NSW GOVERNMENT

Transport for NSW

# Beaches Link and Gore Hill Freeway Connection

## Appendix M

## Contamination

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# Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Technical working paper: Contamination

December 2020

**Prepared for**

Transport for NSW

**Prepared by**

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# Executive Summary

## Context

The Western Harbour Tunnel and Beaches Link program of works is a NSW Government initiative to provide additional road network capacity across Sydney Harbour and to improve connectivity with Sydney's northern beaches. The Western Harbour Tunnel and Beaches Link program of works includes:

- The Western Harbour Tunnel and Warringah Freeway Upgrade project comprises a new tolled motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection project
- The Beaches Link and Gore Hill Freeway Connection project comprises a new tolled motorway tunnel connection from the Warringah Freeway to Balgowlah and Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway.

Transport for NSW is seeking approval under Division 5.2, Part 5 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Beaches Link and Gore Hill Freeway Connection (the project), which is comprised of two main components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and Wakehurst Parkway at Killarney Heights, and an upgrade of Wakehurst Parkway (the Beaches Link)
- Connection and integration works along the existing Gore Hill Freeway at Artarmon (the Gore Hill Freeway Connection)
- A detailed description of the project is provided in Chapter 5 (Project description) of the environmental impact statement.

## Scope

This report has been prepared to support the environmental impact statement for the Beaches Link and Gore Hill Freeway Connection project (the project) and to address the environmental assessment requirements of the Secretary of the Department of Planning and Environment ('the Secretary's environmental assessment requirements'). This report documents the Stage 1 contamination investigation carried out for the project.

The objectives of the investigation were to identify potential areas of environmental interest (AEIs) which would assist in identifying construction limitations/constraints and management options for the project with respect to contamination and to address the Secretary's environmental assessment requirements for soils.

Jacobs carried out the following scope of work to achieve these objectives:

- Review of publicly available information
- Review of information provided by Transport for NSW
- Review of historical aerial photography of the general project area
- Site inspections
- Preparation of this Stage 1 contamination investigation report.

Based on the results of the Stage 1 contamination investigation several potential AEIs were identified. Historical aerial photographs from several years between 1930 and 2005 were reviewed with a focus on potential contamination issues at key surface disturbance areas and construction support sites associated with the project. Several potential contamination issues were identified from the historical aerial photograph review.

There are seven sites registered with the NSW Environmental Protection Authority (EPA) within 500 metres of the project that were either regulated or had been notified. A search of local business directories also indicated four sites next to the project footprint, as well as 49 sites within 500 metres of the project footprint, that had current activities and/or operations which could represent a potential contamination risk. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australian Soil Reserve Information System (ASRIS) database indicated an extremely low to high probability of acid sulfate soils (ASS) at various locations within the project.

The Department of Planning, Industry and Environment groundwater bore database indicated one registered (water supply) well located in St Leonards within 500 metres of the project footprint. The functional nature of the key surface disturbance areas and construction support sites was considered typical of that expected within a highly developed urban area.

In consideration of these sites and the activities associated with the construction and operation of the project, a comparative exposure risk ranking has been applied to these AEIs. The potential AEIs with a moderate to high contamination exposure risk ranking are outlined below:

- Within unsealed areas next to the Warringah Freeway. The likely excavation and exposure of potentially contaminated soils during surface works and rehabilitation of the construction support site at the Cammeray Golf Course construction support site (BL1) (initially established as a construction support site for the Western Harbour Tunnel and Warringah Freeway Upgrade project) presents a moderate contamination risk to construction
- At Punch Street in Artarmon, including the area proposed to become Punch Street construction support site (BL3). The likely excavation and exposure of potentially contaminated soils during construction activities at the Punch Street construction support site (BL3) presents a moderate contamination risk to construction
- At the proposed site of the Motorway Control Centre (Freeway Hotel site) and the adjoining properties at Reserve Road, Artarmon. The likely excavation and exposure of potentially contaminated soils during construction of the Motorway Control Centre and Reserve Road off ramp presents a moderate contamination risk to construction
- At the site of the proposed Flat Rock Drive construction support site (BL2) in Flat Rock Reserve. The historical landfill activities carried out within the areas surrounding the Willoughby Leisure Centre, Bicentennial Reserve and part of Flat Rock Reserve are likely to contain soil, groundwater and possible landfill gas contamination sources associated with the historical buried waste mass
    - Soils/wastes: The likely exposure of contamination (including asbestos) beneath the Flat Rock Drive construction support site (BL2) during construction of the access decline tunnel and associated works presents a moderate contamination risk
    - Landfill gas: It is possible that the waste mass beneath Flat Rock Drive construction support site (BL2) and the adjacent Willoughby Leisure Centre and Bicentennial Reserve may present a source of landfill gas, with the potential for it to migrate towards the proposed Flat Rock Drive construction support site (BL2) as a result of formation pressure due to ground disturbance from construction activities associated with the project. Targeted gas testing would be required as part of Stage 2 contamination investigations
    - Groundwater contamination: The potential for interaction with contaminated groundwater beneath Flat Rock Drive construction support site (BL2) during construction of the access decline tunnel and associated works presents a moderate contamination risk. Also, known groundwater contamination in adjoining areas (Willoughby Leisure Centre and Bicentennial Reserve) could migrate towards to the main tunnel works which travel under Willoughby and Northbridge
- At Spit West Reserve. The likely excavation and exposure of potentially contaminated soils on reclaimed land during construction of the Spit West Reserve construction support site (BL9) presents a moderate contamination risk to construction
- Within Middle Harbour and west of Spit West Reserve. The likely excavation and exposure of contaminated sediments during the construction of the cofferdams in Middle Harbour, Middle Harbour south cofferdam

construction support site (BL7) and Middle Harbour north cofferdam (BL8), as well as the construction of the Spit West Reserve construction support site (BL9), presents a high contamination risk to construction

- Adjacent to the Balgowlah Golf Course. The likely excavation and exposure of potentially contaminated soils and fill during creation of the Balgowlah Golf Course construction support site (BL10), new open space and recreation facilities and the Balgowlah connection surface works presents a moderate contamination risk to construction
- At the former residential premises located along Dudley Street at Balgowlah. The likely excavation and exposure of potentially contaminated soils during demolition of the Dudley Street properties for the creation of the Balgowlah Golf Course construction support site (BL10), new open space and recreation facilities and the Balgowlah connection surface works presents a moderate contamination risk to construction.
- Adjacent to the existing residential premises located at the corners of Judith Street and Kirkwood Street with Wakehurst Parkway at Seaforth. The likely excavation and exposure of potentially contaminated soils during construction of the Wakehurst Parkway south construction support site (BL12) presents a moderate contamination risk to construction
- At the Sydney Water Reservoir site at Seaforth. The likely excavation and exposure of potentially contaminated soils during construction of the Wakehurst Parkway east construction support site (BL13) poses a moderate contamination risk to construction
- Adjacent to the Wakehurst Parkway (Seaforth to Frenchs Forest). The likely excavation and exposure of areas of known soil contamination during the upgrade works to Wakehurst Parkway and adjacent construction of the Wakehurst Parkway south (BL12) and Wakehurst Parkway north (BL14) construction support sites pose a high contamination risk to construction
- Adjacent to the Wakehurst Parkway, which may have been subject to the illegal dumping of waste. The likely excavation and exposure of potentially contaminated soils and waste materials during the upgrade works to the Wakehurst Parkway pose a moderate contamination risk to construction
- At the site of structures and/or buildings located within the project area that contain hazardous building materials. Should any structures and/or buildings require demolition to enable construction, hazardous building materials (where present) would be managed to reduce the potential for contamination and ensure appropriate handling and waste disposal. In accordance with Australian Standard (AS 2601-2001), *The demolition of structures*, a hazardous building materials audit should be carried out before the demolition of any structure and/or building.

With respect to the Secretary's environmental assessment requirements, based on the results of the investigation, the following was concluded:

- Major soil erosion hazards are unlikely to impact on the construction or operation of the project. Standard erosion control measures should be implemented during construction and should be consistent with those detailed in *Managing Urban Stormwater: Soils and Construction* (Landcom, 2004)
- ASS are and may be present within Middle Harbour and/or The Spit. Potential ASS were identified in a sediment sample collected from Middle Harbour. Where sediments in these areas require excavation to facilitate construction, these sediments would need to be assessed for the presence of actual and/or potential ASS prior to excavation. If ASS is identified and if groundwater is likely to be lowered in areas identified as containing ASS, an appropriate ASS management plan should be developed and implemented in accordance in the *Acid Sulfate Soil Manual* (ASSMAC, 1998)
- The risk of areas of saline soils being present within the project area is low to negligible
- Several potential AEIs have been identified which have a moderate to high contamination exposure risk. Further investigations of these sites would be required to quantify the soil contamination risk to construction. These investigations would be carried out before construction activities so that contamination (if present) can be adequately planned for and managed. Any further investigations would be carried out in accordance with NSW EPA guidance endorsed under section 105 of the *Contaminated Land Management Act 1997*. The investigations would be designed in consideration of the potential contamination identified

within this report and the proposed construction activities to be carried out on the respective sites (ie investigations should provide lateral and vertical coverage in context of the proposed construction activities across areas which are to be disturbed only). If soil contamination is identified, appropriate remediation action plans and/or environmental management plans should be developed and implemented to remove or suitably reduce the contamination exposure risks during construction activities

- Contaminated sediments have been identified within Middle Harbour and offshore at Spit West Reserve. These contaminated sediments would need to be managed where disturbed during construction activities to reduce the exposure risk to workers and environmental receivers. Appropriate construction methodology has been developed to remove or suitably reduce the contamination risks from contaminated sediments during construction activities as detailed in Chapter 6 (Construction work) and Appendix P (Technical working paper: Hydrodynamic and dredge plume modelling) (Royal HaskoningDHV, 2020). The technical working paper details dredging methodology to be implemented during construction so as not to cause harm to benthic and marine ecosystems and/or adversely reduce water quality, management and methodologies for excavation of sediments, on site treatment and off-site disposal (land based and/or offshore disposal). Numerous environmental controls are proposed as part of dredging methodology. These controls would reduce or avoid the release of suspended sediments during dredging (eg appropriate dredging equipment) and manage the suspended sediment that would be released (eg the use of silt curtains as floating barriers, suspended in the water to contain suspended sediment). These controls reflect best environmental practice to reduce the water quality impacts of dredging and, as reflected in the modelling results, would result in an overall reduction in the extent and intensity of the dredge plumes
- Groundwater monitoring has been carried out at selected locations within the project area. Monitoring data indicates that groundwater contamination is present beneath and between the Willoughby Leisure Centre and Bicentennial Reserve and may be present beneath Flat Rock Reserve, the proposed location for the Flat Rock Drive construction support site (BL2). Further groundwater investigations should be carried out in these areas to target contaminants of concern and to provide additional information to support treatment of encountered groundwater (if required) during construction and operation of the project
- Potential landfill gas risks associated with the historical landfilling within areas underlying the Willoughby Leisure Centre and Bicentennial Reserve and Flat Rock Reserve, have not been quantified. Further landfill gas investigations should be carried out within these areas to assess the potential presence or absence of gas which could potentially impact upon construction and/or operation of the project if not managed appropriately.

