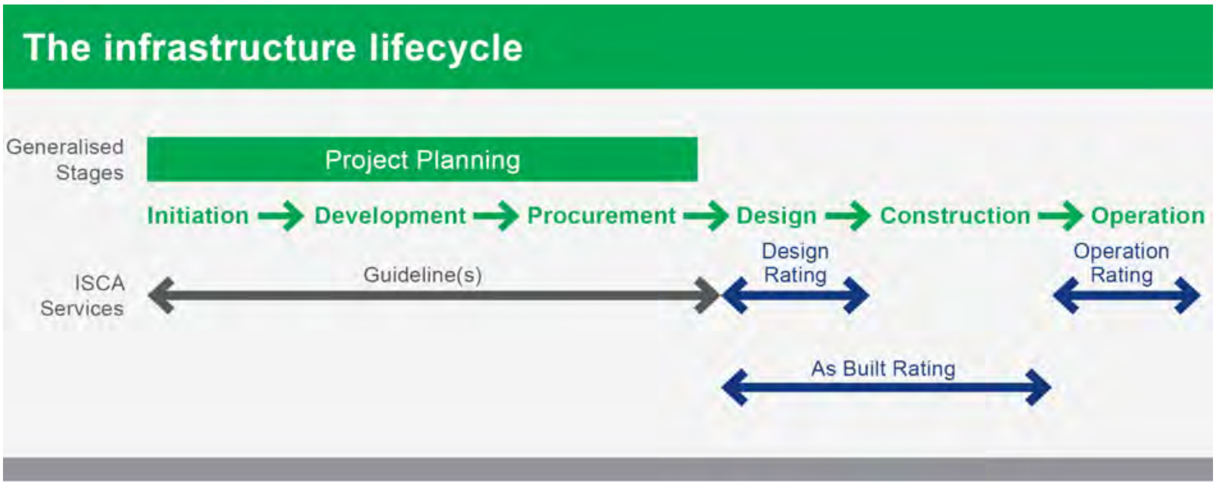


Figure 23-2 IS rating scheme and the project’s target rating

[12] NSW Government (2014) *NSW Waste Avoidance and Resource Recovery Strategy 2014-21*

Sustainability workshops and meetings were held during EIS development with planning and design teams to assess and progress initiatives for achieving the target IS ‘Design’ and ‘As-Built’ rating criteria. Opportunities for future detailed design developments suggested in these workshops were also taken into account.

Sustainability initiatives were identified under the following headings:

- Energy and water, including initiatives for achieving efficiencies in energy and water use through design of tunnel ventilation, stormwater drainage and utilities
- The reduction of waste, including the reuse of construction ancillary facilities used for the New M5 at Arncliffe, as well as the management and reuse of spoil during construction
- Access and movement, including provision for shared cycle and pedestrian pathways for improved connectivity along the Rockdale Wetlands and Recreation Corridor
- Natural landscape and environment, including initiatives to minimise the construction boundary, where possible, and protect ecologically sensitive areas including the wetlands near the President Avenue interchange
- Adaptation to climate change, including initiatives to improve the resilience of the project to future extreme climate events and sea level rise
- Cultural heritage and identity, including initiatives for the preservation of heritage values.

A number of actions were documented for planning and design consideration to embed specific sustainability commitments and targets for implementation by the construction contractor. The construction contractor would be responsible for ensuring that enough credits are achieved to meet the IS 'Excellent' rating.

A project specific Sustainability Management Plan Outline would be prepared to guide the implementation of sustainability throughout the design and construction phases and to facilitate the achievement of the IS rating.

23.3 Ecologically sustainable development

Development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends is referred to as ecologically sustainable development. The principles of ecologically sustainable development have been considered throughout the development of the project.

One of the objectives of the Environmental Planning and Assessment Act 1979 (NSW) (EP&A Act) is to facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment. The SEARs for the project require the project to have regard to ecologically sustainable development. The *Protection of the Environment Administration Act 1991* notes that ecologically sustainable development can be achieved through the implementation of the following principles and programs:

- The precautionary principle
- Inter-generational equity
- Conservation of biological diversity and ecological integrity
- Improved valuation and pricing and incentive mechanisms.

These principles are discussed below in the context of the project and the environmental planning and assessment process.

23.3.1 Precautionary principle

The precautionary principle deals with certainty in decision making, whereby 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 project were considered during the alternatives and options analysis, as discussed in **Chapter 5** (Project alternatives and options).

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.

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 the environmental risk analysis undertaken for **Chapter 8** (Traffic and transport) to **Chapter 21** (Waste management). Safeguards and management measures have been developed to manage impacts identified in these assessments. The safeguards and management measures would result in an acceptable residual risk and no significant serious or irreversible environmental harm.

As discussed in **section 23.2**, sustainability workshops and meetings were held during EIS development with planning and design teams, which sought to preserve opportunities for the implementation of sustainability initiatives in future detailed design development.

23.3.2 Inter-generational equity

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 of future generations.

The project tunnels would have a design life of about 100 years and would be designed to meet the needs of both current and future generations. The project has been considered in terms of intergenerational equity, with the management of potential environmental impacts discussed throughout this EIS.

The project may impact on inter-generational equity through the consumption of fuel resources during construction and operation, contributing to 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, such as bitumen. 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 to reduce 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.

In accordance with the project objectives to improve travel times between southern Sydney and strategic centres in the metropolitan area, increases in average speeds as a result of the operational efficiency of the project tunnels, which would reduce the number of intersections and the frequency of stopping, would result in improved vehicle fuel efficiency.

The project's resilience to future climate change is considered in **Chapter 22** (Climate change and greenhouse gas), which identifies potential climate risks to the project, adaptation incorporated in the project's design development and recommended next steps for the development of adaptation options during detailed design. The project would contribute to building the resilience of metropolitan Sydney by addressing some of the key chronic stresses facing the city, including the need for improved connectivity and reduced congestion.

Under expected traffic conditions the contribution of project tunnel ventilation outlets to pollutant concentrations was found to be negligible for all sensitive receptors identified. Exceedances of some air quality criteria were predicted to occur at a small proportion of sensitive receptors both with and without the project however are expected to be dominated by background concentrations and not as a result of the ventilation outlets. The total number of receptors with exceedances decreased slightly with the project and in the cumulative scenarios. Refer to **Chapter 9** (Air quality) and **Appendix E** (Air quality technical report) for additional detail.

23.3.3 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 project has substantially avoided biodiversity impacts by utilising, as much as possible, already disturbed sites and due to most of the infrastructure being underground. The proposed tunnels are distant from potentially sensitive wetlands. This minimises the potential indirect impacts on migratory bird habitat at the Cooks River and Rockdale wetlands.

Further avoidance of impacts include relocation of a proposed water treatment plant to the already cleared area at the Arncliffe Construction ancillary facility (C1), generating fewer impacts than would be expected from using an undeveloped site. This would include reduction in construction noise, vibration dust and light spill. The following Plant Community Types require offsetting in accordance with the online credit calculator: about 0.47 hectares of 1232 Swamp Oak floodplain swamp forest, about 0.30 hectares of 1795 Swamp Mahogany / Cabbage Tree Palm - Cheese Tree - Swamp Oak tall open forest, and about 0.77 hectares of 1808 Common Reed.

The project would remove about 4.45 hectares of potential foraging habitat for the Grey-headed Flying-fox. While the habitat likely to be impacted is potential foraging habitat, the small area of habitat and its relatively urban context would not present a barrier to movement or breeding for this species. Grey-headed Flying-fox forage across a wide range of vegetation, including two camps within 10 kilometres of the project.

The project is likely to indirectly impact on Green and Golden Bell Frog habitat during construction, particularly at the Marsh Street Green and Golden Bell Frog habitat site. Impacts would include disturbance due to noise, dust and vibration arising from the continued use of the Arncliffe construction ancillary facility. The potential indirect impacts are not expected to be significant and would cease at the completion of construction. These indirect impacts would also likely be less than those arising from the New M5 project, as the project would use already constructed facilities, reducing the overall construction noise, movement of vehicles, light, dust and vibration (refer to **Chapter 12** (Biodiversity)).

Fauna injury or mortality could occur during construction of the project, as a result of direct collision with vehicles and equipment within the project footprint. Mobile species (such as birds) may be able to move away quickly and easily, but other less mobile species, or those with high fidelity with their home range, may be slower to move away or may not relocate at all, potentially resulting in injury or mortality of the individual. Although there is potential for some injury or mortality of fauna species, the project is unlikely to result in a large number of fauna injury or mortality incidents, as the majority of the project would be constructed underground. Where temporary and permanent ancillary facilities and infrastructure occur, the surrounding land is highly urbanised. Implementation of management measures outlined in **Chapter 12** (Biodiversity) would reduce the chances of injury or mortality of fauna. Measures to manage potential impacts on bats would be included in the Construction Flora and Fauna Management Plan.

A number of mitigation measures to minimise ecological direct and indirect impacts would be implemented as part of the project in line with Roads and Maritime *Biodiversity Guidelines – Protecting and managing biodiversity on RTA projects*. These measures would be detailed in the flora and fauna management plan for the project which includes: site-specific environmental induction; identification of clearing limits and protective fencing; vegetation clearance procedures; pre-clearance surveys; erosion and sediment controls; weed management and monitoring.

This EIS provides a detailed assessment of potential impacts on biodiversity and identifies a range of mitigation measures to further avoid and minimise potential impacts. Refer to **Chapter 12** (Biodiversity) and **Appendix H** (Biodiversity development assessment report) for additional detail.

23.3.4 Improved valuation and pricing and incentive mechanisms

The principle of improved valuation and pricing and incentive mechanisms relates to the consideration of environmental factors in the valuation of assets and services. Environmental factors include:

- Polluter pays (i.e. 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 established, should be pursued in the most cost-effective ways.

Environmental factors have been considered throughout the concept design stage for the design, construction and operation of the project. As a consequence, environmental impacts have been avoided or minimised where practical during the concept design development for the project.

Mitigation measures outlined in this EIS will be implemented during construction and operation of the project. These mitigation measures would be revised and updated as required during the detailed design stage of the project and as the project passes through the assessment process.

The value placed on avoiding and minimising environmental impacts is demonstrated in the design features incorporated into the project, including opportunities for reducing emissions through efficient design, for reducing overall waste and properly handling any contaminated waste, for minimising noise through adoption of integrated noise reduction measures, for protecting biodiversity by assessing and managing impacts on habitat and connectivity, and for ensuring sustainability in procurement through procurement of appropriate skills and maximising enforceability of sustainability contract requirements. The cost of these mitigation measures are incorporated into the project cost, as well as the extent of environmental investigations undertaken to inform this EIS.

This project creates the potential for improvements in local amenity with the shared cycle and pedestrian pathways and return of the majority of parklands used for construction facilities restored to park uses and revegetated. The project would also provide improvements to pedestrian and cyclist connections, linking existing active transport networks with new connections or improving existing connections through a reduction in traffic, which would improve the amenity of streetscapes. Land use impacts are detailed in **Chapter 14** (Land use and property). **Appendix C** (Place making and urban design) contains specific guidance on design of a cohesive identity and high quality user experience for the project.

23.4 Management of impacts

The overarching sustainability objectives for the project 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’.

23.4.1 Sustainability management plan

The detailed design would include development and implementation of a detailed Sustainability Management Plan (SMP). 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 project’s detailed design, construction and operation 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 environmental, social and economic costs and benefits over the life of the project.

The Sustainability Management Plan would form part of the 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 Rating 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.

24 Project synthesis

This chapter provides a technical summary and a synthesis of the findings of the Environmental Impact Statement (EIS). The main body of the EIS and Appendices should be referred to for further details. **Table 24-1** sets out the assessment requirements relevant to the project synthesis chapter and where the requirements have been addressed in this EIS.

Table 24-1 SEARs - Project synthesis

Assessment requirements	Where addressed in this EIS
A chapter that synthesises the environmental impact assessment and provides: • A succinct but full description of the project for which approval is sought	Section 24.1
• A description of any uncertainties that still exist around design, construction methodologies and/or operational methodologies and how these would be resolved in the next stages of the project	Section 24.4
• A compilation of the impacts of the project that have not been avoided	Section 24.5
• A compilation of the proposed measures associated with each impact to avoid or minimise (through design refinements or ongoing management during construction and operation) or offset these impacts	Section 24.6
• A compilation of the outcome(s) the proponent would achieve	Section 24.7
• The reasons justifying carrying out the project as proposed, having regard to the biophysical, economic and social considerations, including ecologically sustainable development and cumulative impacts	Section 24.8
The EIS must include, but not necessarily be limited to, the following: • a concise description of the general biophysical and socio-economic environment that is likely to be directly and indirectly impacted by the project (including offsite impacts). Elements of the environment that are not likely to be affected by the project do not need to be described	Section 24.2
• a demonstration of how the project design has been developed to avoid or minimise likely adverse direct and indirect impacts during construction and operation of the project.	Section 24.3

24.1 The project for which approval is sought

This EIS considers the potential impacts of constructing and operating the project summarised in this section.

The project would comprise a new multi-lane road link between the New M5 Motorway tunnel underground at Arncliffe and an intersection at President Avenue at Kogarah. In addition, construction of stub tunnels to provide connections to the future stages of the F6 Extension would be provided at the southern extent of the mainline tunnel.

The proposed route of the project is shown in **Figure 24-1**.

A description of project elements is provided in **Table 24-2**. A more detailed description of the project is provided in **Chapter 6** (Project description).

The design and construction approach presented in this EIS is based on a concept design and is indicative only. It is subject to change during the detailed design once project approval is obtained and detailed construction methodologies would be developed by the contractor(s) delivering the project. Issues raised during exhibition of the EIS may result in changes to the concept design and construction methodology and if so, these would be identified in a Preferred Infrastructure Report.

The project does not include:

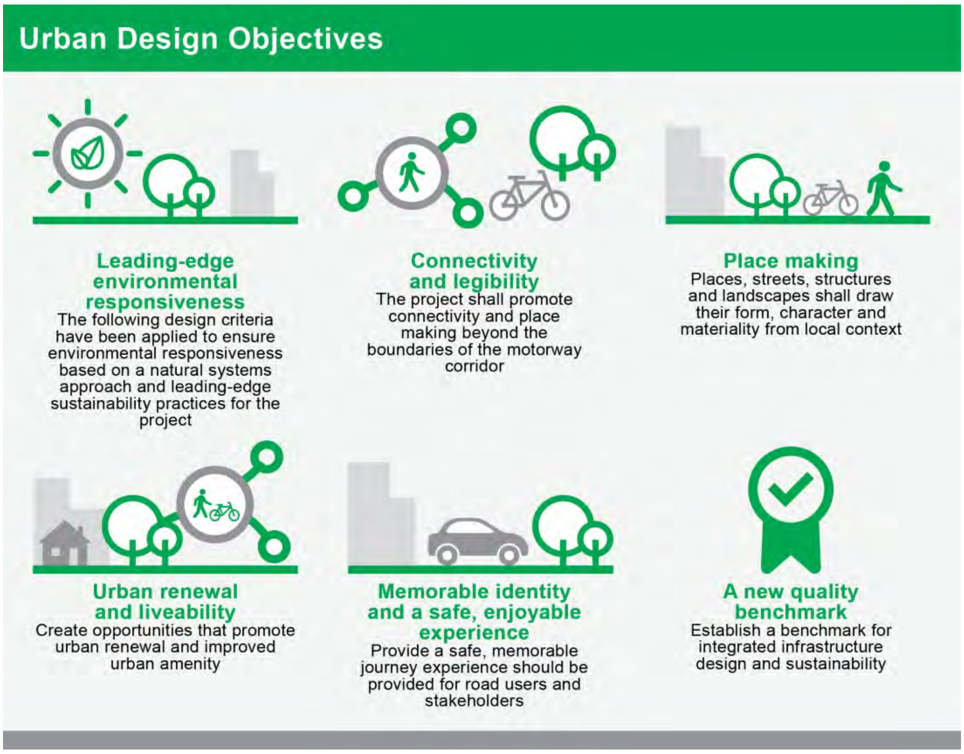
- Ongoing motorway maintenance activities during operation
- Future upgrades to other intersections in the vicinity of the project.

The above activities would be subject to separate planning approval determination as appropriate.