This Stage 1 contamination investigation report has been prepared to meet the requirements of the Infrastructure Sustainability Council of Australia (ISCA) Infrastructure Sustainability Rating Tool objectives to minimise pollution generated by the project.

# Glossary and abbreviations

| Acronym | Meaning |
|---|---|
| **AEIs** | Areas of environmental interest |
| **ANZECC** | Australian and New Zealand Environment and Conservation Council |
| **ASRIS** | Australian Soil Resource Information System |
| **ASS** | Acid sulfate soil |
| **ASSMAC** | Acid Sulfate Soil Management Advisory Committee |
| **BTEX** | Benzene, toluene, ethylbenzene, xylenes |
| **CSIRO** | Commonwealth Scientific and Industrial Research Organisation |
| **EMP** | Environmental Management Plan |
| **EPA** | Environment Protection Authority |
| **ISCA** | Infrastructure Sustainability Council of Australia |
| **ISQG** | Interim Sediment Quality Guidelines |
| **LEP** | Local Environment Plan |
| **LNAPL** | Light non-aqueous phase liquid |
| **LPI** | Land and Property Information |
| **NAGD** | National Assessment Guidelines for Dredging |
| **NEPM** | National Environment Protection Measure |
| **OCP** | Organochlorine pesticides |
| **OPP** | Organophosphate pesticides |
| **PAH** | Polycyclic aromatic hydrocarbons |
| **PCB** | Polychlorinated biphenyls |
| **PFAS** | Per- and poly-fluoroalkyl substances |
| **SEARs** | Secretary's environmental assessment requirements |
| **TBT** | Tributyltin |
| **TCLP** | Toxicity characteristics leaching procedure |
| **TRH** | Total recoverable hydrocarbons |

# 1. Introduction

This section provides an overview of the Beaches Link and Gore Hill Freeway Connection project (the project) including its key features and location. It also outlines the Secretary's environmental assessment requirements addressed in this technical working paper.

## 1.1 Overview

The Greater Sydney Commission's *Greater Sydney Region Plan – A Metropolis of Three Cities* (Greater Sydney Commission, 2018) proposes a vision of three cities where most residents have convenient and easy access to jobs, education and health facilities and services. In addition to this plan, and to accommodate for Sydney's future growth the NSW Government is implementing the *Future Transport Strategy 2056* (Transport for NSW, 2018), that sets the 40 year vision, directions and outcomes framework for customer mobility in NSW. The Western Harbour Tunnel and Beaches Link program of works is proposed to provide additional road network capacity across Sydney Harbour and Middle Harbour and to improve transport connectivity with Sydney's Northern Beaches. The Western Harbour Tunnel and Beaches Link program of works include:

- The Western Harbour Tunnel and Warringah Freeway Upgrade project which comprises a new tolled motorway tunnel connection across Sydney Harbour, and an upgrade of the Warringah Freeway to integrate the new motorway infrastructure with the existing road network and to connect to the Beaches Link and Gore Hill Freeway Connection project
- The Beaches Link and Gore Hill Freeway Connection project which comprises a new tolled motorway tunnel connection across Middle Harbour from the Warringah Freeway and the Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of the Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway at Artarmon.

A combined delivery of the Western Harbour Tunnel and Beaches Link program of works would unlock a range of benefits for freight, public transport and private vehicle users. It would support faster travel times for journeys between the Northern Beaches and areas south, west and north-west of Sydney Harbour. Delivering the program of works would also improve the resilience of the motorway network, given that each project provides an alternative to heavily congested existing harbour crossings.

## 1.2 The project

Transport for NSW is seeking approval under Part 5, Division 5.2 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Beaches Link and Gore Hill Freeway Connection project, which would comprise two components:

- Twin tolled motorway tunnels connecting the Warringah Freeway at Cammeray and the Gore Hill Freeway at Artarmon to the Burnt Bridge Creek Deviation at Balgowlah and the Wakehurst Parkway at Killarney Heights, and an upgrade of the Wakehurst Parkway (the Beaches Link)
- Connection and integration works along the existing Gore Hill Freeway and surrounding roads at Artarmon (the Gore Hill Freeway Connection).

A detailed description of these two components is provided in Section 1.4.

## 1.3 Project location

The project would be located within the North Sydney, Willoughby, Mosman and Northern Beaches local government areas, connecting Cammeray in the south with Killarney Heights, Frenchs Forest and Balgowlah in the north. The project would also connect to both the Gore Hill Freeway and Reserve Road in Artarmon in the west.

Commencing at the Warringah Freeway at Cammeray, the mainline tunnels would pass under Naremburn and Northbridge, then cross Middle Harbour between Northbridge and Seaforth. The mainline tunnels would then split under Seaforth into two ramp tunnels and continue north to the Wakehurst Parkway at Killarney Heights

and north-east to Balgowlah, linking directly to the Burnt Bridge Creek Deviation to the south of the existing Kitchener Street bridge.

The mainline tunnels would also have on and off ramps from under Northbridge connecting to the Gore Hill Freeway and Reserve Road east of the existing Lane Cove Tunnel. Surface works would also be carried out at the Gore Hill Freeway in Artarmon, Burnt Bridge Creek Deviation at Balgowlah and along the Wakehurst Parkway between Seaforth and Frenchs Forest to connect the project to the existing arterial and local road networks.

## 1.4 Key features of the project

Key features of the Beaches Link component of the project are shown in Figure 1-1 and would include:

- Twin mainline tunnels about 5.6 kilometres long and each accommodating three lanes of traffic in each direction, together with entry and exit ramp tunnels to connections at the surface. The crossing of Middle Harbour between Northbridge and Seaforth would involve three lane, twin immersed tube tunnels
- Connection to the stub tunnels constructed at Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- Twin two lane ramp tunnels:
  - Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at the Burnt Bridge Creek Deviation, Balgowlah (about 1.2 kilometres in length)
  - Northbound and southbound connections between the mainline tunnel under Seaforth and the surface at the Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
  - Eastbound and westbound connections between the mainline tunnel under Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length).
- An access road connection at Balgowlah between the Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
- Upgrade and integration works along the Wakehurst Parkway, at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New open space and recreation facilities at Balgowlah
- New and upgraded pedestrian and cyclist infrastructure
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
- Operational facilities, including a motorway control centre at the Gore Hill Freeway in Artarmon, and tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed Circuit Television (CCTV) and other traffic management systems.

Key features of the Gore Hill Freeway Connection component of the project are shown in Figure 1-2 and would include:

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore & Western Line and T9 Northern Line and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network

- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

A detailed description of the project is provided in Chapter 5 (Project description) of the environmental impact statement.

Subject to obtaining planning approval, construction of the project is anticipated to commence in 2023 and is expected to take around five to six years to complete.

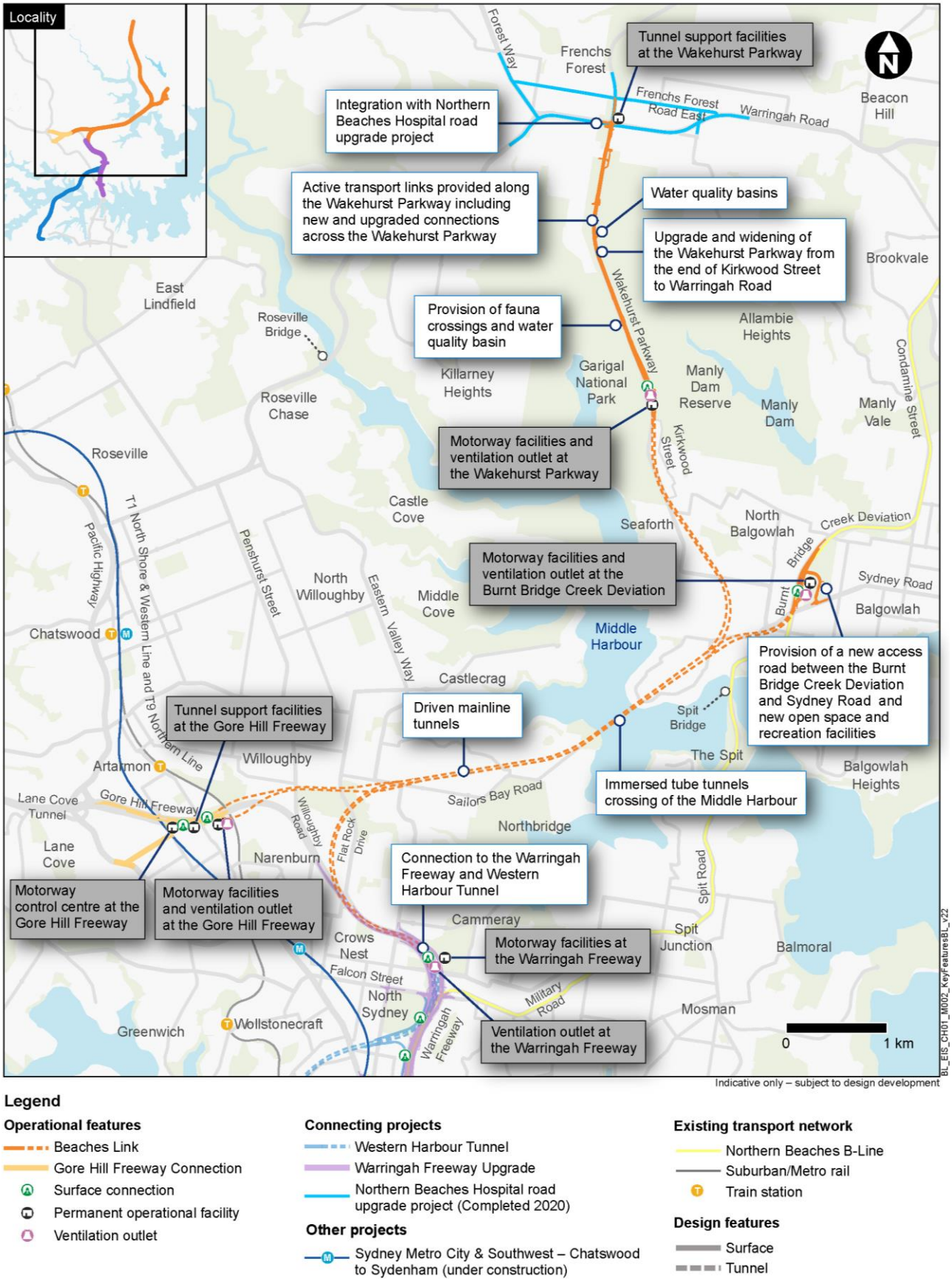


Figure 1-1: Key features of the Beaches Link component of the project

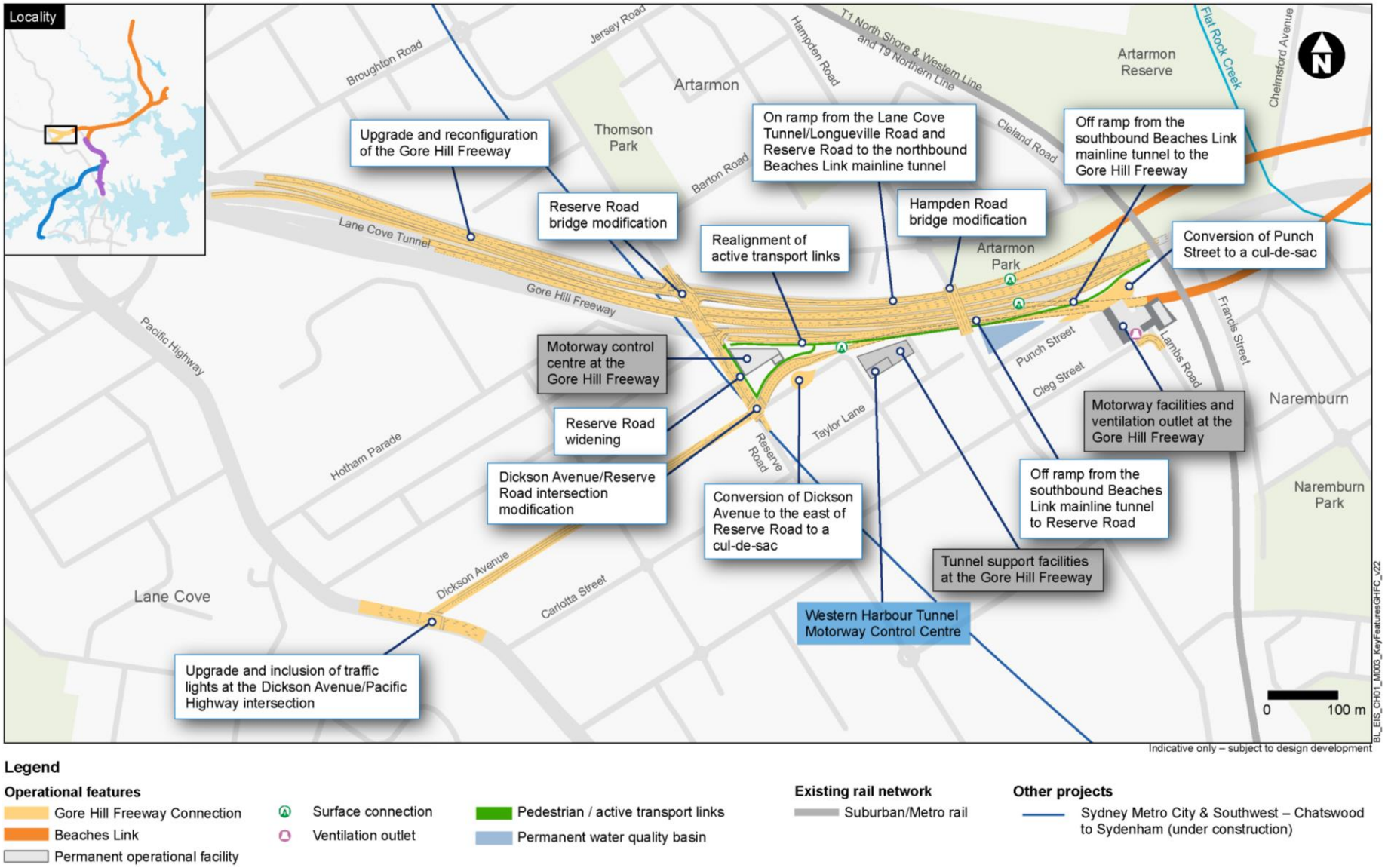


Figure 1-2: Key features of the Gore Hill Freeway component of the project

## 1.5 Key construction activities

The area required to construct the project is referred to as the construction footprint. The majority of the construction footprint would be located underground within the mainline and ramp tunnels. However, surface areas would also be required to support tunnelling activities and to construct the tunnel connections, tunnel portals, surface road upgrades and operational facilities.

Key construction activities would include:

- Early works and site establishment, with typical activities being property acquisition and condition surveys, utilities installation, protection, adjustments and relocations, installation of site fencing, environmental controls (including noise attenuation and erosion and sediment control), traffic management controls, vegetation clearing, earthworks, demolition of structures, building construction support sites including acoustic sheds and associated access decline acoustic enclosures (where required), construction of minor access roads and the provision of property access, temporary relocation of pedestrian and cycle paths and bus stops, temporary relocation of swing moorings and/or provision of alternative facilities (mooring or marina berth) within Middle Harbour
- Construction of the Beaches Link, with typical activities being excavation of tunnel construction access declines, construction of driven tunnels, cut and cover and trough structures, construction of surface upgrade works, construction of cofferdams, dredging and immersed tube tunnel piled support activities in preparation for the installation of immersed tube tunnels, casting and installation of immersed tube tunnels and civil finishing and tunnel fitout
- Construction of operational facilities comprising:
    - A motorway control centre at the Gore Hill Freeway in Artarmon
    - Tunnel support facilities at the Gore Hill Freeway in Artarmon and at the Wakehurst Parkway in Frenchs Forest
    - Motorway facilities and ventilation outlets at the Warringah Freeway in Cammeray (fitout only of the Beaches Link ventilation outlet at the Warringah Freeway (being constructed by the Western Harbour Tunnel and Warringah Freeway Upgrade project), the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
    - A wastewater treatment plant at the Gore Hill Freeway in Artarmon
    - Installation of motorway tolling infrastructure
- Staged construction of the Gore Hill Freeway Connection at Artarmon and upgrade and integration works at Balgowlah and along the Wakehurst Parkway with typical activities being earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of roadside furniture, lighting, signage and noise barriers
- Testing of plant and equipment and commissioning of the project, backfill of access declines, removal of construction support sites, landscaping and rehabilitation of disturbed areas and removal of environmental and traffic controls.

Temporary construction support sites would be required as part of the project (refer to Figure 1-3), and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities. Construction support sites would include:

- Cammeray Golf Course (BL1)
- Flat Rock Drive (BL2)
- Punch Street (BL3)
- Dickson Avenue (BL4)
- Barton Road (BL5)
- Gore Hill Freeway median (BL6)
- Middle Harbour south cofferdam (BL7)
- Middle Harbour north cofferdam (BL8)

- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14).

A detailed description of construction works for the project is provided in Chapter 6 (Construction work) of the environmental impact statement.

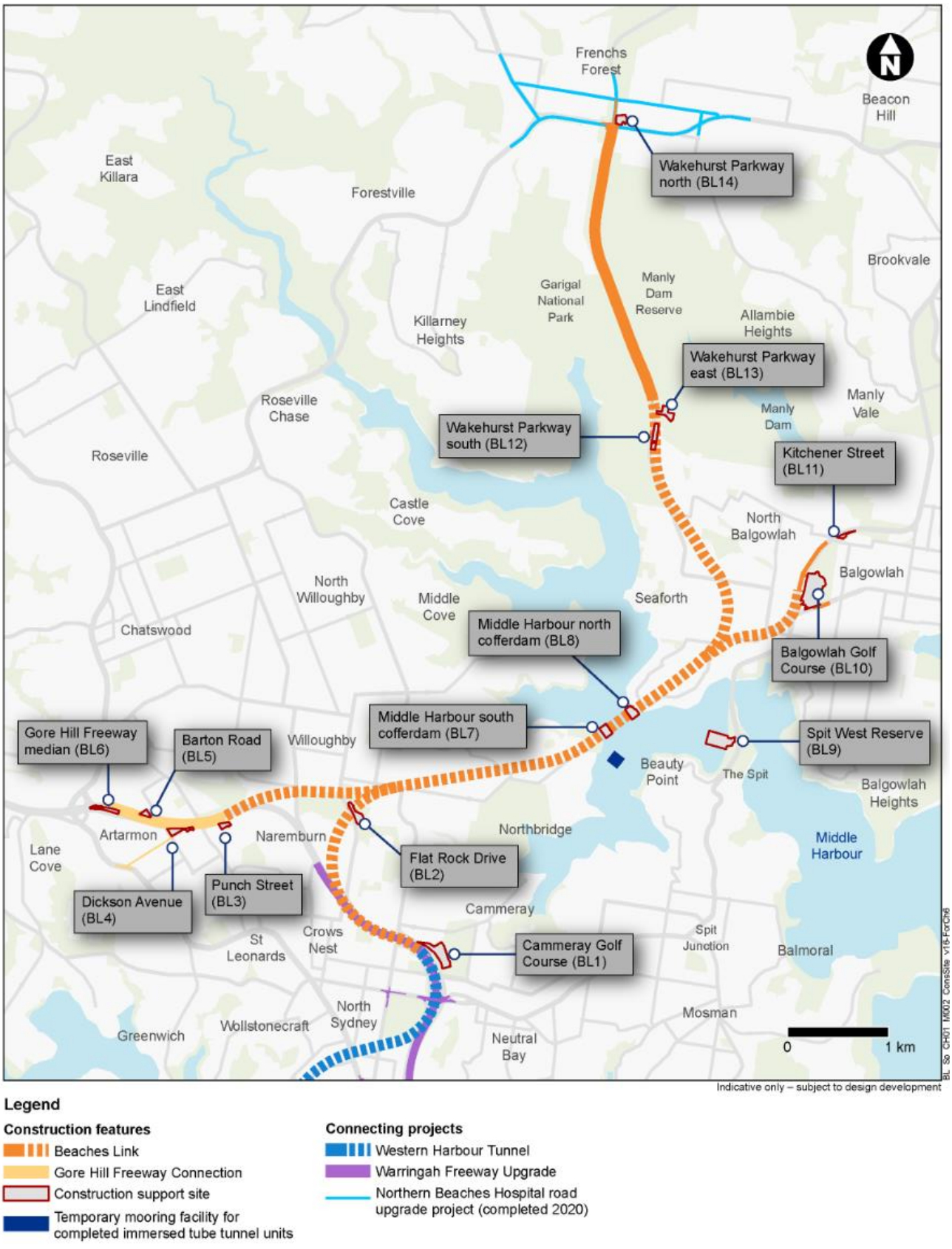


Figure 1-3: Overview of the construction support sites

## 1.6 Purpose of this report

This report has been prepared to support the environmental impact statement for the project, its decision-making process in respect to contamination and to address the environmental assessment requirements of the Secretary of the Department of Planning, Industry and Environment.

The objectives of the Stage 1 contamination investigation were to identify potential areas of environmental interest (AEIs) which would assist in identifying construction limitations/constraints and management options within the project area with respect to contamination.