Table 24-2 Main project elements

Project element	Summary of design
Operational	
Tunnels	• Twin mainline tunnels, three kilometres in length in each direction between the New M5 Motorway connection and stub tunnels (for a connection to future stages of the F6 Extension) • Constructed around 70 metres underground for most of the tunnel length, then variable until just below the surface near the tunnel portal • Line marking of two additional lanes in each direction in the New M5 Motorway tunnels, resulting in four lanes in each direction from St Peters interchange to the F6 Extension tunnel connection at Arncliffe • Mainline tunnels sized to accommodate three lanes of traffic, although initially line marked for two lanes • Connected to the tunnel portal near President Avenue via entry and exit ramp tunnels
President Avenue intersection	• A tunnel portal located north of President Avenue, within the current Rockdale Bicentennial Park East. • Entry and exit ramps (in an open slot and at surface) connect the tunnel portal with the existing surface road network • North facing ramps with two lanes in each direction
President Avenue surface works	• Widening of sections of President Avenue to three lanes eastbound and westbound • Addition of slip lanes to provide a connection to the entry and exit ramps • Raising President Avenue about three metres at the location of the intersection • Cul-de-sacs to close existing local roads including Moorefield Avenue and O'Neill Street • Conversion of Civic Avenue to allow left in/left out movements only at President Avenue • A right turn bay and refuge bay would be provided to formalise a right turn into Lachal Avenue from President Avenue • Line marking for dual right turn lanes from President Avenue into O'Connell Street including two lanes marked on O'Connell Street southbound
President Avenue / Princes Highway intersection	• Widening of the President Avenue and Princes Highway intersection • Upgrade from a two lane signalised right turn from northbound Princes Highway to President Avenue to a three lane signalised right turn • Upgrade from three lanes southbound on Princes Highway with a shared straight/ left turn lane to four lanes including a dedicated, signalised, left turn from Princes Highway onto President Avenue
Reinstatement of Rockdale Bicentennial Park	• Reinstatement of Bicentennial Park, including replanting of riparian vegetation with the wetlands area • Replacement and some reconfiguration of recreational facilities
Shared cyclist and pedestrian pathways	• Dedicated shared cyclist and pedestrian pathways provided between Bestic Street and Civic Avenue, through the reinstated Rockdale Bicentennial Park • A dedicated cyclist and pedestrian overpass over President Avenue.

Project element	Summary of design
Motorway operations	• Three motorway operation complexes would be required: – Arncliffe – including a substation, operational water treatment facility and fitout of a ventilation facility currently being built as part of the New M5 Motorway project – Rockdale (north) - including the Motorway Control Centre, deluge tanks, a workshop and an office – Rockdale (south) - including a ventilation facility, substation and power supply • In-tunnel ventilation systems • Drainage infrastructure to collect surface water and groundwater inflows for treatment • Ancillary infrastructure for electronic tolling, traffic control and signage • Emergency access and evacuation facilities, fire and life safety systems • New service utilities, modifications and connections to existing service utilities
Lighting, tolling and signage	• In-tunnel lighting, surface road lighting, emergency lighting for evacuation of the tunnels • Aviation hazard lighting may be required at the Rockdale ventilation facility • Lighting at tolling points, which would be hooded and directed down towards the toll points to minimise potential light spill • Tolling points at the President Avenue entry and exit ramps. An electronic tag-based free-flow type of roadside tolling equipment would be used. • Message signs related to traffic, location, directions, warnings and variable conditions within the tunnels and on surface roads at tunnel approaches • Integrated speed and lane-use signs along the length of the project • Lighting along the shared pedestrian and cycle pathways.
Utility services	Protection, relocation or realignment of utilities and services at the surface works areas along President Avenue, and at the Rockdale motorway operations complex. Existing major utilities within these areas include: • Power (Ausgrid) – high voltage transmission (33kV or greater) and substations • Secondary Jemena gas mains (1050 kilopascals (kPa)) • Potable water (Sydney Water) – mains of 300 millimetre diameter or greater • Sewer (Sydney Water) – gravity mains of 300 millimetre or greater • Telecommunications – multiple fibre optics cables. Connection to existing electricity, water and wastewater/sewer utilities.
Permanent power supply connection	A permanent power supply connection around seven kilometres in length would be required to service the construction and operation of the project. The connection would run underground from the Rockdale (south) Motorway Operations Complex to the Ausgrid substation in Canterbury located at 16A Hansen Avenue Earlwood.
Road traffic noise attenuation	Mitigation for operational noise will be considered. The use of low noise pavement will be considered first, followed by noise barriers, followed by at-property treatment, as far as reasonable and feasible. The number and location of properties eligible for consideration of architectural treatment will be confirmed during detailed design.
Property acquisition	• Full acquisition of 12 privately owned properties (six industrial, one commercial and five residential) • Partial acquisition of three privately owned properties • Patrial acquisition of four public properties, including about 1.1 hectares of Rockdale Bicentennial Park.

<table>
<tr><th>Project element</th><th>Summary of design</th></tr>
<tr><td>Urban design objectives</td><td>


During detailed design, the architectural treatment of the motorway's operational ancillary facilities and landscaping works next to disturbed areas and along the shared cycle and pedestrian pathways would be guided by the urban design principles, as well as the operational facility performance requirements and outcomes of community consultation.

Preliminary concept plans have been prepared for Rockdale Bicentennial Park and the President Avenue surface works in consideration of the urban design objectives. These would inform the Urban Design and Landscape Plan that would be prepared for the project.
</td></tr>
<tr><td colspan="2">Construction</td></tr>
<tr><td>Construction program</td><td>A construction period of around four years. Construction at most locations would be of less duration then the overall construction period, with some sites only being occupied for a number of months.</td></tr>
<tr><td>Project construction activities</td><td>Construction activities including:

- Preparatory investigations
- Site establishment and enabling work
- Tunnelling
- Surface earthworks and structures
- Construction of motorway operations complexes
- Drainage and construction of operational water management infrastructure
- Construction of the permanent power supply connection
- Road pavement works
- Finishing works.
</td></tr>
</table>

Project element	Summary of design
Construction ancillary facilities	Six key construction ancillary facilities (refer to **Figure 24-4**): • Arncliffe (C1) at Kogarah Golf Course in Arncliffe • Rockdale (C2) at Rockdale, within a Roads and Maritime Depot at West Botany Street • President Avenue (C3) within Rockdale Bicentennial Park and surrounding areas • Shared cycle and pedestrian pathways east (C4) off Bruce Street, within CA Redmond Field • Shared cycle and pedestrian pathways west (C5) adjacent to Muddy Creek off West Botany Street) • Princes Highway construction ancillary facility (C6), located on the north-east corner of President Avenue and Princes Highway.
Traffic management and access	Management of traffic and access to ensure safety and functionality of surrounding roads is maintained. Traffic management measures determined during detailed design and documented in a Construction Traffic and Access Management Plan (CTAMP).
Construction workforce	A construction workforce comprising trades and construction personnel, subcontractor construction personnel and engineering, functional and administrative staff. A variable workforce across the working day with a reduction in personnel for the night shifts. A total peak workforce of around 270 personnel.
Construction work hours	The majority of spoil removal and haulage would occur between 7am - 6pm on weekdays and between 8am - 1pm on Saturday. Spoil haulage may need to occur outside of these hours along arterial roads. When required, night time works would require the use of heavy haulage vehicles.

Figure 24-1 Overview of the project

Figure 24-2 Artist's impression of the tunnel portal within Rockdale Bicentennial Park

Figure 24-3 Artist’s impression of the dedicated shared cycle and pedestrian bridge over President Avenue

C1

- Tunnelling and spoil handling
- Construction of MOC1 (Water treatment plant, substation)
- Fitout, testing and commissioning of tunnels and MOC 1

C2

- Construction of the decline tunnel
- Tunnelling and spoil handling
- Pavement works for internal access road
- Construction of MOC2
- Reconfiguration of the site to enable ongoing/future use for maintenance activities

C3

- Demolition of buildings and vegetation clearing and removal
- Relocation of utilities
- Temporary stockpiling of spoil and fill materials
- Management of any contaminated land, including acid sulphate soils
- Construction of cut-and-cover structures
- Construction of MOC3 (Rockdale ventilation facility and substation)
- President Avenue intersection upgrade works
- Construction of shared pedestrian and cyclist path and overpass

C4/C5

- Site establishment
- Vegetation clearing and removal, topsoil stripping areas and land-form shaping
- Temporary stockpiling of materials
- Construction of the shared pedestrian and cyclist path
- Finishing works including lighting, line marking and signage installation

C6

- Property adjustment and demolition
- Relocation of utilities, stormwater infrastructure, underground storage tanks and substation
- Laydown and parking of construction vehicles and equipment
- Reinstatement of site

LEGEND

- Surface works
- Construction boundary
- Cut-and-cover structures
- Underground construction
- Construction ancillary facility
- Permanent power supply line
- Permanent power supply construction route
- New M5 Tunnel
- Railway line
- Railway station
- Waterway
- Waterbody

Figure 24-4 Construction boundary and construction ancillary facilities

24.2 Existing environment

The project would be located within the Bayside local government area (LGA) and partially within the Canterbury-Bankstown LGA, around nine kilometres to the southwest of the Sydney CBD. Currently all through traffic, including freight vehicles, use the Princes Highway and The Grand Parade to travel from southern Sydney to the Sydney Central Business District (CBD). The current volume of through traffic mixing with local traffic results in substantial traffic congestion, particularly during the AM and PM peak periods.

Topography in the region is characterised by relatively flat and low lying lands with gentle undulating hills. Geology in the area is characterised by Triassic aged Hawkesbury sandstone overlain by Quaternary alluvium. Areas of higher elevation and westerly sections along the tunnel alignment consist of Triassic aged Hawkesbury Sandstone which is present beneath the entire length of the tunnel alignment.

The low elevation areas along the project alignment, for example near the President Avenue intersection entry and exit ramps and tunnel portal, consist of Quaternary alluvium and man-made fill. This man-made fill often contains dredged estuarine sand and mud, demolition rubble and industrial and domestic waste.

Groundwater is present in Hawkesbury Sandstone and the Quaternary alluvium around the edges of Muddy Creek, Cooks River and Rockdale Wetlands. Perched groundwater (i.e. groundwater at a level above the regional water table) may also be encountered within fill and natural soils in more elevated areas.

The tunnel portal at the President Avenue intersection would be constructed within the existing F6 reserved corridor in Rockdale Bicentennial Park. On- and off-ramps would connect the tunnel portal to President Avenue. A total of three native vegetation types were identified within the construction boundary. These are ‘Swamp Oak floodplain swamp forest – Sydney Basin Bioregion and South East Corner Bioregion’, ‘Swamp Mahogany / Cabbage Tree Palm – Cheese Tree – Swamp Oak tall open forest on poorly drained coastal alluvium in the Sydney basin’, and ‘Common Reed on the margins of estuaries and brackish lagoons along the New South Wales coastline’. All three vegetation types are listed as threatened ecological communities.

There is a waterbody within Rockdale Bicentennial Park and other aquatic habitats within or in proximity to the construction boundary include the waterway entering Scarborough Park, Muddy Creek upstream of Bestic Street, and the Cooks River.

A number of residential and community receptors are located in proximity to the surface works and along the shared cycle and pedestrian pathways. C1 would be located on land currently being used to construct the New M5 Motorway, which is zoned as Trade and Technology, Special Use and Open Space under the Cooks Cove SREP 33. C2 would occupy around half the area of the existing Roads and Maritime maintenance depot (35,000 square metres in total), currently zoned as IN2 Light Industrial and SP2 Infrastructure under Rockdale LEP 2011. The land use zoning at C3 is currently a mix of IN2 Light Industrial, SP2 Infrastructure, RE1 Public Recreation and R2 Low Density Residential. The land use zoning at C6 is currently B1 Neighbourhood Centre.

The majority of the motorway operational infrastructure would be located within IN2 Light Industrial and SP2 Infrastructure, or Trade and Technology under the Cooks Cove SREP 33. The majority of the tunnels are located below land zoned as R2 Low Density Residential or IN2 Light Industrial.

24.3 Avoidance or minimisation of impacts through design

The environmental and social impacts of the project have been minimised through design and the construction methods chosen. The key avoidance of environmental and social impacts of the project has occurred through locating the majority of the project underground instead of at the surface through the existing F6 reserved corridor. **Table 24-3** outlines design responses which have allowed for environmental impacts to be avoided.

Table 24-3 Adverse construction impacts avoided or minimised through design

Environmental aspect	Design response
Traffic and transport	• The main construction ancillary facilities are located to allow vehicles (heavy vehicles in particular) to access and egress via the arterial road network to avoid or minimise the use of the local road network.
Noise	• Development of haul routes to minimise the use residential streets • Use of the Arncliffe ventilation facility, being constructed as part of the New M5 Motorway project, therefore reducing potential noise and vibration impacts • Selection of a combination of roadheader excavation and drill and blast methods for construction of the tunnels, which speeds up excavation compared to work solely undertaken with roadheaders, thereby reducing the duration of noise and vibration impacts for residential and commercial properties.
Biodiversity	• Locating the project primarily in tunnel, and using an existing construction ancillary facility at Arncliffe, to reduce the need for vegetation clearance, impacts to a Nationally important wetland (Eve Street Wetland) and Locally important wetlands (Marsh Street, Landing Lights and Spring Street Wetlands), as well as other direct and indirect impacts to terrestrial and aquatic flora and fauna • Construction of the entry and exit ramps as cut-and-cover structures through the majority of Rockdale Bicentennial Park, allowing the reinstatement of the aquatic habitat provided by the waterbody in the Park following construction.
Property and land use	• Locating the project primarily underground to minimise property acquisition • Locating the tunnel portal within the existing F6 reserved corridor • Location of the construction ancillary facilities within land already being used for construction of the New M5 Motorway project at C1, RMS owned land at C2 and within the SP2 Infrastructure zone to minimise property acquisition and changes in land use.
Social and economic	• Locating the project primarily in tunnel to minimise the need for property acquisition and other impacts (such as amenity, community wellbeing, access and connectivity) to residential properties and social infrastructure • Use of an existing Roads and Maritime depot within an industrial area for a major construction site • Construction of the entry and exit ramps as cut-and-cover structures through the majority of Rockdale Bicentennial Park, allowing the partial reinstatement of the Park following construction • Use of the Arncliffe ventilation facility, being constructed as part of the New M5 Motorway project, therefore reducing potential amenity impacts arising from noise, dust and vibration • Alignment and depth of tunnels located within good geological conditions to minimise difficulty and duration of construction impacts • Selection of roadheader excavation and drill and blast methods for construction of the tunnels, which would speed up excavation and reduce the construction timeframe and disruption for the local community.
Groundwater	• Design of the tunnels to reduce groundwater drawdown within the unconsolidated sediments by constructing tanked (undrained) tunnel sections through the alluvium which would also minimise settlement in these areas
Waste	• Selection of roadheader excavation and drill and blast methods for construction of the tunnels which would generate less spoil than a tunnel boring machine • Treatment of contaminated materials (spoil and wastewater) encountered during construction to make suitable for reuse where feasible within or outside of the project.

24.4 Project uncertainties and approach to design refinements

The design presented in this EIS is indicative and subject to further detailed design which may further minimise impacts. The design serves to:

- Confirm that the proposed performance and technical requirements can be achieved
- Validate the feasibility and potential methodologies of the construction
- Identify key risks, constraints and potential environmental impacts.

There remain some uncertainties relating to technical requirements and how the project would be constructed. These would be resolved during detailed design. A summary of the uncertainties that have the potential to impact on the environment, and how these would be resolved, is provided in **Table 24-4**. Considering the implementation of the proposed resolutions, the uncertainties listed are not expected to result in significant or unacceptable impacts to the environment that would not be capable of mitigation or management.