The AEIs were those potential risks associated with soil, groundwater and vapour contamination which may be present as a result of historic and/or current activities carried out on and/or next to the project area.

To achieve these objectives, Jacobs carried out the following scope of work:

- Review of publicly available information from the NSW Environment Protection Authority (EPA), the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australian Soil Resource Information System (ASRIS) database and the NSW Department of Primary Industries (DPI) groundwater database
- Review of information provided by Transport for NSW
- Review of historical aerial photography of the general project area
- Site inspections
- Preparation of a Stage 1 contamination investigation report based on the data obtained from the desktop background review and observations from the inspection of the project area. The expected ground conditions are presented together with any potential contamination issues identified and recommendations for further investigations, if required.

## 1.7 Secretary's environmental assessment requirements

The Secretary's environmental assessment requirements relating to the Stage 1 contamination investigation and where these requirements are addressed in this report are outlined in Table 1-1.

Table 1-1: Secretary's environmental assessment requirements – Soils and contamination

| Secretary's environmental assessment requirements | Where addressed |
|---|---|
| 1) The Proponent must verify the risk of acid sulfate soils (Class 1, 2, 3 or 4 on the Acid Sulfate Soil Risk Map) within, and in the area likely to be impacted by, the project. | Section 3.6 |
| 2) The Proponent must assess the impact of the project on acid sulfate soils (including impact of acidic runoff off site) in accordance with the current guidelines and detail the mitigation measures proposed to minimise potential impacts. | Sections 6.2, 7.2 and 9 |
| 3) The Proponent must assess whether the land and harbour sediment is likely to be contaminated and identify if remediation is required, having regard to the ecological and human health risks posed by the contamination in the context of past, existing and future land uses. | Sections 4.4 and 9 |

| Secretary's environmental assessment requirements | Where addressed |
|---|---|
| 4) Where assessment and/or remediation is required, the Proponent must document how the assessment and/or remediation would be carried out in accordance with current guidelines. | Sections 4.4 and 9 |
| 5) Where contaminated spoil and/or sediments are to be handled, the Proponent must provide details of contamination characteristics and measures to manage this spoil to avoid adverse impact to land and water quality. | Sections 4.4 and 9<br>Refer to Section 6 of Appendix Q (Technical working paper: Marine water quality) for measures to avoid adverse impacts to marine water quality<br>Refer to Section 7.2 of Appendix P (Technical working paper: Hydrodynamics) for the proposed dredge methodology.<br>Refer to Section 8.1 of Appendix O (Technical working paper: Surface water quality and hydrology) for measures to avoid adverse impacts to surface water quality. |
| 6) The Proponent must assess whether salinity is likely to be an issue and if so, determine the presence, extent and severity of soil salinity within the project area. | Section 3.7 |
| 7) The Proponent must assess the impact of the project on soil salinity and how it may affect groundwater resources and hydrology. | Sections 6.3 and 7.3 |
| 8) The Proponent must assess the impact on soil and land resources (including erosion risk or hazard). Particular attention must be given to soil erosion and sediment transport consistent with the practices and principles in the current guidelines. | Sections 6.1, 7.1 and 9<br>Refer to Sections 5.2, 5.4 and 6.4 of Appendix O (Technical working paper: Surface water quality and hydrology) for soil erosion and sediment transport |
| 9) The Proponent must assess the impact of any disturbance of contaminated groundwater and the tunnels should be designed so as to not exacerbate mobilisation of contaminated groundwater and/or prevent contaminated groundwater flow. | Sections 6.6, 7.6 and 9<br>Refer to Section 5.5 of Appendix N (Technical working paper: Groundwater) for further information on existing groundwater quality |

## 1.8 Relevant contamination guidelines

In preparing this report, the following guidelines were considered (where relevant):

- *Acid Sulfate Soils Manual* (Acid Sulfate Soils Management Advisory Committee, 1998)
- Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land (Department of Urban Affairs and Planning & NSW EPA, 1998)
- Guidelines for Consultants Reporting on Contaminated Sites (Office of Environment and Heritage, 2000).

Should further investigations, remediation work and validation be carried out, these activities would need to be carried out in accordance with the following additional guidelines or other appropriate/endorsed guidelines available at that time:

- NSW EPA (2015a), Guidelines on the Duty to Report Contamination under the Contaminated Land Management Act 1997
- Urban and regional salinity – guidance given in the Local Government Salinity Initiative booklets (http://www.environment.nsw.gov.au/salinity/solutions/urban.htm) which includes Site Investigations for Urban Salinity (DLWC, 2002)
- Landslide risk management guidelines presented in Australian Geotechnics Society (2007)
- Soil and Landscape Issues in Environmental Impact Assessment (Jonathan Gray and DLWC, 2000)
- *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom, 2004) and *Volume 2* (A. Installation of Services; B. Waste Landfills; C. Unsealed Roads; D. Main Roads; E. Mines and Quarries) (Department of Environment and Climate Change, 2008)
- Other guidelines made or approved under section 105 of the *Contaminated Land Management Act 1997*
- Standards Australia (2005) Australian Standard AS 4482.1-2005: Guide to the investigation and sampling of sites with potentially contaminated soil. Part 1: Non-volatile and semi-volatile compounds
- Standards Australia (1999) Australian Standard AS 4482.2-1999: Guide to the sampling and investigation of potentially contaminated soils. Part 2: Volatile substances
- Commonwealth of Australia (2009) National Assessment Guidelines for Dredging
- National Environment Protection (Assessment of Site Contamination) Measure 1999 (as revised 2013)
- Australian and New Zealand Environment and Conservation Council (ANZECC) & Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2018) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*
- NSW EPA (2014c) Waste Classification Guidelines
- Department of Environment, Climate Change and Water (2009) Guidelines for Implementing the Protection of the Environment Operations (Underground Petroleum Storage Systems) Regulation 2008
- NSW EPA (1995) Contaminated Sites: Sampling Design Guidelines
- NSW EPA (2017) Contaminated Sites: Guidelines for the NSW Site Auditor Scheme (3rd Edition)
- Department of Environment and Conservation (2007) Contaminated Sites: Guidelines for the Assessment and Management of Groundwater Contamination
- NSW EPA (2015b) Technical Note: Light Non-Aqueous Phase Liquid Assessment and Remediation
- NSW EPA (2014b) Technical Note: Investigation of Service Station Sites
- NSW EPA (2014a) Best Practice Note: Landfarming
- Department of Environment and Conservation (2005) Information for the assessment of former gasworks sites
- Department of Environment, Climate Change and Water (2010) *Vapour Intrusion: Technical Practice Note*
- NSW EPA (2012) Guidelines for the Assessment and Management of Sites Impacted by Hazardous Ground Gases
- WorkCover NSW (2014) Managing asbestos in or on soil.

# 2. Assessment methodology

In preparing the Stage 1 contamination investigation, the following process was implemented:

- Review of existing land uses along and in vicinity to the project alignment, topography, drainage, geology, soils (including erosions hazard, ASS risk and salinity potential), hydrogeology and receiving environments
- Review of historical aerial photographs (1930 to 2005), available aerial imagery services (Google Earth, SIX Maps and Metro Map)
- Searches in the NSW EPA Contaminated Sites Register and Record of Notices and in the Yellow Pages business directory
- Review of previous harbour sediment, soil, groundwater and contamination site investigations
- Visual inspections of surface areas above the tunnel alignment, all above-ground project features, nearby land uses and potential AEIs for contamination.

Based on the above information, AEIs for contamination were identified as well as their associated comparative risks to environmental receivers, construction limitations and site users in consideration of the potential for contamination and proposed construction activities. The comparative risk has been assessed based on the matrix shown in Figure 2-1.

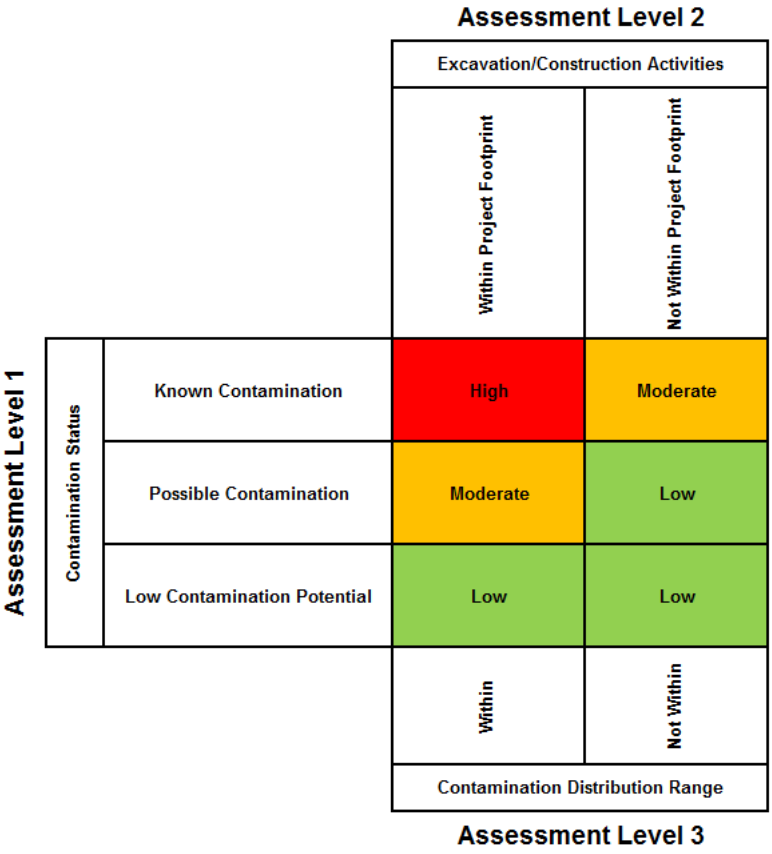


Figure 2-1: Comparative risk assessment matrix

Impacts related to soil erosion hazard, ASS, salinity and contamination during construction and operation were identified and assessed.

Strategies for the management of potential environmental (soil erosion, ASS, soil salinity) and contamination risks identified associated with the construction and operation of the project have been recommended (where applicable).

# 3. Existing environment

The information presented below is based on a review of publicly available information, and observations made during a project area inspection carried out from publicly accessible areas by Jacobs on 18 September 2017 and 5 April 2019.

## 3.1 Location and land use zones

The project spans about seven kilometres from the North Shore suburbs of Cammeray, Naremburn and Artarmon to North Balgowlah and Frenchs Forest. Most of the project would comprise tunnels extending from the Warringah Freeway (at Cammeray) and the Gore Hill Freeway (at Artarmon), beneath Middle Harbour and surfacing at the Wakehurst Parkway at Seaforth and the Burnt Bridge Creek Deviation at Balgowlah. Surface work would continue along the Wakehurst Parkway to Frenchs Forest.

The project would be located within/beneath a range of land use zones as identified in the North Sydney Local Environmental Plan 2013 (NSW Government, 2013a), Willoughby Local Environmental Plan 2012 (NSW Government, 2012a), Mosman Local Environmental Plan 2012 (NSW Government, 2012b), Manly Local Environmental Plan 2013 (NSW Government, 2013b) and Warringah Local Environmental Plan 2011 (NSW Government, 2011).

Land use zones for the project area under the respective local environmental plans are presented is Figure 3-1 to Figure 3-5.

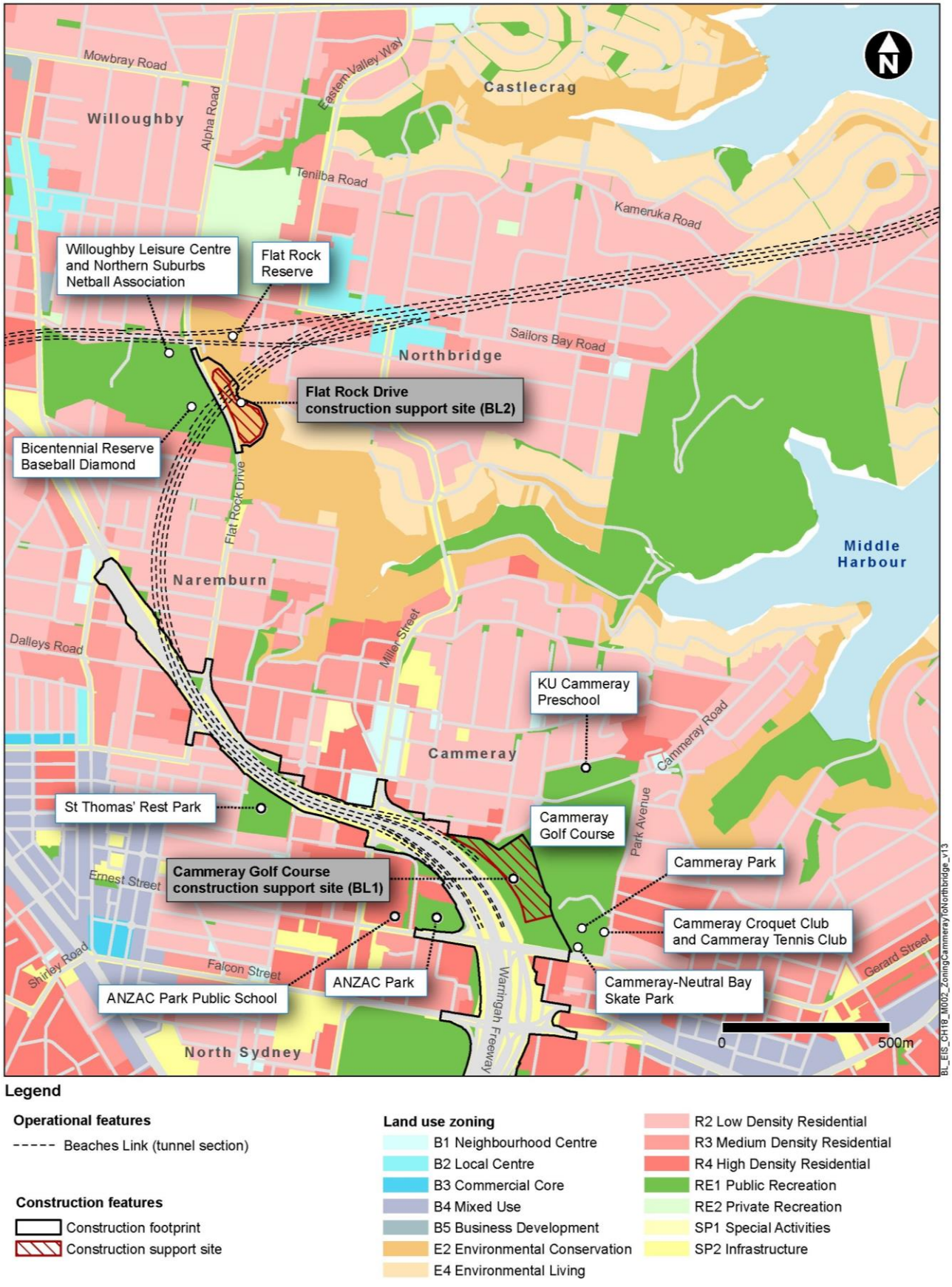


Figure 3-1: Land use zones – Cammeray to Northbridge

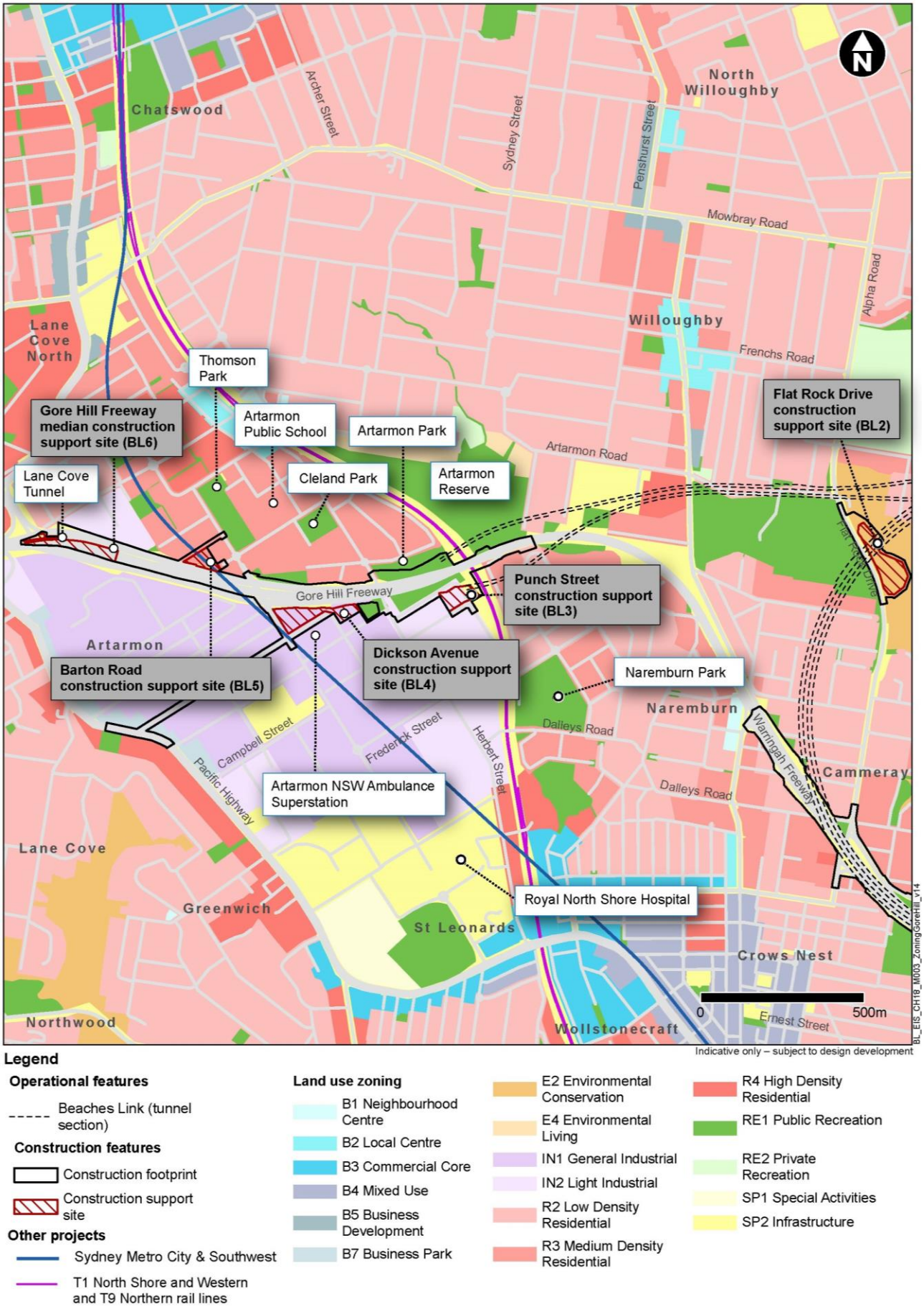


Figure 3-2: Land use zones – Gore Hill Freeway Connection and surrounds


Figure 3-3: Land use zones – Northbridge to Seaforth

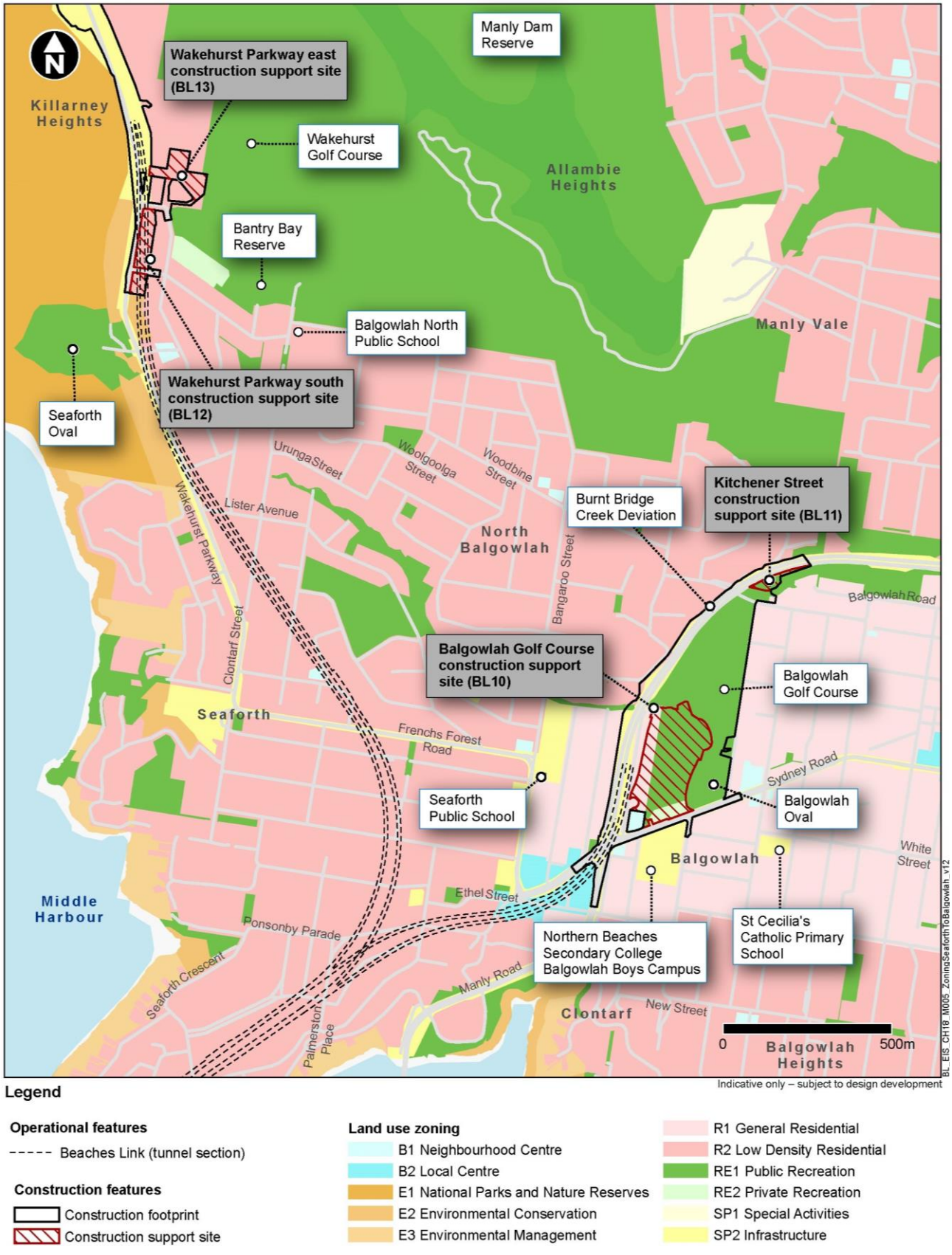


Figure 3-4: Land use zones – Seaforth to Balgowlah

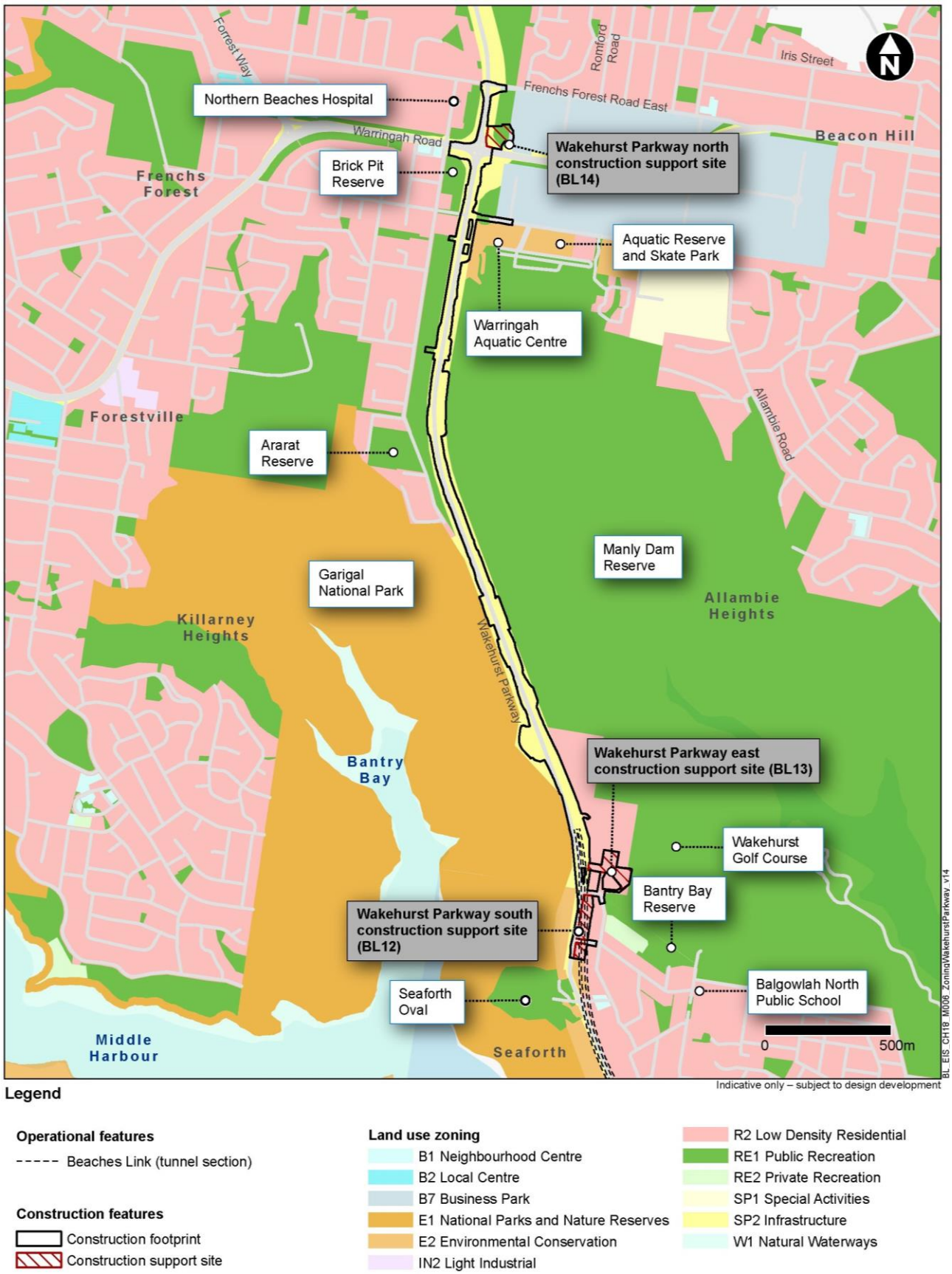


Figure 3-5: Land use zones – Wakehurst Parkway Connection and upgrade

## 3.2 Topography and drainage

The terrain along the project rises from an elevation of around 65 metres Australian Height Datum (AHD) at the southern extent of the project at Cammeray and undulates towards Middle Harbour. The maximum water depth of the Middle Harbour crossing is around 30 metres below sea level.

To the north of Middle Harbour the topography has a steep incline up to the ridge line at North Balgowlah, before resuming a moderate incline towards Frenchs Forest, reaching an elevation of around 150 metres AHD at Warringah Road at the northern extent of the project area.

During the site inspection, no obvious areas of inconsistent topography were noted that could indicate considerable areas of filling, except for the Willoughby Leisure Centre and Bicentennial Reserve. Based on historical information, it is understood that localised areas of quarrying and filling activities may have been carried out near the project at the Gore Hill Freeway. No visual evidence of these quarrying and filling activities was noted during the site inspection.

The northern aboveground alignment of project from Frenchs Forest to North Balgowlah is generally situated along the catchment boundary between Bates Creek and Bantry Bay to the west, and Manly Creek and Manly Dam to the east.