Table 24-4 Resolution of key project uncertainties

Key uncertainties	Category	Proposed resolution for uncertainty
Shared pedestrian and cycle pathway – alignment, connections, President Avenue bridge access, on road cycleway design (form, route and connections)	Design	The alignment of the shared cyclist and pedestrian pathways would be confirmed following consultation with stakeholders including Bayside Council and Sydney Water.
Mainline tunnel alignment – avoid poor ground conditions	Design	Confirmation of the final tunnel alignment and depth will occur when a design and construction contractor is engaged to deliver the project. Future consultation to inform communities and affected stakeholders about the final alignment and depths of the tunnels and to explain differences with the concept design assessed in this EIS.
Configuration and detailed design of motorway operations complexes	Design	Refinement of the design and configuration for the motorway operations complexes will be confirmed during detailed design, including the interface with the New M5 Motorway at Arncliffe (MOC1). The design detail would be refined in accordance with performance requirements for elements such as the ventilation facilities, the urban design objectives and principles developed for the project, and the outcomes of consultation.
Work required along surface roads to integrate the project with the existing network	Design	A strategy to ensure appropriate network integration of the project will be developed. This strategy would include: • Working with Council to manage local traffic, particularly along O'Connell Street, Moorefield Avenue and Civic Avenue • Working with Council to confirm access changes along President Avenue between West Botany Street and Princes Highway (for example at Moorefield Avenue) • Working with other road projects (for example the New M5 Motorway project) to manage traffic in the St Peters, Alexandria and Mascot areas • A proposed Road Network Performance Review Plan to confirm the operational traffic impacts of the projects on surrounding arterial roads and major intersections • Active traffic management measures both on the motorway and arterial networks.
Ground conditions within the construction boundary (including in the area of the construction decline at C2)	Construction	Additional investigations would be carried out to adequately characterise the ground conditions within the construction boundary prior to construction, including: • Quantity and type of soil and groundwater contamination • Quantity of groundwater inflows during excavations.

Key uncertainties	Category	Proposed resolution for uncertainty
The nature and extent of utility works outside of the project footprint	Construction	• The nature and extent of utility changes would be confirmed during the detailed design development of the project • Future and ongoing consultation would be undertaken with utility providers to effectively stage and manage utility works.
Relocation of community facilities from Rockdale Bicentennial Park	Construction	The relocation of community facilities such as playing fields, a playground and skate park would be undertaken in consultation with Bayside Council.
Place making and urban design	Design	The final design and arrangement of public open space, including the reinstatement of Rockdale Bicentennial Park, would be undertaken in consultation with Bayside Council and included in an Urban Design and Landscape Plan.
The timing and provision of noise mitigation options for road traffic noise	Design	• Confirm the detailed design, update the operational road traffic noise model to confirm predicted noise levels • Ongoing community and stakeholder consultation to assist in informing and determining appropriate additional noise mitigation.
The locations and extent of likely ground settlement	Design	Further assessment of potential settlement impacts, including numerical modelling, would be undertaken based on detailed design.
The final alignment of the permanent power supply	Design	The final alignment of the permanent power supply would be determined following consultation with Transgrid, Canterbury-Bankstown Council, Bayside Council and other stakeholders.

24.5 Compilation of adverse impacts

Table 24-5 provides a summary of the potential construction impacts of the project, and **Table 24-6** provides a summary of the potential impacts of the project during operation.

Potential residual impacts would be further reviewed during detailed design development and construction planning and where necessary additional measures would be implemented to ensure these impacts are suitably mitigated.

Table 24-5 Summary of construction impacts

Issue	Summary of key adverse impacts
Traffic and transport	• Relatively small and short-term increase in the volume of traffic on the existing road network • Temporary road occupation and/or road closures, and cyclist and/or pedestrian diversions • Vehicular access will be heavily constrained during utilities relocation and pavement widening works during the President Avenue / Princes Highway intersection upgrade works.
Air quality	• Potential temporary dust impacts during construction, however these are not expected to be significant • Potential odour impacts during the excavation of the cut-and-cover tunnels due to the presence of acid sulfate soils
Health, safety and hazards	No significant residual impacts anticipated
Noise and vibration	Exceedances of the *Interim Construction Noise Guideline* noise management levels affecting sensitive receptors
Biodiversity	• Removal of around 1.24 hectares of native vegetation which comprises two threatened ecological communities listed under the *Biodiversity Conservation Act 2016* • Loss of around 4.45 hectares of potential foraging habitat for the Grey-headed Flying Fox, however, no roosting sites or camps occur within the study area and is therefore not likely to significant impact this species.
Landscape and visual impacts	• High-moderate landscape character impact on the Rockdale Bicentennial and Scarborough Parks open space and recreation area • High-moderate visual impacts on views from the Ilinden Sports Centre, Rockdale Bicentennial Park, Brighton Memorial Playing Fields and President Avenue • Moderate visual impact on views from the Brighton-Le-Sands school, the intersection of President Avenue and the Princes Highway and West Botany Street
Property and land use	• Full acquisition of 12 privately owned properties (six industrial, one commercial and five residential) • Partial acquisition of three privately owned properties • Partial acquisition of four public properties, including about 1.1 hectares of Rockdale Bicentennial Park • Potential settlement impacts on Muddy Creek constructed channel • Moderate impacts on land use at within Rockdale Bicentennial Park and moderate/high impacts at West Botany Street.
Social and economic	• Moderate social impacts associated with the acquisition of private property • Moderate impacts to amenity • Temporary changes to access and connectivity • Temporary relocation of sporting and recreational facilities at Rockdale Bicentennial Park • Impacts to businesses as a result of changes in traffic, access, parking and amenity
Soils and contamination	Potential for contamination to be present at concentrations above the adopted assessment criteria and pathways for exposure to human and ecological receptors
Geology and groundwater	• Potential for large quantities of inflows of groundwater during construction and operation which would result in increased groundwater drawdown

Issue	Summary of key adverse impacts
Surface water and flooding	• Disturbance of Rockdale wetland and Northern Scarborough Pond during construction from sedimentation and treated groundwater and surface water discharges • Adverse impacts on flood behaviour during construction associated with the Arncliffe construction ancillary facility (C1), the Rockdale construction ancillary facility (C2), President Avenue construction ancillary facility (C3) and the shared cycle and pedestrian pathways construction ancillary facilities (C4/C5)
Non-Aboriginal heritage	• Direct impacts to local heritage item Patmore Swamp by the proposed surface works at President Avenue • Impacts to items of non-Aboriginal heritage which are discovered during demolition or earthworks
Aboriginal cultural heritage	• Potential impact on previously identified places of Aboriginal cultural significance (such as at Patmore Swamp) • Potential impact on previously unidentified Aboriginal heritage items • Potential impact on previously unidentified Aboriginal cultural heritage places or values
Waste management	No significant residual impacts anticipated. Moderate residual impacts include: • Generation of large quantities of unusable spoil due to tunnelling • Impacts associated with poor waste management during construction
Climate change risk and greenhouse gas	No significant residual impacts anticipated. Moderate residual impacts include: • Climate change risks associated with increases in extreme rainfall and storm events, which may impact upon construction activities and construction ancillary facilities with potential delays to the project construction program • Greenhouse gas emissions (GHG) generated during project construction
Sustainability	A Sustainability Management Plan would be prepared for the project. No significant residual impacts anticipated.
Cumulative impacts	Potential for construction traffic, air quality and noise fatigue for sensitive receptors around C1. Potential for cumulative impacts on receptors due to concurrent construction activities.

Table 24-6 Summary of operational impacts

Issue	Summary of key adverse impacts
Traffic and transport	• Some increased congestion is forecast along President Avenue, Kogarah, and on the exit ramps to the St Peters interchange, due to the forecast increase in demand to and from the project
Air quality	• Under expected traffic conditions, the predicted contribution of tunnel ventilation outlets to pollutant concentrations is expected to be minimal for all receptors • Potential increase in pollutant concentrations on some parts of the road network, particularly within the vicinity of the new President Avenue intersection as a result of increase in traffic
Health, safety and hazards	No significant residual impacts anticipated.
Noise and vibration	• A total of 109 receptors (including residential and school receptors) are predicted to have exceedances of the Noise Policy for Industry (NSW EPA 2017) operational road traffic noise criteria • Potential increase in traffic noise levels by greater than 2 dB(A) on Civic Avenue, Kogarah and O'Connell Street, Monterey, as a result of traffic taking alternative routes to avoid congestion
Biodiversity	No significant residual impacts anticipated
Landscape and visual impacts	• High-moderate landscape character impact on the Rockdale Bicentennial and Scarborough Parks open space and recreation area • High-moderate impact on views from President Avenue

Issue	Summary of key adverse impacts
Property and land use	• Moderate impacts on land use at Marsh Street, Roads and Maritime Depot and the Princes Highway / President Avenue intersection • Moderate/high impacts at West Botany Street
Social and economic	• Impacts to amenity through an increase in road infrastructure • Permanent changes to access and connectivity • Impacts to businesses as a result of changes in traffic, access, parking and amenity
Soils and contamination	No significant residual impacts anticipated
Geology and groundwater	No significant residual impacts anticipated
Surface water and flooding	No significant residual impacts anticipated
Non-Aboriginal heritage	Potential visual impacts to some local heritage items based on changes from open space to motorway operational infrastructure
Aboriginal cultural heritage	No significant residual impacts anticipated
Waste management	No significant residual impacts anticipated
Climate change risk and greenhouse gas	No significant residual impacts anticipated
Sustainability	A Sustainability Management Plan would be prepared for the project. No significant residual impacts anticipated.
Cumulative impacts	• Increases in daily traffic along the west of President Avenue and West Botany Street in the cumulative scenario (2036) • The New M5 Motorway entry and exit ramps would experience increased traffic, with a corresponding reduction in the level of service in peak hours. • Minor increase in surface traffic within the vicinity of St Peters Interchange

24.6 Compilation of management measures

The proposed measures associated with each impact to avoid or minimise (through design refinements or ongoing management during construction and operation) or offset these impacts are outlined in **Table 24-7**.

Roads and Maritime has developed, through its contract specifications, a model specification that requires construction contractors to implement an environmental management system in the form of a Construction Environmental Management Plan (CEMP) during construction of the project. The CEMP provides a structured approach to the management of environmental issues identified in the EIS. Implementing the CEMP would effectively ensure that the project meets regulatory and policy requirements in a systematic manner and continually improves its performance. The strategies defined in the CEMP would be developed in consideration of the project approval requirements, and the safeguards and mitigation measures presented in the EIS. The CEMP establishes the system for implementation, monitoring and continuous improvement to minimise impacts of the project on the environment.

Table 24-7 Compilation of mitigation measures

Impact	ID	Measure	Timing
Traffic and transport			
Construction Traffic and Access	TT1	A Construction Traffic and Access Management Plan (CTAMP) will be prepared as part of the Construction Environmental Management Plan. The CTAMP will detail processes to minimise delays and disruptions and identify and respond to changes in road safety as a result of project construction works. The CTAMP will be prepared in accordance with applicable guidelines and relevant standards, guides and manuals. The CTAMP will: • Ensure all relevant stakeholders are considered during all stages of the project • Provide safe routes for pedestrians and cyclists during construction • Develop project staging plans in consultation with relevant traffic and transport stakeholders, which would include measures to manage impacts during special events (such as sporting events) • Plan and stage works to minimise the need for road occupancy, where possible • Minimise the number of changes to the road users' travel paths and, where changes are required, implement a high standard of traffic controls which effectively warn, inform and guide • Comprehensively communicate changes in traffic conditions on roads or paths to emergency services, public transport operators, other road user groups and other affected stakeholders • Identify measures to manage the movements of construction-related traffic to minimise traffic and access disruptions in the public road network • Minimise the use of local roads by the project's heavy vehicles and identify haulage routes • Propose a car parking strategy for construction staff at the various worksites, in consultation with local councils and stakeholders associated with any facilities adjacent to the project site • Minimise the loss of on-road parking for local residents • Stage the construction works on key parts of the network – such as Princes Highway, President Avenue and West Botany Street – to enable these key roads to continue to function with as minimal impact as possible.	Prior to construction
	TT2	Where required, changes in bus stops will be undertaken in consultation with Transport NSW and bus operators, with the community to be informed of any potential changes in advance. Wayfinding signage will be provided directing commuters to adjacent or relocated bus stops. Footpaths will be provided to any relocated bus stops such that accessibility standards are met.	Construction

Impact	ID	Measure	Timing
	TT3	During construction, work with the TMC to observe traffic flows and incidents from CCTV footage and where reasonable and feasible, modify sites and activities to address issues identified by TMC.	Construction
	TT4	Spoil haulage vehicles will be managed to minimise movements in the AM and PM peak periods.	Construction
	TT5	Minimise local road closures and maintain adequate property access to the road network. Property owners would be consulted and agree to any changes to access.	Construction
	TT6	The movements of haulage vehicles accessing ancillary construction sites will be coordinated to minimise potential queuing and traffic and access disruptions in the local area.	Construction
Damage or impacts to road infrastructure resulting from construction works.	T7	Prior to impacting roads, a road dilapidation report will be prepared, in consultation with relevant council(s) and road owners, identifying existing conditions of local roads and mechanisms to repair damage to the road network caused by heavy vehicle movements associated with the project.	Prior to construction Construction
Operational road network performance impacts including potential increased traffic on some parts of the network, particularly President Avenue, West Botany Street and Bestic Street as a result of the project.	TT8	A review of operational network performance will be undertaken 12 months and five years from commencement of operation to confirm the operational traffic impacts of the project on surrounding arterial roads and major intersections. The review would identify relevant mitigation measures, if required to address impacts on road network performance. The results of the review will be considered in future operational network performance planning carried out by Roads and Maritime.	Operation
Air quality			
Impacts from ambient air quality from dust generation and deposition during construction	AQ1	A Construction Air Quality Management Plan will be developed and implemented to monitor and manage potential air quality impacts associated with the construction of the project and activities at construction ancillary facilities. The management plan will identify project construction activities with the potential to have air quality impacts and the controls required to avoid, minimise and mitigate these impacts. The plan will include measures to: • Minimise project and cumulative dust generation from stockpiles, haulage routes, work activities, exposed ground surfaces and acoustic sheds • Minimise generator and vehicle emissions during construction of the tunnel • Inspect and address corrective actions • Modify or cease dust generating works during unfavourable weather conditions. The Plan will be implemented for the duration of construction.	Prior to construction
	AQ2	Demolition activities, including removal of hazardous building materials will be planned and carried out in a manner that minimises the potential for dust generation. Removal of hazardous building materials will be completed prior to the commencement of general demolition works.	Construction

Impact	ID	Measure	Timing
Odour impacts	AQ3	Odorous material would be treated immediately on-site, and removed from site where necessary. Areas of odorous materials would be excavated in a staged process to allow for treatment and handling. Exposed areas of odorous material would be kept to a minimum to reduce the total emissions from the site. On-site odour measurements would be carried out during excavation works to determine odour emission rates. Results from the monitoring would be used to inform future excavation and treatment activities on site.	Construction
Impacts on air quality within project tunnels and from the ventilation outlets during operation	AQ4	Tunnel infrastructure will be designed in such a way that the generation of pollutant emissions by the traffic using the tunnel is minimised. In-tunnel air quality will be managed through monitoring and management of the ventilation systems and, where necessary, traffic management.	Detailed design
	AQ5	An in-tunnel air quality monitoring system will be included in the detailed design to monitor and assess ambient and in-tunnel air quality against relevant criteria. This will require sufficient, appropriately placed monitors to calculate a journey average.	Construction and operation
Health, safety and hazards			
Hazardous substances and dangerous goods spill	HS1	A Pollution Incident Response Management Plan (PIRMP) will be prepared for the project. The PIRMP will be prepared in accordance with legislative requirements and include measures to manage hazardous substances and dangerous goods including storage, handling and spill response.	Construction
Improper handling and transport of hazardous substances and dangerous goods	HS2	A Work Health and Safety Plan will be implemented during construction of the project, supplemented by site and activity specific Safe Work Method Statements.	Construction
	HS3	Transport of dangerous goods and hazardous substances will be conducted in accordance with relevant legislation and codes.	Construction Operation
	HS4	An Incident Response Protocol will be developed as part of the Emergency Response Plan for the project and implemented in the event of an accident or incident. The protocol is to detail operational management measures associated with the storage, handling and transport of hazardous substances and dangerous goods, including spill response.	Prior to operation
	HS5	The transport of dangerous goods and hazardous substances will be prohibited through the mainline tunnels and entry and exit ramps during operation.	Operation
Impact of lighting on airport operations	HS6	The project will be constructed and operated in accordance with the design requirements of CASA and the Sydney Airport Master Plan 2033, with respect to lighting.	Construction
	HS7	Should the exhaust plumes or structures at any of the F6 Extension Stage 1 ventilation outlets be assessed as a 'controlled activity' under the Airports Act and the Airspace Regulations, then the project will be operated in accordance with conditions of approval from the Secretary of DIRDC.	Operation