The tunnel would dive north of the Warringah Freeway and continue to Killarney Heights and Balgowlah. This part of the alignment would pass beneath a high area in the regional topography which would influence drainage to the west and east of the alignment. The main surface drainage feature in the northern area of the project is Burnt Bridge Creek at North Balgowlah. Burnt Bridge Creek flows east from North Balgowlah, through Balgowlah and then towards Manly Vale and intersects the project at the Burnt Bridge Creek Deviation.

Between Middle Harbour and the Warringah Freeway, the project crosses beneath Flat Rock Creek and the upper Willoughby Creek catchment. Both Flat Rock Creek and Willoughby Creek drain to Middle Harbour. The project crosses Flat Rock Creek in two locations. Flat Rock Creek is mostly a concrete lined channel or buried box culvert through Artarmon and Willoughby with areas downstream of the project reverting to a more natural state.

The project area lies within the Sydney Metro catchment of the Sydney basin region. The Sydney Metro catchment is bounded by the Hawkesbury Nepean catchment to the west and the Tasman Sea to the east. The Sydney Metro catchment consists of eight sub catchments and includes local rivers and channels. The project would be located within the following sub catchments:

- Middle Harbour
- Northern Beaches (up to Narrabeen).

Topography and drainage within the project area are presented on Figure 3-6.

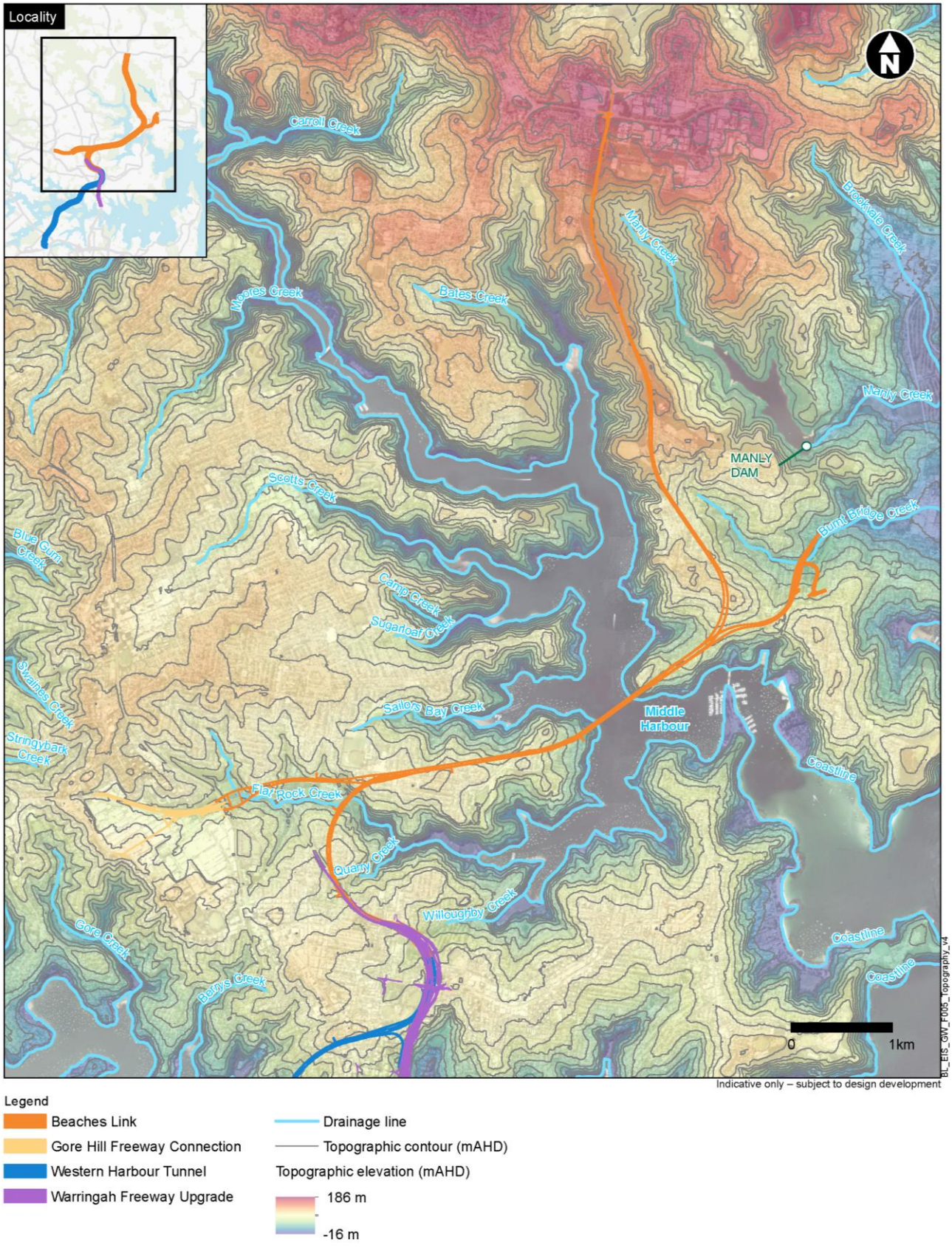


Figure 3-6: Topography and drainage

## 3.3 Geology

The geology of the alignment is dominated by the Hawkesbury Sandstone of the Permo Triassic age Sydney Basin. In elevated areas, the Hawkesbury Sandstone is overlain by the Ashfield Shale of the Wianamatta Group. An intermediate formation between the Hawkesbury Sandstone and the Ashfield Shale, the Mittagong Formation, is sometimes identified but is not mapped along the project alignment. In places the Sydney Basin sedimentary formations have been structurally deformed and include the presence of faults, dykes, and joint swarms.

The Sydney 1:100,000 Geological Series Sheet 9130 (NSW Department of Mineral Resources, 1983) indicated that most of the project area is predominantly underlain by Hawkesbury Sandstone (Rh) with isolated occurrences of Ashfield Shale (Rwa) present in the south eastern portion of the project area (North Sydney and Neutral Bay).

A description of the geological formations underlying the project area is provided in Table 3-1 and presented as Figure 3-7.

Table 3-1: Geological units underlying the project area

| Age | Geological unit | Description |
|---|---|---|
| **Quaternary** | Fill | Typically comprising waste, emplaced material and engineered fill with a high potential for contamination. Reclaimed land areas are generally located next to the harbour and include parkland, residential, industrial, and open space areas. |
| | Undifferentiated estuarine and alluvial sediments | Holocene and Pleistocene age interbedded sands and clays with discontinuous "inter fingered" lenses of sand and clay. May contain zones of colluvium.<br>May be present as palaeochannel infill deposits. |
| | Marine sediments | Pleistocene age primarily clayey sediments with intermittent sand lenses. Possibly containing gas, fissured. |
| **Jurassic** | Igneous Intrusion | Dykes. |
| **Mid Triassic** | Ashfield Shale | Consists of four variable thickness sub units of siltstone and laminate. |
| | Mittagong Formation | Fine grained sandstone and inter bedded sandstone/siltstone. |
| | Hawkesbury Sandstone | Medium to coarse grained, quartzose sandstone. A combination of highly cross bedded and massive sandstone units with interbedded siltstone. |

Source: AECOM, 2015. WestConnex New M5 Environmental Impact Statement – Technical working paper: Groundwater Appendix Q, November 2015 and WSP | Parsons Brinckerhoff, 2016.

### 3.3.1 Anthropogenic fill material

In general, a thin layer of fill (less than one metre thick) is commonly encountered in urban areas and is associated with minor modifications to the topography, landscaping and pavement construction. Such fill can be highly variable in composition and compaction. Thicker deposits of fill are expected towards the mouths of the infilled channels, associated with land reclamation, back filled quarries, landfills, stream capture and urban development in these areas.

One of the main areas of fill is located alongside Flat Rock Creek. Following the opening of an incinerator in Flat Rock Gully in the 1930's, Willoughby Council began the disposal of garbage in an open tip below the incinerator in the late 1940's. Over the following decades the site of the open tip expanded and is understood to have extended from Willoughby Road in the west to Flat Rock Drive in the east, extending to the immediate eastern side of Flat Rock Drive. Drainage works enclosed the creek though this location in a concrete tunnel and up to 160 feet (about 50 metres) of garbage and landfill was dumped over it (McKillop, 2012). In 1934 the Walter Burley Griffin Incinerator was built, with ash generated from the incineration of refuse deposited until the incinerator was closed in 1967 when it became obsolete. From the 1940s industrial and domestic waste was tipped and burnt in the area on both sides of Flat Rock Drive and into Flat Rock Reserve, which ceased in 1985. The landscaped area on the east side of Flat Rock Drive is situated on about 30 metres of landfilled waste material and soil fill.

Interpretation of historical records indicates that up to 40 metres of fill have been placed along Flat Rock Creek (WSP, 2016).

### 3.3.2 Palaeochannels

The occurrence of infilled palaeochannels or palaeovalleys is generally limited to beneath the main harbour areas. Some smaller occurrences of palaeochannel style deposits or basal sands may occur in the larger onshore drainages such Flat Rock Creek. The deeper sediments within these palaeovalleys are inferred to be of Pleistocene age.

Experience from previous tunnel projects in Sydney indicates that palaeovalleys are critical in tunnel design because the rock mass beneath palaeovalleys is often more structurally complex due to the association with geological structures such as faults and dykes and valley stress relief. Additionally, they can store and transmit large volumes of surface and groundwater resulting in increased groundwater inflow in tunnels and deep excavations.

Palaeovalley geometry along the project alignment is variable and generally increases in width and depth towards the palaeovalley axes in Sydney Harbour and Middle Harbour extending to a maximum depth of 85 metres below sea level near South Head at the entrance to Sydney Harbour. The deepest palaeovalley sediments along the alignment are anticipated in a buried palaeovalley in Middle Harbour near Seaforth where they are inferred to be about 30 metres deep and to a depth of -60 metres AHD.

### 3.3.3 Jurassic volcanics

Jurassic basaltic dykes intrude the shale and sandstone formations of the Sydney Basin. The dyke orientations are generally consistent with the main structural orientations and typically strike in two dominant directions; either between 90 and 120 degrees or between five and 35 degrees. The dykes are of variable thickness ranging from less than three metres up to 16 metres wide (Appendix N (Technical working paper: Groundwater). Dykes typically act as a hydraulic barrier perpendicular to their orientation and can result in partitioning of groundwater. Dykes can also have elevated permeability parallel to strike resulting from jointing and alteration related to the original intrusion and subsequent weathering. As such they can present a risk to tunnelling. If unmanaged, dykes can result in a potentially hazardous situation as tunnelling through a depressurised aquifer can break through the dyke to encounter a fully pressurised formation. Dykes may also provide a conduit for higher groundwater inflows, especially when in proximity to open water bodies such as the harbour.

Dykes are known to cross the project alignment at Seaforth. It is also likely that numerous other dykes would be encountered. However, it is difficult to map poorly defined outcrops in an urban environment and therefore the frequency of the occurrence of dykes along a linear feature is difficult to assess.

### 3.3.4 Ashfield shale

The Ashfield Shale consists of marine deposits made up of clay, silt and sand that have been mildly deformed and have developed into a laminated shale. It is generally a dark grey to black siltstone/mudstone or laminate (thin alternating layers of siltstone and sandstone). In some parts the shale may become carbonaceous with variable silt and clay particles throughout. The shale grades upwards into partly carbonaceous silty shale with siderite nodules and ironstone bands. The unit is laminated although retains bedding planes at some locations. Structural defects are present in the shale such as faults, fractures and shears (AECOM, 2015).

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

Where it outcrops, the shale typically weathers to a stiff to hard clay with medium to high plasticity and the weathered profile generally extends down three metres to 10 metres in depth. However, it has been noted to reach depths greater than 40 metres in former brick pits (AECOM, 2015).

### 3.3.5 Mittagong formation

The Mittagong Formation is composed of a series of interbedded dark shale and sandstone of varying thicknesses and is the unit of change from the Ashfield Shale and underlying Hawkesbury Sandstone. The shale beds are very similar to the Ashfield Shale, though it is typically no more than 0.5 metres thick while the sandstone beds are up to five metres thick and are fine to medium grained and contain more silt than the Hawkesbury Sandstone (AECOM, 2015). Due to its reduced thickness, the Mittagong Formation rarely outcrops across the Sydney Basin and has been identified to occur at the contact between the Ashfield Shale and Hawkesbury Sandstone in the project area at Cammeray.

### 3.3.6 Hawkesbury sandstone

The Hawkesbury Sandstone was deposited in a fluvial paleo environment, likely to have been a braided river setting, and as such is highly stratified. The sandstone is ubiquitous across the Sydney Basin and is up to 290 metres thick. Most excavations for the project would be within the Hawkesbury Sandstone unit.

Hawkesbury Sandstone is often described as medium to coarse grained and consists of three main depositional environments, namely: massive sandstone facies: cross bedded or sheet facies; and shale/siltstone interbedded facies. The sheet facies make up about 70 per cent of the unit with primary beds that range in thickness from less than 0.5 metres to greater than five metres but generally occur between one and two metres. Secondary structural features such as joints, fractures and faults are also present.

The sandstone weathers to a clayey sandy soil, typically up to one to two metres in depth. Within the upper ten metres of the profile a duricrust may be present where iron cementation has caused the development of ferricrete or coffee rock, or similarly, silica cementation may cause the development of silcrete. Deep orange and red coloured iron staining is characteristic of the Hawkesbury Sandstone that can be concentrated along water bearing fractures and discontinuities (AECOM, 2015).

### 3.3.7 Structural geology

#### 3.3.7.1 Bedding

Bedding surfaces in the Hawkesbury Sandstone in this part of the Sydney Basin typically dip gently toward the south at up to five degrees (locally up to 10 degrees). Local increases in dip are generally associated with depositional channel structures. Minor siltstone bands or siltstone breccia zones frequently occur in the base of these channel structures. Primary bedding planes are generally spaced between 0.5 and three metres and may be tight to open. Bedding related structures can include clay infills, crushed seams, in situ weathering, iron staining and limonite coating (AECOM, 2015).

Laboratory testing has shown that the cross bedded or sheet facies does not usually represent planes of weakness in fresh or slightly weathered rock. However, in moderately to highly weathered sandstone the cross beds can form surfaces of incipient parting or low shear strength. Both bedding and cross bed partings in the Hawkesbury Sandstone are typically planar to undulating and rough on a small scale with occasional clay, carbonaceous or mica films and infills (AECOM, 2015).

#### 3.3.7.2 Faults

Figure 3-7 shows the main known structural features in the project area. Within the Sydney region there are four major north to northeast striking fault zones, and of most significance to the project alignment is the Luna Park Fault Zone. This major fault zone spans the entire project area and generally present as joint swarms or brecciated zones and often have associated gauge development. The fault zones have had an important influence on geomorphological development.

These structural features have been recorded at numerous locations within the Sydney Basin and are generally continuous, mappable and relatively predictable, although not always uniformly linear across the Sydney Region (Och et al., 2009).

The Luna Park Fault Zone has been shown to comprise up to three metres wide crushed zones with closely spaced jointing and faulting. The faulting shows normal and reverse movement, as well as strike slip offset. Extensions of this fault have been identified at stages along a five kilometres strike length. Other occurrences have been identified at Walsh Bay, Darling Island, Star City Casino and Camperdown to the south and Anderson Park to the north (AECOM, 2015). The Luna Park Fault Zone, and an associated parallel trending joint swarm mapped at Willoughby Creek, are projected to intersect the alignment at Middle Harbour.