Impact	ID	Measure	Timing
Impact of electric and magnetic fields	HS8	The project substations will be designed to ensure that the exposure limits for the general public detailed in by the Draft Radiation Standard (Australian Radiation Protection and Nuclear Safety Agency 2006) will not be exceeded at the boundary of the substation sites.	Detailed design
Noise and vibration			
Construction noise	NV1	A Construction Noise and Vibration Management Plan (CNVMP) will be prepared. The CNVMP will include processes and responsibilities to assess, monitor, minimise and mitigate noise and vibration impacts during construction. The plan will: • Identify relevant performance criteria in relation to noise and vibration • Identify noise and vibration sensitive receptors and features in the vicinity of the project • Include standard and additional mitigation measures from the Construction Noise and Vibration Guideline (CNVG) (Roads and Maritime 2016) and details about when each will be applied • Describe the process(es) that will be adopted for carrying out location and activity specific noise and vibration impact assessments to assist with the selection of appropriate mitigation measures • Consider cumulative construction noise impacts and construction noise fatigue • Include protocols that will be adopted to manage works required outside standard construction hours, in accordance with relevant guidelines including for management of respite periods • Detail monitoring that will be carried out to confirm project performance in relation to noise and vibration performance criteria. The CNVMP will be implemented for the duration of the construction of the project.	Prior to construction
	NV2	Detailed noise assessments will be carried out for all ancillary facilities required for construction of the project. The requirement for temporary noise walls within ancillary facilities and adjacent to construction works, and the requirement for other appropriate noise management measures, is to be assessed and implemented prior to the commencement of activities which have the potential to cause noise or vibration impacts.	Prior to construction

Impact	ID	Measure	Timing
	NV3	All residents affected by noise from the construction of the project which are expected to experience an exceedance of the construction NMLs will be consulted about the project prior to the commencement of the particular activity, with the highest consideration given to those that are predicted to be most affected as a result of the works. Roads and Maritime would consult with vulnerable members of the community who are likely to be more susceptible to adverse health effects of noise (especially those who are elderly, who do not speak English, are housebound, or who may be unwell) to accommodate their preferences for noise mitigation, as far as practicable. Consultation would also be undertaken with all schools likely to be affected, and in particular Cairnsfoot Special School, to determine suitable mitigation measures where necessary. The information provided to the residents will include: • General sequencing and locations of construction work • The hours of the project works • Construction noise and vibration impact predictions for the works • Construction noise and vibration mitigation measures likely to be implemented on site. Community consultation regarding construction noise and vibration will be detailed in the Community Involvement Plan for the construction of the project and will include a complaints handling process. The community will be able to provide feedback via a 24 hour, toll-free project information and complaints line, a dedicated email address and postal address for the project. For out of hours works, consultation with affected residents will take place with consideration to Practice note vii of the ENMM and Strategy 2 of the ICNG.	Prior to construction
	NV4	Noisy work (as defined in the EPL) and vibration intensive activities (those activities that exceed the vibration criteria) will be scheduled to be undertaken during standard construction hours as far as possible. Works or activities that cannot be undertaken during standard construction hours will be scheduled as early as possible during the evening and/or night-time periods. Respite measures are to be implemented for noisy work and vibration intensive activities in a manner consistent with EPL and Roads and Maritime guideline requirements.	Construction
	NV5	Receptors identified as requiring at-property operational noise mitigation will be identified and offered treatment prior to commencement of construction works that affects them.	Prior to construction
	NV6	Construction vehicle movements (on and off site) will be managed to avoid or minimise noise impacts. Where reasonable and feasible, spoil will only be removed from site during the day. Mitigation measures for vehicle movements outside of standard construction hours are to be included in the CNVMP.	Construction

Impact	ID	Measure	Timing
	NV7	Vibration generating activities will be managed to minimise the potential for impacts on structures and sensitive receptor(s), including maximising safe working distances where practicable, or use of alternate methods to minimise vibration where safe working distances cannot be achieved. Where alternatives cannot be implemented, vibration monitoring is to be undertaken and receptors notified in advance of works. Vibration monitors are to provide real-time notification of exceedances of levels approaching cosmetic damage criteria.	Construction
Operational noise	NV8	Operational noise and vibration mitigation measures are to be identified in an Operational Noise and Vibration Review (ONVR). Requirements for at-property noise treatments in properties identified as 'eligible' in the EIS will be reviewed as part of the ONVR and progress of the detailed design. The implementation of treatments will be undertaken in accordance with Roads and Maritime Guidelines.	Detailed design
	NV9	Within 12 months of the commencement of the operation of the project, actual operational noise performance will be compared to predicted operational noise performance. The need for additional mitigation or management measures to address identified operational performance issues and meet relevant operational noise criteria would be assessed and implemented where reasonable and feasible.	Operation
Biodiversity			
Removal of native vegetation and habitat, including threatened plants	B1	Detailed design will avoid or minimise the need for native vegetation and habitat removal for the construction of the project, where feasible. A plan for the rehabilitation of all areas directly affected by construction, including water bodies, would be included as part of the CFFMP (refer B4 below).	Detailed design
Indirect impacts on native vegetation and habitat	B2	Detailed design of the project will avoid or minimise artificial light impacts on biodiversity within and immediately adjacent to the operational project (e.g. downward-facing lighting along the shared cycle and pedestrian pathways)	Detailed design
Impacts to wetlands and riparian land	B3	Detailed design of the project will avoid or minimise disturbance to wetlands and riparian land during both construction and operation, as far as practical. This will include location of stockpiles outside of riparian corridors where reasonable and feasible.	Detailed design

Impact	ID	Measure	Timing
Impacts to flora and fauna	B4	A Construction Flora and Fauna Management Plan (CFFMP) will be prepared. The CFFMP would outline processes and responsibilities with regard to avoiding, managing and/or mitigating biodiversity impacts during construction. The plan will include: • A process for pre-clearance surveys prior to vegetation clearing • A process for vegetation clearing including the establishment of exclusion zones at the limit of clearing to protect sensitive areas. Exclusion zones will be established in accordance with Guide 2 Exclusion Zones of Roads and Maritime's Biodiversity Guidelines[1] • An unexpected finds procedure for both flora and fauna • A procedure for managing inadvertent impacts to both flora and fauna • A process for identifying and managing priority and environmental weeds and other pests prior to, during, and after construction (including within vegetation exclusion zones) • A protocol to minimise the potential for the spread of pathogens such as Chytrid or Phytophthora fungus into and out of the site during construction • A process for dewatering and restoration of the Rockdale Wetland, including measures developed by an aquatic ecologist to handle and relocate aquatic fauna. The processes and procedures will be prepared in accordance with relevant Roads and Maritime guidelines.	Prior to construction
Impacts to Green and Golden Bell Frogs	B6	All construction site inductions will contain a relevant section on identifying and managing potential risks to the Green and Golden Bell Frog. This will include identification of the frog and its habitat, a clear outline of the location of no-go zones for construction personnel, equipment and materials (including herbicides and pesticides), hygiene protocols and what to do in the event of an unexpected find. Frog exclusion fencing and sediment controls will be installed. Any Green and Golden Bell Frogs encountered within the construction boundary during construction are to be collected by a qualified and experienced herpetologist and relocated within the adjacent golf course by the herpetologist. Impacts to Green and Golden Bell Frog due to light spill will be mitigated with lighting directed to minimise construction night time light spill outside of all construction areas, particularly onto the RTA ponds and Kogarah Golf Course. The ground surface within the Arncliffe construction ancillary facility (excluding the operational footprint) will be reinstated to a condition the same or better than prior to the commencement of construction of the New M5 Motorway project in consultation with relevant stakeholders.	Construction, and post- construction

[1] RTA, 2011, *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects.*

Impact	ID	Measure	Timing
Landscape and visual			
Impacts to views from the construction of surface infrastructure for the project including construction ancillary facilities, particularly within the vicinity of President Avenue interchange	LVIA1	An Urban Design and Landscape Plan will be prepared. The plan will detail built and landscape features to be implemented prior to operation of the project. The plan is to be developed in consultation with local council.	Prior to construction
	LVIA2	Where reasonable and feasible, existing trees will be retained and protected within construction areas.	Construction
	LVIA3	Construction and operational lighting will be oriented to minimise glare and light spill impacts on adjacent receptors.	Construction Operation
	LVIA4	The design and maintenance of construction compound hoardings will aim to minimise visual impacts and landscape character impact, including the prompt removal of graffiti.	Construction
	LVIA5	Where trees are removed to facilitate construction of the project, replacement trees would be selected and planted in accordance with the tree management strategy developed for the project. The strategy would provide for the following: • Consideration of all options to minimise the need for tree removal and to retain as many trees as possible • Preparation of comprehensive tree reports (by a qualified arborist) for trees requiring protection, pruning, or removal, to guide the approach to managing trees • Measures to minimise damage to, and ensure the health and stability of, trees to be retained, in accordance with AS4970-2009 Protection of trees on development sites • Replacement of trees where removal cannot be avoided, in accordance with the following general principles: – net increase in the number of replacement trees – provision of replacement trees to achieve similar outcomes as those removed where possible, such as screening, amenity, etc. – replacement trees are to have a minimum pot size of 75 litres, except where the plantings are consistent with the pot sizes specified in a relevant authority's plans for vegetation management, or as agreed by the relevant authority(s) (such as Bayside Council) – trees to be planted within 500 metres of the project area wherever practicable, or in another location determined in consultation with the relevant council • Consideration of plant species that would benefit Grey-headed Flying-fox foraging • Targets to be achieved such as established vegetation cover and water quality parameters.	Construction

<table>
<tr><th>Impact</th><th>ID</th><th>Measure</th><th>Timing</th></tr>
<tr><td colspan="4">Property and land use</td></tr>
<tr><td>Property acquisition</td><td>PL1</td><td>Prior to the commencement of works, a toll-free Acquisition Assistance Line will be established and maintained for a period of up to six months following completion of the final acquisition for the project. The Acquisition Assistance Line is to provide ongoing dispute resolution, a counselling program and contact information for relevant services for relocated persons.</td><td>Prior to construction</td></tr>
<tr><td>Creation of residual land</td><td>PL2</td><td>Residual land remaining following construction of the project would be confirmed to identify appropriate land use, taking into consideration the location, land use characteristics, area and adjacent land uses.</td><td>Construction</td></tr>
<tr><td>Ground settlement</td><td>PL3</td><td>Ground settlement at buildings, roads, parking areas and parks as a result of the project will be managed to comply with the following criteria unless more stringent criteria are subsequently determined by the project.:
<table>
<tr><th>Surface and sub surface structures</th><th>Maximum settlement</th><th>Maximum angular distortion</th><th>Limiting tensile strain* (percent)</th></tr>
<tr><td>Buildings – Low or non-sensitive properties
(i.e. ≤up to 2 levels and carparks)</td><td>30 mm</td><td>1 in 350</td><td>0.1</td></tr>
<tr><td>Buildings – High or sensitive properties (i.e. ≥ 3 levels and heritage items)</td><td>20 mm</td><td>1 in 500</td><td>0.1</td></tr>
<tr><td>Roads and parking areas</td><td>40 mm</td><td>1 in 250</td><td>N/A</td></tr>
<tr><td>Parks</td><td>50 mm</td><td>1 in 250</td><td>N/A</td></tr>
</table>
* As defined in Burland et al. ‘Building response to tunnelling – Case Studies from construction of the Jubilee Link Extension’, London, Thomas Telford (2001).</td><td>Detailed design
Construction</td></tr>
<tr><td></td><td>PL4</td><td>Prior to the commencement of construction, pre-construction Building Condition Surveys will be offered in writing, to the owners of properties where there is a potential for construction activities to cause cosmetic or structural damage. If accepted, a comprehensive written and photographic condition report would be produced by an appropriate professional prior to relevant works commencing.</td><td>Prior to construction</td></tr>
<tr><td>Utility impacts</td><td>PL5</td><td>Interface agreements will be entered into with relevant owners of infrastructure and utility services likely to be impacted by construction of the project. The agreements will likely identify:
• Minimum separation distances and appropriate settlement criteria for utility infrastructure
• Settlement monitoring requirements during construction
• Contingency actions in the event that settlement limits are exceeded.</td><td>Prior to construction</td></tr>
</table>

Impact	ID	Measure	Timing
Impacts to the Bardwell Valley Golf Club	PL6	Work with the Bardwell Valley Golf Club to determine staging of construction works and construction method to minimise impact on the activities and operation of the Golf Club.	Construction
Social and economic			
Amenity	SE1	A Site Establishment Management Plan will be prepared prior to construction and will have regard to the amenity of adjacent areas and minimising impacts to adjacent sensitive receivers, including potential noise, dust, traffic, visual, lighting and overshadowing and overlooking impacts.	Prior to construction
Social infrastructure	SE2	Provision of temporary alternative sporting and recreational facilities in nearby locations, including a skate park, children's disability playground and sporting fields, will be investigated during detailed design to account for the temporary loss of these facilities during construction of the project at the President Avenue construction ancillary facility (C3).	Detailed design Prior to construction
Impacts to businesses	SE3	A Business Management Plan will be prepared prior to construction to detail the process for identification and communication with businesses adversely affected by construction works.	Prior to construction
Construction fatigue	SE4	Prepare and implement a Construction Fatigue Protocol as part of the CNVMP to address potential construction fatigue impacts. The Protocol will include consideration of noise attenuation and periods of respite for affected stakeholders, where reasonable and feasible, and restricting out of hours work where practicable.	Prior to construction
Community consultation	SE5	A Community Communication Strategy would be prepared prior to construction to detail the processes to facilitate communication between the project team and the community.	Prior to construction
Social infrastructure	SE6	A Community and Social Management Plan will be prepared. The plan will detail the process for identification and implementation of measures to offset community and social impacts associated with the project. The plan is to be prepared by a suitably qualified and experienced person(s) in consultation with the community and relevant councils.	Operation

Impact	ID	Measure	Timing
Soils and contamination			
	SC1	A Construction Soil and Water Management Plan (CSWMP) will be prepared for the project. The plan will detail the process and measures to manage and monitor soil and water impacts associated with the construction works, including contaminated land. The CSWMP will: • Describe measures to minimise and /or manage sediment and erosion within the project footprint, including overland flow, including requirements for Erosion and Sediment Control Plans (ESCP). • Describe stockpile management measures, including location restrictions, separation of waste types, stabilisation and sediment controls • Describe measures for managing waste, including spoil classification and handling • Describe procedures for managing unexpected contamination finds • Describe procedures for managing groundwater impacts including treatment requirements • Describe procedures for dewatering accumulated water on site and within sediment basins, including discharge criteria and sign off • Describe spill management procedures including requirements for locating and maintaining spill response materials such as spill kits • Detail surface water and groundwater monitoring requirements, including discharge criteria. Measures are to be consistent with the Blue Book (Landcom 2004) and relevant Roads and Maritime guidelines.	Prior to construction

Impact	ID	Measure	Timing
Impacts on site workers and/or local community through disturbance and mobilisation of contaminated material	SC2	A Hazardous Building Materials Management Plan will be prepared detailing measures to manage the removal of known and unexpected hazardous building materials, including asbestos within buildings and soil. The plan is to be prepared in accordance with relevant guidelines.	Construction
	SC3	Detailed site (contamination) investigations will be undertaken in accordance with the NSW EPA (1995) *Sampling Design Guidelines* within the following ancillary facilities and construction sites prior to commencement of construction at these sites: • Rockdale construction ancillary facility (C2) • President Avenue construction ancillary facility (C3), specifically Bicentennial Park and 427 to 441 West Botany Street • Parts of the Shared cycle and pedestrian pathways where earth works are required within Civic Avenue, Bicentennial Park, Rockdale Women's Sports Field, Greg Atkins Mini Field, CA Redmond Field and White Oak Reserve • Princes Highway construction ancillary facility (C6), the 7-Eleven service station at 734 Princes Highway, Kogarah • The substation within St George TAFE. Where required, based on the results of the additional investigations, a Remedial Action Plan (RAP) will be prepared prior to construction.	Prior to construction Construction
Impacts on soil and water quality through incorrect handling of contaminated material	SC4	Construction water treatment plants will be established and operated at the Arncliffe Construction Ancillary Facility (C1), Rockdale Construction Ancillary Facility (C2) and President Avenue Construction Ancillary Facility (C3) to treat water from the tunnel works. Discharge from these plants will be managed to achieve the applicable ANECC criteria. Where feasible, water from the water treatment plants will be reused for construction activities.	Construction
Acid sulfate soils	SC5	An Acid Sulfate Management Plan will be prepared detailing processes to manage actual and potential acid sulfate soils disturbed during construction.	Construction
Landfill gas and leachate	SC6	Further detailed investigation and assessment will be undertaken in Bicentennial Park in order to develop management plans for leachate and landfill gas management. The purpose of the management plans will be to minimise nuisance odours to the surrounding area during excavation, and to prevent the accumulation of gases in buildings, basins and subsurface service trenches and pits associated with the project. The management plans may include measures such as excavation staging, leachate and gas management, and gas and odour monitoring.	Construction
Erosion and sedimentation	SC7	A soil conservation specialist will be engaged for the duration of construction to provide advice regarding erosion and sediment control.	Construction

Impact	ID	Measure	Timing
Salinity	SC8	Prior to ground disturbance in areas of very high potential soil salinity, testing will be carried out to confirm the presence of saline soils. If saline soils are encountered, they will be managed in accordance with Site Investigations for Urban Salinity (DLWC 2002).	Construction
Groundwater and geology			
Operational tunnel inflows higher than expected which may exceed the inflow criteria of 1 L/sec/km for any kilometre length of tunnel.	GW1	Where fractured Hawkesbury Sandstone is intersected, a combination of techniques will be investigated to reduce the bulk hydraulic conductivity	Construction
	GW2	Appropriate waterproofing measures will be identified and included in the detailed design to reduce the inflow into the tunnels. A target of one litre per second per kilometre for any kilometre length of the tunnel during operation will be adopted.	Detailed design
Groundwater drawdown impacting a water supply well water level by more than two metres	GW3	Impacts on water supply bores will be 'made good' as soon as practicable. Where water supply bores cannot be made good, alternate measures are to be implemented to replace supply.	Construction and Operation
Alteration of groundwater flows and levels due to the installation of subsurface project components	GW4	Measures to reduce potential impacts to groundwater flows due to subsurface components of the project will be identified and included in the detailed construction methodology and the detailed design as relevant.	Detailed design
Actual groundwater inflows and drawdown in adjacent areas exceed predictions	GW5	A detailed groundwater model will be developed by the construction contractor. The model will be used to predict groundwater inflow rates and volumes within the tunnels and groundwater levels (including drawdown) in adjacent areas during construction and operation of the project.	Detailed design
	GW6	Groundwater inflow and groundwater levels in the vicinity of the tunnels will be monitored during construction and compared to model predictions and groundwater performance criteria applied to the project. The detailed groundwater model will be updated based on the results of the monitoring as required and proposed management measures to minimise potential groundwater impacts adjusted accordingly to ensure that groundwater inflow performance targets are met.	Construction

Impact	ID	Measure	Timing
Impacts to groundwater quality, groundwater levels or groundwater flows	GW7	Prior to construction, a groundwater monitoring program will be prepared and implemented to monitor groundwater levels, construction and operational groundwater inflows in the tunnels, and groundwater quality in the three main aquifers impacted by construction works. The program will identify groundwater monitoring locations, performance criteria in relation to groundwater inflow and levels, and potential remedial actions that will be considered to address potential impacts. As a minimum, the program will include monthly manual groundwater level and quality monitoring and weekly monitoring of inflow volumes and quality.	Prior to construction
Adverse impacts on the local hydrogeological regime due to groundwater discharge	GW8	An operational water treatment plant will be constructed at the Arncliffe Motorway Operations Complex (MOC1) to manage and treat groundwater from the tunnel prior to discharge. Discharge will be undertaken in accordance with the approval conditions and agreed discharge criteria.	Operation
Treated groundwater may be discharged to stormwater without consideration to a suitable sustainable use.	GW9	Sustainable water re-use options will be reviewed for treated groundwater during operations.	Construction
Geology (ground movement)			
Ground movements may cause impacts to structures on the surface.	GM01	A geotechnical model of representative geological and groundwater conditions will be prepared by the construction contractor during the detailed design phase prior to the commencement of tunnelling. The model will be used to assess predicted settlement impacts and ground movement during the construction and operation of the project	Detailed design
	GM02	Further assessment of potential settlement impacts, including numerical geotechnical modelling will be undertaken prior to excavation and tunnelling to assess the cumulative predicted settlement, ground movement, stress redistribution and horizontal strain profiles caused by excavation and tunnelling, including groundwater drawdown and associated impacts, on adjacent surface and sub-surface structures. Criteria for surface and sub-surface structures at risk will be determined in consultation with the owner(s) of the structures. Where modelling predicts exceedances of these criteria, an instrumentation and monitoring program will be implemented to measure settlement, distortion or strain as required. Appropriate mitigation measures will be identified and implemented in consultation with the owner(s) prior to excavation and tunnelling works to where possible not exceed the settlement criteria.	Detailed design

Impact	ID	Measure	Timing
Surface water and flooding			
Impacts on surface water quality	SWF1	A program to monitor potential surface water quality impacts of the project will be developed and included in a Construction Soil and Water Management Plan (CSWMP). The program will include the water quality monitoring parameters (including pH, turbidity, dissolved oxygen, nitrogen and metals) and the monitoring locations (including Muddy Creek, Rockdale Bicentennial Park, North Scarborough Ponds and Cooks River) identified in Annexure G of Appendix L (Surface water technical report) Continuous surface water level and groundwater level monitoring will be undertaken within Bicentennial Park Pond and surrounding area for at least 12 months prior to the commencement of construction. Monthly groundwater quality would also be undertaken in the surrounding area. The data would be used as a baseline to monitor impacts on surface and groundwater levels and groundwater quality within the Pond during construction. The surface water monitoring program will continue for a minimum of three years following the completion of construction, or until the affected waterways are certified by a suitably qualified and experienced independent expert as being of an equal or better condition than pre construction conditions (or as otherwise required by any project conditions of approval).In the instance that during detailed design it cannot be demonstrated that treated construction wastewater would meet the discharge criteria for Scarborough Ponds, in particular nutrient concentrations, treated construction wastewater from C2 and C3 will be discharged to the Muddy Creek stormwater catchment.	Prior to construction Construction Operation
Impacts on water bodies	SWF2	All works within watercourses or on waterfront land will be managed in accordance with the Controlled Activities on Waterfront Land guidelines (DPI 2012). The following specific measures are required to manage impacts within Bicentennial Park Pond : • Installation of a temporary barrier to isolate the excavation works from the rest of the pond and prevent mobilisation of sediment and pollutants into adjacent areas. Water within the construction zone will be treated by the construction water treatment plant. Sediment mobilised during installation of the barrier will also be managed. • Retention of hydrologic connectivity through Bicentennial Park Pond throughout construction.	Construction
	SWF3	A Water Reuse Strategy for the construction and operational phases of the project will be developed prior to construction. This will outline the construction and operational water requirements and potential water sources to supply the water demand.	Prior to construction

Impact	ID	Measure	Timing
Impacts on flood behaviour	SWF4	A Flood Management Strategy (FMS) will be prepared prior to construction to demonstrate how flooding risks and behaviours will be mitigated during both the construction and operational phases. The FMS will include floor level survey for identified affected properties. The FMS would be prepared prior to commencement of construction by a suitably qualified and experienced person in consultation with directly affected landowners, Sydney Water, OEH, SES and relevant councils.	Prior to construction
Impacts on flood behaviour	SWF5	Entries to tunnel excavations, including cut and cover sections of tunnel will be protected against flooding, to an appropriate flood standard. The same hydrologic standard will be applied to tunnel ancillary facilities such as tunnel ventilation buildings, operational water treatment plants, emergency facilities and electrical substations. A minimum level of flood immunity of one exceedance per year would be provided to shared user paths within the project footprint.	Detailed design Construction
	SWF6	As a minimum, site facilities are to be located outside high flood hazard areas based on a one per cent AEP flood. For site facilities located within the floodplain, the FMS is to identify how risks to personal safety and damage to construction facilities and equipment will be managed.	Construction
Impacts on surface water quality	SWF7	Treatment measures would be implemented within the waterbodies of Scarborough Park North and Rockdale Bicentennial Park disturbed by the project during construction, to reduce algal bloom conditions and contribute to achieving the NSW Water Quality Objectives over time. Treatments would be considered in consultation with Bayside Council and shall include gross pollutant traps in drainage lines; inclusion of macrophyte zones and bank reshaping of the wetland zones; the use of solar powered devices to aerate the water column.	Detailed design
	SWF8	The findings of the pre and post construction water level monitoring and relevant water quality monitoring in Bicentennial Park Pond will be reviewed as part of an investigation by a suitably qualified and experienced independent expert to certify that the Pond has been restored to an equal or better level than pre construction conditions, in terms of its hydrology and water quality, including a review of how water quality within the downstream waters may have been affected by the restoration works.	Operation
	SWF9	The project will be designed to manage the potential impacts of future climate change on flooding behaviour in accordance with the procedures set out in *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC, 2007) and in *Australian Rainfall and Runoff* (GA 2016).	Detailed design
Non-Aboriginal heritage			
General	NAH1	A Construction Heritage Management Plan will be prepared for the project. The plan will detail measures to minimise impacts on identified heritage features within the project boundary and will also detail procedures to manage unexpected heritage finds.	Prior to construction

Impact	ID	Measure	Timing
	NAH2	Impacts to non-Aboriginal heritage items will, to the greatest extent practicable, be avoided and minimised. Where impacts are unavoidable, works will be undertaken in accordance with the relevant management strategy as defined for the non-Aboriginal heritage item.	Prior to construction Construction
Kings Wetland	NAH3	Consultation will be undertaken with Bayside Council regarding the impacts that would occur to the Kings Wetland (heritage item listed on the Rockdale LEP 2011). Roads and Maritime will provide a copy of the proposed landscape rehabilitation plan to Council to facilitate comment on the proposed impacts and mitigation measures.	Prior to construction
Patmore Swamp	NAH4	Notification and consultation will be undertaken with Bayside Council outlining the impacts that would occur to the Patmore Swamp (heritage items listed on the Rockdale LEP 2011).	Prior to construction
Kings Wetland	NAH5	A protection area will be established either side of the proposed haul road to reduce impacts within the boundaries of the heritage listing. The delineation of the protection area will be maintained throughout the construction period. As part of the detailed design phase, the haul road through the boundaries of the heritage listing will be further optimised with a view to reducing the requirement for the removal of vegetation, as far as is practical. At the conclusion of construction, parts of the area within the boundaries of the heritage listing will be rehabilitated.	Detailed design Construction
Patmore Swamp	NAH6	A protection area will be established as a no-go area during construction along either side of the proposed shared cycle and pedestrian pathways and along the new boundary of President Avenue and Patmore Swamp, to preserve as much of the existing vegetation as is practical within the boundaries of the heritage listing. The delineation of the protection area will be maintained throughout the construction period. A heritage interpretation strategy will be prepared to outline opportunities for heritage interpretation being integrated into the design of the shared cycle and pedestrian pathway through Patmore Swamp.	Construction
Bardwell Park Railway Station group	NAH7	The installation of the permanent power supply across the Bardwell Park Railway Station group overbridge would be undertaken to avoid permanent changes to the fabric and visual appearance of the bridge. Should this be unavoidable, further assessment will be undertaken during detailed design.	Prior to construction
Shop and residence	NAH8	Use of machinery should be limited within a seven metre distance to avoid cosmetic damage to existing structures. A visual inspection and assessment should be undertaken by a heritage specialist before works commence to ensure no additional mitigation measures are required.	Pre- Construction and Construction
Aboriginal cultural heritage			
Unexpected discovery of Aboriginal objects	AH1	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).	Construction

Impact	ID	Measure	Timing
Unexpected discovery of human remains	AH2	If human remains are discovered during construction, they would be managed in accordance with the *Standard Management Procedure: Unexpected Heritage Items* (Roads and Maritime Services, 2015).	Construction
Recognising the prior presence of Aboriginal people	AH3	The project would recognise the prior presence of Aboriginal people by highlighting resource zones they may have used. This could be undertaken through the implementation of interpretive signage and incorporated in to the Place making and Urban Design Strategy. Should this be pursued, it will be undertaken in consultation with the MLALC.	Construction
Waste management			
Waste generation and disposal	W1	A Construction Waste Management Plan will be prepared for the project prior to construction and will detail appropriate waste management procedures. The CWMP will: • Document expected waste types and volumes for the project • Describe procedures for managing office and project waste materials including separation, treatment and disposal in accordance with relevant guidelines • Detail waste reporting requirements including the implementation of a waste register • Detail the process for identifying waste re-use sites including approval requirements.	Prior to construction
	W2	A Spoil Management Plan will be prepared for the project. The plan will detail spoil management measures including spoil haulage routes and spoil disposal sites.	Prior to construction
Large volumes of spoil directed to landfill due to inadequate recycling and reuse	W3	The project will target the reuse or recycling of 95 percent of uncontaminated spoil generated for beneficial purposes in accordance with the project spoil management hierarchy.	Construction
Unexpected waste volumes and types during construction	W4	Suitable areas will be identified to allow for contingency management of unexpected waste materials, including contaminated materials. Suitable areas will be required to be hardstand or lined areas that are appropriately stabilised and bunded, with sufficient area for stockpile storage.	Construction

Impact	ID	Measure	Timing
Climate change			
Climate change adaptation	CC1	A review of the climate change risk assessment will be undertaken during detailed design, with adaptation actions implemented to address extreme and high risks. Adaptation measures for medium risks will be considered and implemented where reasonable and feasible.	Detailed design
	CC2	The increased potential for heat stress among construction personnel will be considered when refining construction Work Health and Safety Management Plans. Measures will be implemented to create greater awareness and education of personnel around health and wellbeing during periods of extreme heat.	Construction
	CC4	The projected increase in the intensity and frequency of extreme rainfall, which may lead to exacerbated risk of road incidents, will be considered during detailed design.	Detailed design
	CC5	Implementation of operational procedures will be considered for surface connections to increase safety during extreme rainfall events, including the potential use of variable speed signs and reduced speed limits.	Detailed design
	CC6	Emergency management planning will include consultation and collaboration with other key agencies to enable a coordinated response.	Detailed design
	CC7	Emergency management procedures will consider worst case scenarios with multiple events (e.g. evacuation of the tunnel required during a storm/ flash flood event).	Detailed design
	CC8	The upgrade of bus stop facilities on President Avenue in proximity to the tunnel portals to incorporate shading/ areas of respite for commuters will be considered during detailed design.	Detailed design
	CC9	Roads and Maritime will consider the possibility of using treated water, normally discharged to waterways to irrigate green space (if feasible) in proximity to the project to provide cooling, particularly during periods of extreme heat. This approach will depend on suitability and salinity of water and potential for reuse.	Detailed design
Greenhouse gas			
Generation of greenhouse gas emissions	GG1	Targets to reduce GHG emissions, including the use of green power and/or other renewable energy sources, will be included as part of the project's Sustainability Management Plan to assist in achieving 'Design' and 'As Built' ratings of Excellent under the Infrastructure Sustainability Council of Australia infrastructure rating tool.	Detailed design
	GG2	An updated GHG assessment based on detailed design will be undertaken for ongoing monitoring and review of emissions during construction.	Detailed design

Impact	ID	Measure	Timing
	GG3	Energy efficiency will be considered during the design of mechanical and electrical systems such as the tunnel ventilation system, tunnel lighting, water treatment systems and electronic toll and surveillance systems. Energy efficient systems will be installed where reasonable and practicable. The installation and use of solar power on operational infrastructure will be considered as part of detailed design, in order to improve the operational energy efficiency of the project.	Detailed design
	GG4	Opportunities to use low emission construction materials, such as recycled aggregates in road pavement and surfacing, and cement replacement materials will be investigated and incorporated where feasible and cost-effective.	Construction
	GG5	Construction site layouts will be designed to reduce travel distances and double handling of materials so as to reduce fuel usage and emission generation.	Construction
	GG6	Construction plant and equipment will be well maintained to allow for optimal fuel efficiency.	Construction
	GG7	Raw materials will be managed to reduce energy requirements for their processing. For example, stockpiled materials will be covered or provided undercover storage where possible to reduce moisture content of materials, and therefore the process and handling requirements.	Construction
	GG8	Locally produced goods and services will be procured where feasible and cost effective to reduce transport fuel emissions.	Construction

24.7 Compilation of performance outcomes

The project design has been prepared in consideration of the 'desired performance outcomes' provided in the SEARs. **Table 24-8** outlines how each performance outcome will be achieved by the project.

Table 24-8 Demonstration of how the project will achieve the desired performance outcomes

Desired performance outcomes	Project outcome
Environmental Impact Assessment Process The process for assessment of the proposal is transparent, balanced, well focussed and legal.	The EIS has been prepared in accordance with Part 3 of Schedule 2 of the EP&A Regulation. Based on the results of the environmental investigations carried out for this EIS, it is considered that matters of national environmental significance and the environment of Commonwealth land are not likely to be significantly impacted by the project. Accordingly Roads and Maritime has decided that a referral to the Commonwealth is required at this stage.
Environmental Impact Statement The project is described in sufficient detail to enable clear understanding that the project has been developed through an iterative process of impact identification and assessment and project refinement to avoid, minimise or offset impacts so that the project, on balance, has the least adverse environmental, social and economic impact, including its cumulative impacts.	• The project had been described in detail in Chapter 6 (Project description). • The merits of the project, staging options and concept design options were considered in the context of a range of alternatives based on how well they performed with reference to transport, environmental, engineering, social and economic factors (refer to Chapter 5 (Project alternatives and options)). The preferred design provides a combination of benefits compared with other options assessed, including improved access, minimised impacts on properties and on future development potential.
Assessment of Key Issues[2] Key issue impacts are assessed objectively and thoroughly to provide confidence that the project will be constructed and operated within acceptable levels of impact.	The assessment of key issues has been conducted objectively and thoroughly. The implementation of environmental management and mitigation measures would ensure the project is constructed and operated within acceptable levels of impact. Refer to Chapter 8 (Traffic and transport), Chapter 9 (Air quality), Chapter 11 (Noise and vibration) and Chapter 12 (Biodiversity).
Consultation The project is developed with meaningful and effective engagement during project design and delivery.	Consultation has been undertaken to inform the design process. The Construction Contractors will respond to complaints in a timely and appropriate manner so that stakeholders' concerns are managed effectively and promptly.
Transport and traffic Network connectivity, safety and efficiency of the transport system in the vicinity of the project are managed to minimise impacts. The safety of transport system customers is maintained. Impacts on network capacity and the level of service are effectively managed. Works are compatible with existing infrastructure and future transport corridors.	• The performance of the local traffic network would not be significantly impacted during construction • Access to properties will generally be maintained during construction • With the project, overall network productivity is improved, with longer or more trips able to take place in less time.

[2] Key issues are nominated by the Proponent in the SSI project application and by the Department in the SEARs. Key issues need to be reviewed throughout the preparation of the EIS to ensure any new key issues that emerge are captured. The key issues identified in this document are not exhaustive but are key issues common to most SSI projects.

Desired performance outcomes	Project outcome
Air quality The project is designed, constructed and operated in a manner that minimises air quality impacts (including nuisance dust and odour) to minimise risks to human health and the environment to the greatest extent practicable.	• Effective management of dust, odour and other emissions during construction • The tunnel ventilation design will maintain in-tunnel air quality in accordance with relevant criteria • Effective dispersion of emissions from the tunnels • There would be no marked redistribution of air quality impacts as a results of the project as a result of the ventilation facilities and changes to the surface road network • There would be no significant increase in concentration predicted at receptor locations which already had a relatively high concentration in the Do Minimum cases • Exceedances of some air quality criteria (e.g. annual $PM_{2.5}$) occurred both with and without the project due to existing high background concentrations however the total number of receptors with exceedances decreased slightly with the project and in the 2036 cumulative scenario.
Health and safety The project avoids or minimises any adverse health impacts arising from the project. The project avoids, to the greatest extent possible, risk to public safety.	• Effective management of dust, odour and other emissions during construction would avoid human health impacts • No person exposed to unacceptable levels of air pollution • No region identified as socially disadvantaged where the main air and noise impacts may occur. • Exposures to nitrogen dioxide within the tunnel would be below the health based criteria levels under all conditions and exposures would be further reduced in vehicle cabins with vehicle windows closed and ventilation is on recirculation. Even in congested conditions inside the tunnels, no significant adverse health impacts are expected to occur. • The motorway design achieves safe and efficient road user movements, and care will be taken to minimise incidents and crashes minimised during construction • Construction and operational noise management measures would ensure noise impacts are managed to comply with relevant criteria and therefore minimise the potential for health impacts • For both construction and operational aspects of the project no issues were identified that had the potential to result in significant safety risks to the community.
Noise and Vibration – Amenity Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on acoustic amenity. Increases in noise emissions and vibration affecting nearby properties and other sensitive receptors during operation of the project are effectively managed to protect the amenity and well-being of the community.	• Feasible and reasonable management measures would be implemented during construction and operation to ensure noise impacts would not result in a significant change to the existing noise environment.

Desired performance outcomes	Project outcome
Noise and Vibration – Structural Construction noise and vibration (including airborne noise, ground-borne noise and blasting) are effectively managed to minimise adverse impacts on the structural integrity of buildings and items including Aboriginal places and environmental heritage. Increases in noise emissions and vibration affecting environmental heritage as defined in the Heritage Act 1977 during operation of the project are effectively managed.	• Vibration intensive construction works would be managed to avoid or minimise adverse impacts on the structural integrity of buildings and heritage items • Vibration impacts from tunnelling has been assessed and determined to be compliant with the applicable guidelines
Biodiversity The project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity. Offsets and/or supplementary measures are assured which are equivalent to any remaining impacts of project construction and operation.	• Areas of Green and Golden Bell Frog habitat have the potential to be affected indirectly • 27 ecosystem credits would be required to offset the removal of two threatened flora communities • No species credits would be required by the project • Potential Grey-headed Flying-fox and Southern Myotis habitat would be directly affected by the project however no significant impacts are expected to either species as a result of the loss of habitat • Overall impacts to aquatic biodiversity would be relatively minor, considering existing conditions, scale and recovery potential • Compensatory tree planting will be completed following completion of construction.
Place making and urban design The project design complements the visual amenity, character and quality of the surrounding environment. The project contributes to the accessibility and connectivity of communities.	• A "net improvement in public recreation" policy whereby the project results in an overall improvement in terms of public recreation facilities will be investigated • Where active and passive open space is lost, either temporarily or permanently, alternative locations would be investigated with Bayside Council and key stakeholders • The majority of Rockdale Bicentennial Park would be reinstated following construction • Moderate adverse visual and landscape character impacts at and around Rockdale Bicentennial Park during construction • Minor impacts to visual amenity and landscape character due to operational surface infrastructure • Receptors are not expected to experience significant changes to their night-time visual and light environment during construction and operation.

Desired performance outcomes	Project outcome
Socio-economic, Land Use and Property The project minimises adverse social and economic impacts and capitalises on opportunities potentially available to affected communities. The project minimises impacts to property and business and achieves appropriate integration with adjoining land uses, including maintenance of appropriate access to properties and community facilities, and minimisation of displacement of existing land use activities, dwellings and infrastructure.	• Access to properties not acquired, leased or otherwise occupied for project purposes will generally be maintained at all times during construction and operation. Where this is not possible, consultation will be carried out with the landowner and/or tenant to provide equivalent standards of access • Social infrastructure affected by the project (e.g. Rockdale Bicentennial Park) would be temporarily located or reconfigured to allow continued use of these facility by the community during construction • The majority of amenity and community wellbeing, and access and connectivity impacts during construction would be temporary and short term • Appropriate access and visibility during business hours would be maintained during construction where possible • A "net improvement in public recreation" policy whereby the project results in an overall improvement in terms of public recreation facilities will be investigated • Construction of the project would have a positive impact on the local and Greater Sydney economy
Water – Hydrology Long term impacts on surface water and groundwater hydrology (including drawdown, flow rates and volumes) are minimised. The environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems including estuarine and marine water (if applicable) are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	• Potential impacts to surface water hydrology, geomorphology and water resources are considered to be confined to the construction footprint with the application of the proposed management measures • Treated construction wastewater will be discharged to highly disturbed, less sensitive, estuarine environments • The tunnels will be designed and constructed to minimise groundwater inflow • The project will aim to maximise reuse of treated water • Baseline and continuous surface water and groundwater level monitoring will be conducted prior to and during construction works.
Water – Quality The project is designed, constructed and operated to protect the NSW Water Quality Objectives where they are currently being achieved, and contribute towards achievement of the Water Quality Objectives over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable).	• Potential impacts to surface water quality during construction of the project are considered to be management with the application of the proposed management measures • Potential impacts to surface water quality during operation of the project are able to be mitigated by the proposed design and application of the proposed management measures
Flooding The project minimises adverse impacts on existing flooding characteristics. Construction and operation of the project avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, or dam failure.	• All construction sites have the potential to be impacted by flooding to some degree, however the Flood Management Strategy (FMS) would be prepared to manage the risk of adverse flood impacts being experienced by construction workers and infrastructure • Flooding criteria will be met during project detailed design • The performance of the downstream drainage network will be maintained during operation.

Desired performance outcomes	Project outcome
Soils The environmental values of land, including soils, subsoils and landforms, are protected. Risks arising from the disturbance and excavation of land and disposal of soil are minimised, including disturbance to acid sulfate soils and site contamination.	• Risks arising from the disturbance of soil and groundwater contaminated and acid sulfate soils would be able to be mitigated during construction and operation through further investigation and the implementation of the proposed management measures • Acid sulfate soils and other contamination will be managed in accordance with good practice measures to protect environmental values and humans health.
Heritage The design, construction and operation of the project facilitate, to the greatest extent possible, the long-term protection, conservation and management of the heritage significance of items of environmental heritage and Aboriginal objects and places. The design, construction and operation of the project avoid or minimises impacts, to the greatest extent possible, on the heritage significance of environmental heritage and Aboriginal objects and places.	• Impacts on heritage items will be minimised during construction and works will be undertaken in accordance with relevant management strategies for specific heritage items where impacts are unavoidable • Visual impacts to heritage items will be mitigated through individually tailored landscape treatments • Key heritage values and stories will be incorporated into the final urban design and landscaping outcomes.
Sustainability The project reduces the NSW Government's operating costs and ensures the effective and efficient use of resources. Conservation of natural resources is maximised.	• Opportunities will be taken to reduce material use and maximise the use of materials with low embodied environmental impact, where practical • Water and electricity efficiency measures will be implemented where possible.
Waste All wastes generated during the construction and operation of the project are effectively stored, handled, treated, reused, recycled and/or disposed of lawfully and in a manner that protects environmental values.	• Uncontaminated spoil will be recycled or reused either on-site or off-site • Off-site waste re-use will be managed in accordance with relevant NSW EPA resource recovery exemptions and requirements • Waste will be disposed of at appropriately licensed facilities.
Climate Change Risk The project is designed, constructed and operated to be resilient to the future impacts of climate change.	• The project would have little to no impact on climate change risks associated with increases in extreme rainfall and storm events, extreme heat events and interdependencies with power supply infrastructure. • The projects would have moderate vulnerability to extreme rainfall and storm events, however flooding impacts would be minimised and managed through the FMS and the raising of the President Avenue intersection. • Backup power and other redundancy measures have been built in, to ensure temporary continuity of powered infrastructure in the event of a power outage.

24.8 Project justification

There is currently no motorway link between the existing M1 Princes Motorway south of Waterfall and the Sydney motorway network. The project would form the first stage of an important link which would connect the A1 Princes Highway at Loftus with the New M5 Motorway, the M5 Motorway, the M4 Motorway and the proposed Western Harbour Tunnel and Beaches Link.

The project, as part of an integrated transport solution for Sydney, is expected to reduce traffic on parts of the Sydney road network. This investment in Sydney's road network would contribute to improvements across the network and generate benefits to the Australian economy.

Congestion across metropolitan Sydney is estimated to already cost up to $5 billion per annum, and will rise to $8 billion if nothing is done. Population growth will place further pressure on the NSW transport network and the key travel demand corridors connecting regional cities and major centres across the greater Sydney metropolitan area. Currently, users of the Princes Highway and The Grand Parade frequently experience congestion and delay, and travel times are unacceptably long during peak hours. Through traffic along the Princes Highway and The Grand Parade reduces the safety and amenity of the area.

The project, through a connection with the New M5 Motorway, would facilitate improved connections between southern Sydney, the Sydney CBD and Port Botany, as well as better connectivity between key employment hubs and local communities. An improved efficiency of the road network and forecast travel time savings would help promote economic development in southern Sydney, resulting in economic benefits for NSW. Together with future stages of the F6 Extension, it would also provide improved connections for residents and businesses between the Sydney CBD and the Illawarra Region.

The project would ease congestion on surface roads between Arncliffe and Kogarah by providing an underground motorway alternative. This would improve pedestrian safety and urban amenity, and would therefore support urban amenity improvements and place making opportunities for the Princes Highway (north of President Avenue) and The Grand Parade. Both corridors would maintain their capability as movement corridors for incident management purposes. The easing of congestion would also improve road safety and support the use of public transport such as buses and Rockdale and Kogarah train stations.

In addition, the project would provide a shared cycle and pedestrian pathway aimed at improving north-south accessibility and connectivity for active transport movements between Bestic Street and Civic Avenue.

The merits of the project were considered in the context of a range of strategic alternatives (refer to **Chapter 5** (Project development and alternatives)), based on the extent to which they could meet the project objectives. The development of the F6 Extension was chosen as the preferred option as it would ease congestion on surface roads, in areas with some of the slowest peak hour vehicle speeds in Sydney, improve local air quality and amenity as well as provide opportunities for place making. The project would form the first stage of the F6 Extension and would address the future transport infrastructure objectives and the strategic need identified in this environmental impact statement.

Design options for the project were also assessed on how well they performed with reference to transport, environmental, engineering, social and economic factors. The preferred design provides a combination of benefits compared with other options assessed, including improved access, minimised impacts on properties and on future development potential.

The environmental and social impacts of the project have been minimised by locating the majority of the project underground, with permanent surface infrastructure located within the existing F6 reserved corridor. A motorway tunnel option for the project avoids significant impacts to the high value of the ecological and recreational resources, and therefore the social and economic environment, within the existing F6 reserved corridor that would occur if a new surface road alternative had been adopted.

The use of the existing F6 reserved corridor for the full length of the project was also discounted due to the engineering challenge given the poor geotechnical conditions, the significant constraints on any northern end connection at the surface due to previous commercial and residential developments, and the poor project viability without an underground connection to the New M5 Motorway.

The construction and operation of the project would result in temporary and permanent impacts on the environment. These impacts would be minimised through the implementation of the mitigation and management measures which aim to ensure the best possible environmental outcomes are achieved during its construction and operation. There would be some potential residual impacts that would be further reviewed during detailed design development and construction planning and where necessary additional measures would be implemented to ensure these impacts are suitably mitigated.

The project is consistent with the project objectives, and is consistent with, or does not preclude, a number of strategic plans for transport (including *Future Transport Strategy 2056*[3] and *NSW Freight and Ports Strategy*[4]), development and freight that have been prepared at a national, State and regional level.

A consideration of the project against the objects of the EP&A Act is outlined in **Table 24-9**.

Table 24-9 Project justification with consideration of the objects of the Environmental Planning and Assessment Act 1979

Object of the Environmental Planning and Assessment Act 1979	Comment
a. To promote the social and economic welfare of the community and a better environment by the proper management, development and conservation of the State's natural and other resources	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, where such materials are cost and performance competitive • An energy efficiency and greenhouse gas management plan would be prepared as part of the project's Sustainability Management Plan. The plan would identify initiatives to be implemented during design and construction of the project to reduce carbon emissions, energy use and embodied life cycle impacts • Water efficiency measures would be implemented, with rainwater, stormwater, groundwater and tunnel inflow water would be reused, recycled or reclaimed where feasible during operation of the project • The project would seek to reuse or recycle uncontaminated spoil generated where possible, either within the project or at other locations. Construction and demolition waste would be reused and/or recycled as part of the project where possible. The improved efficiency of the road network and the predicted travel time savings would result in a reduction in fuel use in the future. Additionally, the project would result in a long-term reduction in greenhouse gas emissions due to the smoother traffic flow. A reduction in emissions contributes to improved sustainability, including minimising the use of resources and supporting inter-generational equity and climate change outcomes. Where reasonable and feasible, the project has been designed to avoid impacts on the natural and built environment and to minimise the need for land acquisition. The project would provide improved traffic conditions, safety and efficiency on parts of the surface road network, and would result in improvements to local amenity.

[3] NSW Government (2017) *Draft Future Transport Strategy 2056*
[4] Transport for NSW (2013b) *NSW Freight and Ports Strategy*.

Object of the Environmental Planning and Assessment Act 1979	Comment
b. To facilitate ecologically sustainable development by integrating relevant economic, environmental and social considerations in decision-making about environmental planning and assessment	The project is consistent with the four principles of ecologically sustainable development: • Precautionary principle: This EIS was prepared adopting a conservative approach, which includes an assessment of the worst case impacts and scenarios • Inter-generational equity: The project may impact on inter-generational equity through the consumption of fuel resources and contributing to the decline of available fuel resources. However, the project would also result in improved vehicle fuel efficiency • Conservation of biological diversity and ecological integrity: The design and assessment of the project has been undertaken with the aim of identifying, avoiding, minimising and mitigating impacts to biodiversity and ecological integrity. Consistent with the *Biodiversity Conservation Act 2016* and the SEARs, a biodiversity offset strategy has been developed to compensate for the unavoidable loss of ecological values as a result of the project. • Improved valuation and pricing and incentive mechanisms: The value placed on avoiding and minimising environmental impacts is demonstrated in the design features incorporated into the project (for example locating the project primarily underground. The cost of mitigation measures have been incorporated into the project cost, as well as the extent of investigations undertaken to inform this EIS.
c. To promote the orderly and economic use and development of land	• Improved efficiency of the road network results in economic benefits for NSW • The project has been designed to minimise impacts to the surrounding natural and built environments, and to minimise disruption to existing development patterns. • Provision of an underground motorway alternative is an orderly and economic approach to support urban amenity improvements.
d. To promote the delivery and maintenance of affordable housing	Not applicable to this project.
e. To protect the environment, including the conservation of threatened and other species of native animals and plants, ecological communities and their habitats	Where impacts to native vegetation or planted vegetation are unavoidable, mitigation measures have been proposed to minimise the potential for indirect impacts. Some threatened flora species would be impacted by the project. Consistent with the *Biodiversity Conservation Act 2016* and the SEARs, a biodiversity offset strategy has been developed to compensate for the unavoidable loss of ecological values as a result of the project.
f. To promote the sustainable management of built and cultural heritage (including Aboriginal cultural heritage)	• Impacts on heritage items will be minimised during construction and works will be undertaken in accordance with relevant management strategies for specific heritage items where impacts are unavoidable • Visual impacts to heritage items will be mitigated through individually tailored landscape treatments • Key heritage values and stories will be incorporated into the final urban design and landscaping outcomes.
g. To promote good design and amenity of the built environment	• The project has been designed to minimise impacts to community facilities and open space • The project would provide an additional shared cycle and pedestrian pathway and overpass • Opportunities for a net improvement in recreational and sporting facilities • An Urban Design and Landscaping Plan would be prepared and implemented
h. To promote the proper construction and maintenance of buildings, including the protection of the health and safety of their occupants	The construction of motorway operational infrastructure including the ventilation facility, Motorway Control Centre, water treatment plant and other ancillary infrastructure would be completed in line with the applicable Australian and international safety standards, as well as any Roads and Maritime Safety in Design guidelines.

Object of the Environmental Planning and Assessment Act 1979	Comment
i. To promote the sharing of the responsibility for environmental planning and assessment between the 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 through historical and continuing consultation activities.
j. To provide increased opportunity for community participation in environmental planning and assessment	Community consultation has been carried out through all stages of the project development, with targeted consultation commencing in July 2018. Community feedback has been considered at each stage of the project development to inform the selection of the preferred corridor alignment and subsequent design development and refinements. Community consultation would continue through the detailed design, construction and operational stages, should the project be approved.

25 References

Acid Sulfate Soils Management Advisory Committee (1998) Acid Sulfate Soils Assessment Guidelines

Advisory Committee on Tunnel Air Quality (2014) Technical Paper 04: Road Tunnel Ventilation Systems NSW Government

AECOM (2014) NorthConnex – Environmental Impact Statement – Submissions and Preferred Infrastructure Report. ISBN 978-1-925093-99-5

AECOM (2015) New M5 Environmental Impact Statement

AECOM (2015) Technical Working Paper: Contamination New M5 Environmental Impact Statement Volume 2F, Appendix O, 18 November 2015

AECOM (2015) Westconnex Stage 2: M5 Factual Contamination Assessment

Albani, A.D., Rickwood, P.C.,Quilty, P.G. and Tayton J.W.; (2015) he morphology and late Quaternary paleogeomorphology of the continental shelf off Sydney NSW Australian Journal of Earth Sciences, 62 681-694, 2015.

Attenbrow, V (2010) Sydney's Aboriginal Past: Investigating the Archaeological and Historical Records. Sydney: University of New South Wales Press.

Australia state of the environment (2011) Independent report by the State of the Environment 2011 Committee to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities. Canberra: DSEWPC, 2011

Australian and New Zealand Environment and Conservation Council (1990) Technical Basis for Guidelines to Minimise Annoyance Due to Blasting Overpressure and Ground Vibration

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2000) National Water Quality Management Strategy, Paper No. 4, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Volume 1, The Guidelines

Australian Bureau of Statistics (2016) Australian Statistics Business Indicators

Australian Bureau of Statistics (2016) census

Australian Bureau of Statistics (2016) Percentages exclude 'number of motor vehicles not stated'. As a result totals do not add to 100 per cent.

Australian Bureau of Statistics (2018) IRSD http://stat.data.abs.gov.au/Index.aspx?DataSetCode=ABS_SEIFA_LGA

Australian Bureau of Statistics (2016) Census Data 2016

Australian Bureau of Transport Statistics (2016) Travel to work data

Australian Government Department of Infrastructure and Transport ((2013) Walking, Riding and Access to Public Transport: Supporting Active Travel in Australian Communities

Australian Government Department of the Environment (1992) National Strategy for Ecologically Sustainable Development

Australian Government Department of the Environment and Energy (2017) 2017 Review of Climate Change Policies

Australian Government Department of the Environment and Energy (2018) Quarterly Update of Australia's National Greenhouse Gas Inventory: September 2017

Australian Government Department of the Environment and Energy (2018) State and Territory Greenhouse Gas Inventories 2016

Australian Radiation Protection and Nuclear Safety Agency (2006) Draft Radiation Standard – Exposure Limits for Magnetic Fields

Australian Standard (2010) Piling – Design and Installation. Australian Standard. Standard AS 2159-2009 Third Edition, including Amendment No 1

Austroads (2015) Guide to Road Tunnels

Austroads (2016) Guide to Road Design

Barnett B, Townley LR, Post V, Evans RE, Hunt RJ, Peeters L, Richardson S, Werner AD, Knapton A and Boronkay A (2012) Australian Groundwater Modelling Guidelines, Waterlines Report Series No 82, National Water Commission, Canberra, 191 pp. June

Barrington, G (1802) The History of New South Wales, including Botany Bay, Port Jackson, Parramatta, Sydney and all its Dependents

Bayside Council (2011) Rockdale Development Control Plan 2011

Bayside Council (2011) Rockdale Local Environmental Plan 2011

Bayside Council (2017) DA-2017/179 http://rccweb.rockdale.nsw.gov.au/EPlanning/Pages/XC.Track/SearchApplication.aspx?id=285529

Bayside Council (2018) Bird monitoring data for Landing Lights wetland April 2016 – July 2017. Available at https://www.rockdale.nsw.gov.au/Pages/pdf/LLWBM-AprJul.pdf

Biosphere Environmental Consulting (2000 - 2017) Biosphere Environmental Consultants 2000-2017. Various monitoring reports on Green and Golden Bell Frog at Arncliffe. Reports to NSW Roads and Maritime Services

British Standard (BS) 7385:Part 2-1993 (1993) Evaluation and Measurement for Vibration in Buildings Part 2

Brundtland Commission (1987) Our Common Future

Bureau of Infrastructure, Transport and Regional Economics (2010) Long-term Projections of Australian Transport Emissions: Base Case 2010. Bureau of Infrastructure, Transport and Regional Economics, Canberra.

Bureau of Meteorology (2018) National Atlas of Groundwater Dependent Ecosystems, accessed January 2018 (http://www.bom.gov.au/water/groundwater/gde/)

Bureau of Transport Statistics (2015) Household Travel Survey Highlights 2014/2015.

Bureau of Transport Statistics (2015) Household Travel Survey Highlights 2014/2015

C. Jeremy Hung, PE, James Monsees, PhD, PE, Nasri Munfah, PE, and John Wisniewski, PE (2009) Technical Manual for Design and Construction of Road Tunnels – Civil Elements

California Office of Environmental Health Hazard Assessment (2013) Individual Acute, 8-hour, and Chronic Reference Exposure Level Summaries

Canadian Council of Ministers of the Environment, Quebec (2010) Canadian Soil Quality Guidelines, Carcinogenic and Other Polycyclic Aromatic Hydrocarbons (PAHs) (Environmental and Human Health Effects), Scientific Criteria Document (revised)

CASA (1999) Lighting in the vicinity of aerodromes: Advice to lighting designer

CDM Smith (2016) WestConnex Stage 2. New M5 Groundwater Modelling Report

Chapman, G.A. and Murphy, C.L (1989) Soil Landscapes of the Sydney 1:100,000 sheet 9130. Soil Conservation Service of NSW, Sydney

Climate Change Authority; Maddocks et al. (2014) Maddocks et al.

Collins, D (1802) An Account of the English Colony in New South Wales. Vol. 2.

Collins, D. (1798) An Account of the English Colony in New South Wales. Vol. 1. (B. H. Fletcher, Ed.). London: T. Cadell Jun. & W. Davie

Committee on the Medical Effects of Air Pollutants. (2015) Statement on the Evidence for the Effects of Notrogen Dioxide on Health

Commonwealth Department of Environment and Energy (2017) EPBC Act Protected Matters Search Tool

Commonwealth of Australia (2010) Survey guidelines for Australia's threatened frogs

Commonwealth of Australia (2013) Matter of National Environmental Significance Significant Impact Guidelines

CSIRO & BoM (2015) Climate Change in Australia

DEH (2003) Technical Report No. 1: Toxic Emissions from Diesel Vehicles in Australia, Environment Australia.

Department of Environment and Climate Change (2009) Interim Construction Noise Guideline

Department of Environment and Conservation (2007) Guidelines for the Assessment and Management of Groundwater Contamination

Department of Environment, Climate Change and Water (2010) Code of Practice for Archaeological Investigation of Aboriginal Objects in New South Wales

Department of Environment, Climate Change and Water (2011) Road Noise Policy

Department of Environment, Climate Change and Water (2017) Directory of Important Wetlands Australia

Department of Land and Water Conservation (1989) Guidelines for the Use of Acid Sulfate Soils Risk Maps

Department of Land and Water Conservation (2002) Site investigations for urban salinity

Department of Land and Water Conservation (2002) Site Investigations for Urban Salinity

Department of Planning (2008) Acid Sulfate Soils Assessment Guideline

Department of Planning and Environment (2018) Bayside West Precincts 2036

Department of Primary Industries (2013) Salinity hazard report for Catchment Action Plan upgrade - Hawkesbury-Nepean CMA

Department of Primary Industries (2013) Sydney Hazard for Catchment Action Plan Update

Deutsches Institut für Normung (1999) DIN 4150:Part 2-1999 Structural vibration – Effects of vibration on structures

Deutsches Institut für Normung (1999) DIN 4150:Part 3-1999 Structural vibration – Effects of vibration on structures

DIRD (2012) National Airports Safeguarding Framework Guideline E: Manageing the Risk of Distractions to Pilots from Lighting in the Vicinity of Airports

Earth Tech (2007) Sydney Metropolitan Catchment Management Authority Waterways Health Strategy

Eco Logical Australia (2015) WestConnex New M5 EIS – Biodiversity Assessment Report

enHealth (2012) Environmental Health Risk Assessment, Guidelines for assessing human health risks from environmental hazards Commonwealth of Australia, Canberra

Environment Protection and Heritage Council. (2013) Expansion of the multi-city mortality and morbidity study, Final Report

Equatica (2011) Bicentennial Park Wetland Concept Report, prepared for Rockdale City Council

European Topic Centre on Air Pollution and Climate Change Mitigation (2013) Assessment of population exposure to air pollution during commuting in European cities, ETC/ACM Technical Paper 2013/2

Fairfull and Witheridge (2003) Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings

Fairfull, S. (2013) Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management (2013 update). NSW Department of Primary Industries

Flynn, M (1995) Place of Eels: Parramatta and the Aboriginal Clans of the Sydney Region: 1788-1845

Golder (2013) Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PMN10, O3, NO2, SO2, Golder Associates for National Environment Protection Council Service Corporation.

Golder (2016) Westconnex New M5 Phase 2 Environmental Site Assessment – Kogarah Golf Course, Marsh Street, Arncliffe, NSW

Golder (2017) Design Package Report Groundwater Monitoring Progress Report (Project-wide), July 2017 M5N-GOL-TER-100-200-GT-1516-C

Golder Associates (2017) Design Package Report. Hydrogeological Design Report. (FD). The New M5 Design and Construct. Report No M5N-GOL-DRT-100-200-GT-1525-R,

Government Architect New South Wales http://www.governmentarchitect.nsw.gov.au/thinking/integrated-design-policy/introducing-better-placed

Government Architect New South Wales www.governmentarchitect.nsw.gov.au/articles/2017/06/sydney-green-grid

Greater Sydney Commission (2018) Eastern City District Plan

Greater Sydney Commission (2018) Greater Sydney Region Plan

Greater Sydney Commission (2018) South District Plan

Handy, S (2002) Amenity and Severance

Hansson et al. 2011; Lindström 2008; Wen & Rissel 2008 (2011)

Hansson, E, Mattisson, K, Björk, J, Östergren, P-O & Jakobsson, K (2011) Relationship between commuting and health outcomes in a cross-sectional population survey in southern Sweden' BMC Public Health, vol. 11, no. 1, p. 834.

Healthy Spaces and Places (2009) Design Principles: Parks and Open Space https://www.healthyplaces.org.au/site/parks_and_open_space_full_text.php

Horton, D. R. (1996) Aboriginal Australia. Canberra, ACT: Aboriginal Studies Press

Infrastructure Australia (2015) Australian Infrastructure Audit

Infrastructure NSW (2012) First things first - The State Infrastructure Strategy 2012 – 2032

Infrastructure NSW (2014) NSW Infrastructure Strategy Update 2014

Infrastructure NSW (2018) Final Business Casew Summary: F6 Extension - Stage 1

Infrastructure Sustainability Council of Australia (ISCA) (2012) What is infrastructure sustainability?

Institute of Air Quality Management (2014) Guidance on the assessment of dust from demolition and construction. Institute of Air Quality Management, London. http://iaqm.co.uk/text/guidance/construction-dust-2014.pdf

Institute of Australian Consulting Arboriculturalists (2010) IACA Significance of a Tree, Assessment Rating System (STARS)

Intergovernmental Panel on Climate Change (2013) Fifth Assessment Report

Jalaludin, B, Khalaj, B, Sheppeard, V & Morgan, G (2008) 'Air pollution and ED visits for asthma in Australian children: a case-crossover analysis

Knibbs, de Dear & Morawska (2010) Effect of cabin ventilation rate on ultrafine particle exposure inside automobiles', Environmental science & Technology, vol. 44, no. 9, May 1. Pp. 3546-3551

Kohen, J. (1993) Darug and their Neighbours: The Traditional Aboriginal Owners of the Sydney Region. Sydney: Darug Link in association with Blacktown and District Historical Society.

Landcom (2004) Managing Urban Stormwater: Soils and Construction Volume 1

Lindbergh, J (2009) AMBS celebrates National Archaeology Week - Australian Museum. Retrieved October 15, 2012, from http://australianmuseum.net.au/BlogPost/Science-Bytes/AMBS-celebrates-National-Archaeology-Week

Longley (2014) TP11: Criteria for in-Tunnel and Ambient Air Quality NSW Advisory Committee on Tunnel Air Quality

Lotsearch (2017) Environmental Risk and Planning Report, Stage 1 F6 Extension (Section 1 to Section 5)

Lyall and Associates (2017) Southlink Motorway Flooding and Drainage Investigation, Volume 1 – Report

Manly Hydraulics Laboratory (2006) Survey of Tidal Limits and Mangrove Limits in NSW Estuaries 1996 to 2005

Mirza S. (2006) Durability and sustainability of infrastructure — a state-of-the-art report. Canadian Journal of Civil Engineering, 33(6): 639–649

Mokonyama, M. (2012) The social impact of introducing a tolling scheme on a pre-existing urban network', Association of European Transport and Contributors

Morgan, G, Broom, R & Jalaludin (2013) Summary for Policy Makers of the Health Risk Assessment on Air Pollution in Australia Prepared for National Environment Protection Council by the University Centre for Rural Health, North Coast, Education Research Workforce, A collaboration between The University of Sydney, Southern Cross University, The University of Western Sydney, The University of Wollongong, Canberra.

National Environment Protection Council (1999) National Environmental Protection Measure (Assessment of site Contamination) (ASC NEPM), May 2013

National Environment Protection Council (1999) National Environment Protection (Assessment of Site Contamination) Measure (ASC NEPM) 2013

National Environment Protection Council (1999) Schedule B1, Guideline on Investigation Levels For Soil and Groundwater, National Environment Protection (Assessment of Site Contamination) Measure

National Environment Protection Council (2000) Review of the National Environment Protection (Ambient Air Quality) Measure, Discussion Paper, Air Quality Standards,

National Environment Protection Council (2003) National Environment Protection (Ambient Air Quality) Measure,

National Environment Protection Council (2014) Draft Variation to the National Environment, protection (Ambient Air Quality) Measure, Impact Statement

National Environment Protection Council. (1998) National Environment Protection (Ambient Air Quality) Measure - Revised Impact Statement

National Environmental Protection Council (2003) National Environment Protection (Ambient Air Quality) Measur

National Environmental Protection Council (2010) Review of the National Environment Protection (Ambient Air Quality) Measure,

National Health and Medical Research Council (1989) Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields

National Health and Medical Research Council (2015) Australian Drinking Water Guidelines

National Health and medical Research Council (2008) Air Quality in and Around Traffic Tunnels, Systematic Literature Review

National Transport Commission (2015) Australian Dangerous Goods Code

Navin Officer Heritage Consultants. (2003) Cultural Heritage Assessment of the Proposed Port Botany Expansion.

NSW Department of Environment and Climate Change (2008) Managing Urban Stormwater: Soils and Construction Volume 2

NSW Department of Environment and Climate Change (2009) Interim Construction Noise Guideline

NSW Department of Environment and Conservation (2006) Assessing Vibration: a technical guideline

NSW Department of Environment, Climarte Change and Water (2011) NSW Road Noise Policy

NSW Department of Environment, Climarte Change and Water (2011) NSW Road Noise Policy

NSW Department of Planning (2011) Hazardous and Offensive Development Application Guidelines: Applying SEPP 3

NSW Department of Planning and Environment (2018) Bayside West Precincts (Arncliffe, Banksia and Cooks Cove) Draft Land Use and Infrastructure Strategy

NSW Department of Planning and Environment (2016) 2016 New South Wales State and Local Government Area Population Projections, 2011 – 2036

NSW Department of Planning and Environment (2016) Bayside West Precincts (Arncliffe, Banksia and Cooks Cove) Draft Land Use and Infrastructure Strategy

NSW Department of Planning and Environment (2016) Bayside West Precincts (Arncliffe, Banksia and Cooks Cove) Draft Land Use and Infrastructure Strategy. Department of Planning and Environment, Sydney.

NSW Department of Primary Industries (2013) Policy and Guidelines for Fish Habitat Conservation and Management (update 2013)

NSW Department of Urban Affairs and Planning and NSW EPA (1998) Managing Land Contamination, Planning Guidelines SEPP 55-Remediation of Land

NSW EPA (2000) Application notes – NSW industrial noise policy

NSW EPA (2012) Air Emissions Inventory for the Greater Metropolitan Region in New South Wales – 2008 Calendar Year. Technical Report No. 1 – Consolidated Natural and Human-Made Emissions: Results. NSW Environment Protection Authority, Sydney South

NSW EPA (2012) Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases

NSW EPA (2014) NSW Waste Avoidance and Resource Recovery Strategy 2014-21

NSW EPA (2014) Waste Classification Guidelines: Part 1 Classifying Waste

NSW EPA (2015) Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997

NSW EPA (2016) Approved Methods for the Modelling and Assessment of Air Pollutants in NSW.

NSW EPA (2016) Approved Methods for the Modelling and Assessment of Air Pollutants in NSW. NSW Environment Protection Authority, Sydney. http://www.epa.nsw.gov.au/resources/epa/approved-methods-for-modelling-and-assessment-of-air-pollutants-in-NSW-160666.pdf

NSW EPA (2016) Environmental Guidelines: Solid Waste Landfills (Second Edition)

NSW EPA (2017) Guidelines for the NSW Site Auditor Scheme (Third Edition)

NSW EPA (2017) Noise Policy for Industry

NSW EPA (2012) Air Emissions Inventory for the Greater Metropolitan Regional in New South Wales, 2008 Calendar Year, On-Road Mobile Emissions: Results

NSW Government (2014) A Plan for Growing Sydney

NSW Government (2014) NSW Government Resource Efficiency Policy

NSW Government (2016) New South Wales 2016 State and Local Government Area Population Projections

NSW Government (2017) Toll Relief – free rego for drivers. https://www.nsw.gov.au/your-government/the-premier/media-releases-from-the-premier/toll-relief-free-rego-for-drivers/

NSW Government (2018) Bayside Council https://www.strongercouncils.nsw.gov.au/new-councils/bayside-council/

NSW Government (2018) Georges River Council https://www.strongercouncils.nsw.gov.au/new-councils/georges-river-council/

NSW Government (2014) A Plan for Growing Sydney

NSW Government (2014) A Plan for Growing Sydney, NSW Government, Sydney

NSW Government (2014) Land Acquisition Information Guide

NSW Government (2016) Review of the NSW Land Acquisition (Just Terms) Compensation Act 1991

NSW Government (2016) Review of the NSW Land Acquisition (Just Terms) Compensation Act 1991

NSW Government (2017) Draft Future Transport Strategy 2056

NSW Government (2017) Draft Future Transport Strategy 2056

NSW Government (2017) draft Future Transport Strategy 2056

NSW Government (2018) Future Transport Strategy 2056

NSW Government Advisory Committee on Tunnel Air Quality (2016) In-tunnel air quality (nitrogen dioxide) policy. Advisory Committee on Tunnel Air Quality. NSW Government, Sydney, February 2016. http://www.chiefscientist.nsw.gov.au/__data/assets/pdf_file/0004/81778/In-Tunnel-Air-Quality-Policy-FINAL.pdf

NSW Government Architect (2017) Better Placed, A design led approach: developing an Architecture and Design Policy for New South Wales

NSW Government Architect (2017) Sydney Green Grid, Spatial framework and project opportunities

NSW Government Transport (2011) Metropolitan Road Freight Hierarchy on the State Road Network Practice Note

NSW Health (2003) M5 East Tunnels Air Quality Monitoring Project, South Eastern Sydney Public Health Unit & NSW Department of Health

NSW Health (2004) Comparison of personal exposures to air pollutants by commuting mode in Sydney, BTEX & NO2, NSW Department of Health, Sydney

NSW Health, 2004, Comparison of personal exposures to air pollutants by commuting mode in Sydney, BTEX & NO2, NSW Department of Health, Sydney

NSW Office of Environment & Heritage (2017) NSW State Heritage Register. Retrieved from http://www.environment.nsw.gov.au/heritage/listings/stateheritageregister.htm

NSW Office of Environment and Heritage (2011) Guidelines for Consultants Reporting on Contaminated Sites

NSW Office of Environment and Heritage (2014) NSW Government Resource Efficiency Policy

NSW Office of Environment and Heritage (2016) A Draft Plan to Save NSW Energy and Money

NSW Office of Environment and Heritage (2016) NSW Climate Change Policy Framework

NSW Office of Environment and Heritage (2015) New South Wales Air Quality Statement 2014. NSW and Office of Environment and Heritage, Sydney, January 2015

NSW Office of Environment and Heritage (2016) Sydney Metropolitan Catchment Management Authority Vegetation Mapping v 3.0

NSW Office of Environment and Heritage (2017) Biodiversity Offsets Scheme

NSW Office of Environment and Heritage (2017) Visual information system online Vegetation Classification database

NSW Roads and Maritime Services (2013) Environmental Impact Assessment Practice Note – Social and economic assessment (EIA-N05).

NSW Roads and Maritime Services (2011) Procedure for Aboriginal Cultural Heritage Consultation and Investigation

Pacific Environment (2015) Westconnex New M5 Plume Rise Assessment

PEL (2016) Road tunnels: reductions in nitrogen dioxide concentrations in-cabin using vehicle ventilation systems, Prepared by Pacific Environment Limited for NSW Roads and Maritime Services

Permanent International Association of Road Congresses (2012) Road tunnels: vehicle emissions and air demand for ventilation. World Road Association, Paris. Report 2012R05, December 2012

Roads and Maritime Services (2016) Roads and Maritime Environmental Sustainability Strategy 2015–2019

Roads and Maritime Services (2001) Environmental Noise Management Manual

Roads and Maritime Services (2005) Guidelines for the Management of Acid Sulfate Materials

Roads and Maritime Services (2008) Roads and Maritime Services Erosion and Sediment Management Procedure

Roads and Maritime Services (2011) Procedure for Preparing an Operational Noise and Vibration Assessment

Roads and Maritime Services (2014) Beyond the Pavement: Urban Design Procedures and Design Principles

Roads and Maritime Services (2015) Application Notes – Noise Criteria Guideline

Roads and Maritime Services (2015) Noise Criteria Guideline

Roads and Maritime Services (2015) Noise Mitigation Guideline

Roads and Maritime Services (2016) Construction Noise and Vibration Guideline

Roads and Maritime Services (2016) Noise Model Validation Guideline

Roads and Maritime Services (2016) Roads and Maritime Environmental Sustainability Strategy 2015–2019

Roads and Maritime Services (2016) Technical Guide – Management of road construction and maintenance wastes (NSW Roads and Maritime Services

Roads and Maritime Services (2016) Traffic Volume Viewer

Roads and Maritime Services (2017) Tunnel urban design guidelines

Roads and Maritime Services (2018) RMS Guidance note EIA-N04 Guidelines for Landscape Character and Visual Impact Assessment

Roads and Maritime Services (previosuly RTA) (2011) Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects.

Roads and Traffic Authority (2011) Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects

RPS (2018) F6 Extension. Groundwater Model report. RPS Group Australia. Report Number HS2017/01. Prepared for AECOM

Russell G. (2007) Hawkesbury Sandstone Groundwater Attributes and Geological Influences. UTS/UNSW 20th Anniversary Hydrogeology Symposium 20 July 2007, University of Technology, Sydney

Safe Work NSW (2004) Moving Plant on Construction Sites: Code of Practice

SMEC (2017) F6 Extension – EIS Section A Phase 1: Groundwater Monitoring Boreholes Geotechnical Factual Report Prepared for Roads and Maritime Services – Contract No. 14.2166.0517-0047, Reference No. 30012460-053-Rev0, 2017, 8 January

SMEC (2017) F6 Northern Geotechnical Investigations – Geotechnical Factual Report – Contract No. 14.2166.0517.0047, 23 February

SMEC (2017) F6 Northern SEA Geotechnical Investigations Final Geotechnical Factual Report Prepared for Roads and Maritime Services – Contract No. 14.2166.0517-0047, Reference No. 30012460, 13 September

SMEC (2018) F6 Extension Stage 1 Geotechnical Investigations

SMEC (2018) F6 Extension Stage 1 Geotechnical Investigations Draft Geotechnical Factual Report – Contract 17.000302526.1197, Reference No. 30012161-023-RevA-Draft GFR, 23 February

State Library of NSW (2006) EORA: Mapping Aboriginal Sydney 1770-1850. (K. V. Smith & T. Willsteed, Eds.). Sydney: State Library of New South Wales.

State Transit (2017) Bus routes around the President Avenue intersection site operated by State Transit

Stone et al (1998) Acid Sulfate Soil Manual

Sydney Airport Corporation Limited (2009) Sydney Airport Environment Strategy 2010-2015.

Sydney Metro (2016) Sydney Metro Chatswood to Sydenham EIS

Sydney Metropolitan Catchment Management Authority (2011) Botany Bay & Catchment Water Quality Improvement Plan

Sydney Metropolitan Catchment Management Authority (2018) v.1, February 2018

Texas Commission on Environmental Quality (2007) 1,3-Butadiene

Texas Commission on Environmental Quality (2013) ,3-Butadiene, Development Support Document

Texas Commission on Environmental Quality (2013) Development Support Document, Formaldehyde

Texas Commission on Environmental Quality (2013) Development Support Document, Toluene

Texas Commission on Environmental Quality (2013) Development Support Document, Xylenes

Texas Commission on Environmental Quality (2014) Formaldehyde, 24-hours Ambient Air Monitoring Comparison Value, Development Support Document

Threlkeld, L. E (1927) Specimens of a Dialect of the Aborigines of New South Wales; Being the First Attempt to Form Their Speech Into a Written Language. Sydney: Monitor Office.

Transport Authorities Greenhouse Group (2013) Greenhouse Gas Assessment Workbook for Road Projects

Transport for NSW (2013) NSW Freight and Ports Strategy

Transport for NSW (2013) NSW Freight and Ports Strategy.

Transport for NSW (2017) NSW Sustainable Design Guidelines Version 4.0

Transport for NSW (n.d) Household Travel Survey: Sydney 2015/16 data, accessed via Statistical Area Level 3 (SA3) Viz & Sydney SMA Regions Viz TfNSW, Sydney, Australia

Transport for NSW (2012) NSW Long Term Transport Master Plan TfNSW, Sydney, Australia

Transport for NSW (2013) NSW Freight and Ports Strategy

Transport for NSW (2013) Sydney's Bus Future: Simpler, faster, better bus services

Transport for NSW (2017) Freight https://www.transport.nsw.gov.au/industry/freight

Trasndev (2016) Bus routes around the President Avenue intersection site operated by Transdev

U.S. Environmental Protection Agency, Washington (2005) Toxicological Review of Toluene (CAS No. 108-88-3), In Support of Summary Information on the Integrated Risk Information System (IRIS), U.S

U.S. Environmental Protection Agency, Washington. (1998) Toxicological Review of Naphthalene (CAS No. 91-20-3), In Support of Summary Information on the Integrated Risk Information System (IRIS)

U.S. Environmental Protection Agency. (2015) Integrated Science Assessment for Oxides of Nitrogen–Health Criteria, Second External Review Draft

United States Environmental Protection Agency, Washington, D.C. (2009) Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, (Part F, Supplemental Guidance for Inhalation Risk Assessment)

United States Environmental Protection Agency. (2002) Health Assessment Document For Diesel Engine Exhaust

United States Environmental Protection Agency. (2011) Most recent review of the Primary National Ambient Air Quality Standards for Carbon Monoxide

US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. (2007) Toxicological Profile for Xylene

Walker and Kass (1991) A.0. Map 5123

WestConnex Delivery Authority (2015) WestConnex M4 East EIS

WHO Regional Office for Europe (2010) WHO Guidelines for Indoor Air Quality, Selected Pollutants

WHO Regional Office for Europe (2013) Health Effects of Particulate Matter, Policy implications for countries in eastern Europe, Caucasus and central Asia,

WHO Regional Office for Europe. (2010) WHO Guidelines for Indoor Air Quality, Selected Pollutants

WHO Regional Publications, European Series (2000) Transport, environment and health

Work Cover NSW (2005) Storage and Handling of Dangerous Goods

World Health Organisation (2000) WHO air quality guidelines for Europe, 2nd edition, 2000 (CD ROM version),

World Health Organisation, Geneva (2000) Guidelines for Air Quality

World Heath Organisation (2000) Transport, environment and health WHO Regional Publications, European Series, No. 89.

World Heath Organisation (2010) WHO Guidelines for Indoor Air Quality, Selected Pollutants, WHO Regional Office for Europe

Wright, R. (1997) Report on Human Skeletal Remains from Kogarah in New South Wales (No. E.85991).