Joint spacing varies according to stratigraphy, proximity to near surface weathering and proximity to major geological structures. Assessment of a more regional spread of geotechnical data, from projects such as Sydney Metro North West (previously known as North West Rail Link), M4-M5 Link and Sydney Metro City & Southwest, indicates that jointing within the Hawkesbury Sandstone is typically extremely widely spaced (two metres to up to six metres) with zonal occurrences that are usually moderately widely spaced (60 millimetres to 200 millimetres). More widely spaced jointing of up to 25 metres also occurs (AECOM, 2015).

Localised areas of sub vertical joints may also occur, especially for the north/northeast striking set, with spacing from 0.1 metres to 0.5 metres (eg Luna Park Fault Zone, Martin Place Joint Swarm and General Post Office (GPO) Fault Zone). These localised areas are often associated with preferential groundwater flows, deeper weathered profiles and some discrete faulting and brecciation and have a greater vertical continuity than the general population of joints.

Faults, as with dykes, present risks to tunnelling (from a construction workplace health and safety risk perspective) in that they can act as conduits or as barriers to groundwater flow. Groundwater may exploit these enhanced flow zones and present elevated inflows, or a sudden in rush potential where barriers to flow are penetrated. This can be exacerbated when the aquifers either side of the faults are at different pressures.

Tunnelling itself can enhance or exacerbate the inherent permeability of joints or brecciated zones through stress relief and dilation.

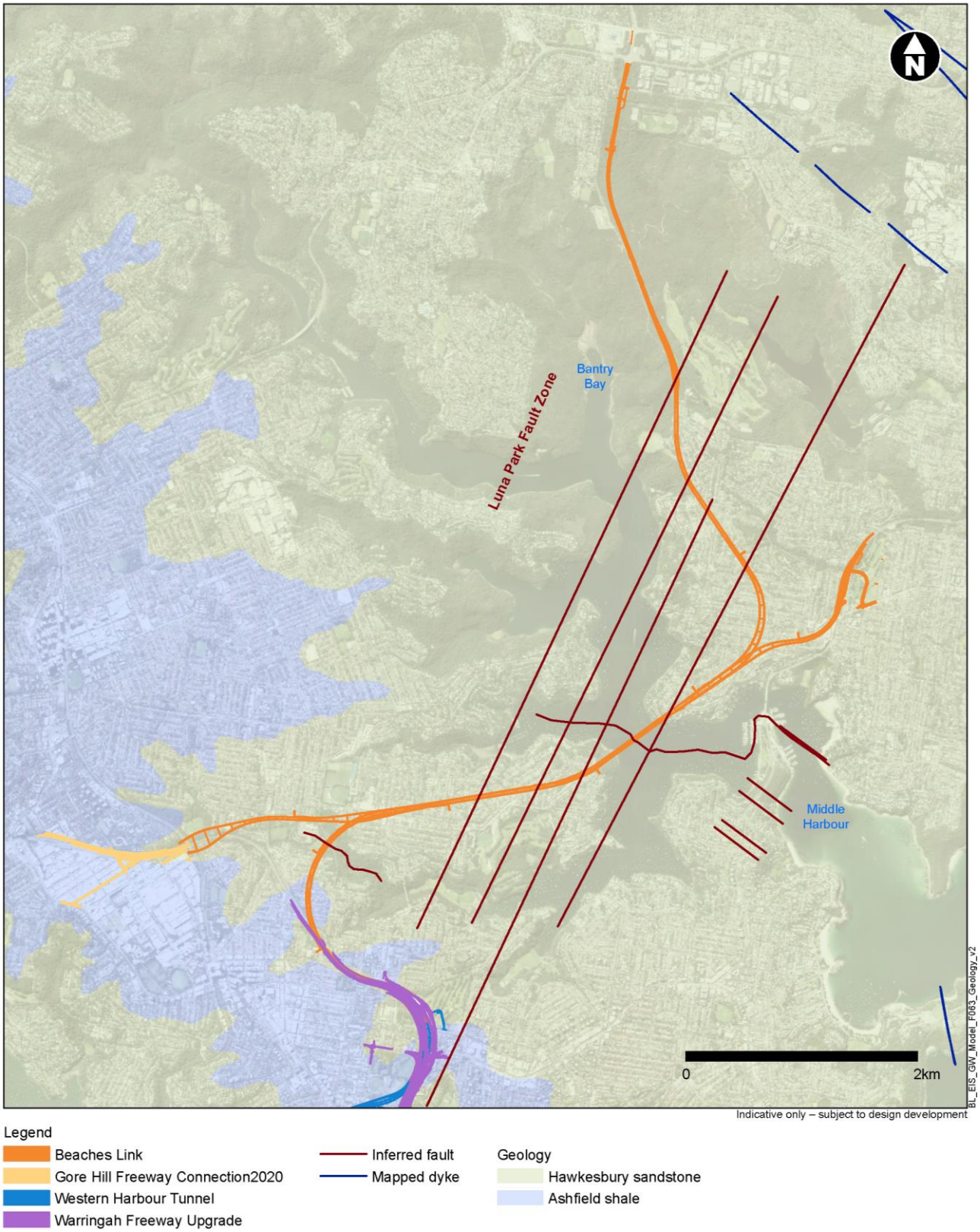


Figure 3-7: Geological units

## 3.4 Soils

The Sydney 1:100,000 Soil Landscape Series Sheet 9130 (Soil Conservation of NSW, 1966) indicates that the residual soils within the project area includes the Blacktown (bt), Disturbed (xx), Hawkesbury (ha), Gymea (gy), Lucas Heights (lh), Lambert (la), Somersby (so) and Glenorie (gn) landscape groups. Most of the project area is underlain by the Gymea landscapes with Hawkesbury landscapes surrounding the shorelines. A description of the soils underlying the project area is provided in Table 3-2 and presented as Figure 3-8.

Table 3-2: Soil units underlying the project area

| Unit | Description |
|---|---|
| Blacktown (bt) | ▪ Landscape – found on gently undulating rises on Wianamatta Group shales with local reliefs of up to 30 metres and slopes of less than five per cent<br>▪ Soils – shallow to moderately deep hardsetting mottled texture contrast soils, red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and in drainage lines<br>▪ Limitations – moderately reactive, highly plastic subsoil, with low fertility and poor drainage. |
| Disturbed (xx) | ▪ Landscape – occurs within other landscapes and is mapped as xx. The topography varies from level plains to undulating terrain and has been disturbed by human activity to a depth of at least 100 centimetres<br>▪ Soils – the original soil has been removed, greatly disturbed or buried. Most of these areas have been levelled to slopes of less than five per cent. Landfill includes soil, rock, building and waste material. The original vegetation has been completely cleared<br>▪ Limitations – are dependent on nature of fill material and include subsidence resulting in a mass movement hazard, soil impermeability leading to poor drainage and low fertility. Care must be taken when these sites are developed. |
| Glenorie (gn) | ▪ Landscape – low rolling and steep hills. Local relief 50–120 m, slopes 5–20 per cent. Convex narrow (20–300 metre) ridges and hillcrests grade into moderately inclined side slopes with narrow concave drainage lines. Moderately inclined slopes of 10–15 per cent are the dominant landform elements<br>▪ Soils - shallow to moderately deep (less than 100 centimetres) red, brown and yellow podzolic soils on crests and slopes. Siliceous sands, leached sands and humic gleys on shale lenses and along drainage lines<br>▪ Limitations - high soil erosion hazard, localised impermeable highly plastic, moderately reactive. |
| Gymea (gy) | ▪ Landscape – found on undulating to rolling low hills on Hawkesbury Sandstone with local reliefs of 20–80 metres and slopes of 10–25 per cent and rock outcrops of less than 25 per cent<br>▪ Soils – shallow to moderately deep yellow earths and earthy sands on crests and inside of benches<br>▪ Limitations – high soil erosion, rock outcrop, shallow highly permeable soil, and very low soil fertility. |

| Unit | Description |
|---|---|
| Hawkesbury (ha) | ▪ Landscape – found on rugged, rolling to very steep hills on Hawkesbury Sandstone with local reliefs of 40–200 metres and slopes of more than 25 per cent and rock outcrops of more than 50 per cent<br>▪ Soils – shallow (less than 50 centimetres), discontinuous lithosols/siliceous sands associated with rock outcrops, earthy sands, yellow earths and some yellow podzolic soils on the inside of benches and along joints and fractures<br>▪ Limitations – extreme soils erosion hazard, mass movement (rockfall) steep slopes, rock outcrop, shallow, stony, highly permeable soils with low fertility. |
| Lambert (la) | ▪ Landscape – undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20–120 metres, slopes 20 per cent. Rock outcropping greater than 50 per cent. Broad ridges, gently to moderately inclined slopes, wide rock benches with low broken scarps, small hanging valleys and areas of poor drainage. Open and closed heathland, scrub and occasional low eucalypt open woodland<br>▪ Soils – shallow (less than 50 centimetres) discontinuous earthy sands and yellow earths on crests and insides of benches; shallow (less than 20 centimetres) siliceous sands/lithosols on leading edges; shallow to moderately deep (less than 150 centimetres) leached sands, grey earths and gleyed podzolic soils in poorly drained areas; localised yellow podzolic soils associated with shale lenses<br>▪ Limitations – very high soil erosion hazard; rock outcropping; seasonally perched water tables; shallow, highly permeable soil; very low soil fertility. |
| Lucas Heights (lh) | ▪ Landscape – gently undulating crests and ridges on plateau surfaces of the Mittagong formation (alternating bands of shale and fine grained sandstones). Local relief to 30 metres, slopes less than 10 per cent. Rock outcropping is absent. Extensively or completely cleared, dry sclerophyll low forest and woodland<br>▪ Soils – moderately deep (50–150 centimetres), hard setting yellow podzolic soils and yellow soloths, yellow earths on outer edges<br>▪ Limitations – stony soil, low soil fertility, low available water capacity. |
| Somersby (so) | ▪ Landscape – gently undulating to rolling rises on deeply weathered Hawkesbury Sandstone plateau. Local relief to 40 metres, slopes less than 15 per cent. Rock outcropping is absent. Crests are broad and convex, valleys are narrow and concave. Extensively cleared, low open woodland and scrubland<br>▪ Soils – moderately deep to deep (100–300 centimetres) red earths and yellow earths overlying laterite gravels and clays on crests and upper slopes; yellow earths and earthy sands on mid slope; grey earths, leached sands and siliceous sands on lower slopes and drainage lines; gleyed podzolic soils in low lying poorly drained areas<br>▪ Limitations – localised permanently high water tables, areas of laterite, and stony soil, very low soil fertility, highly permeable soil. |

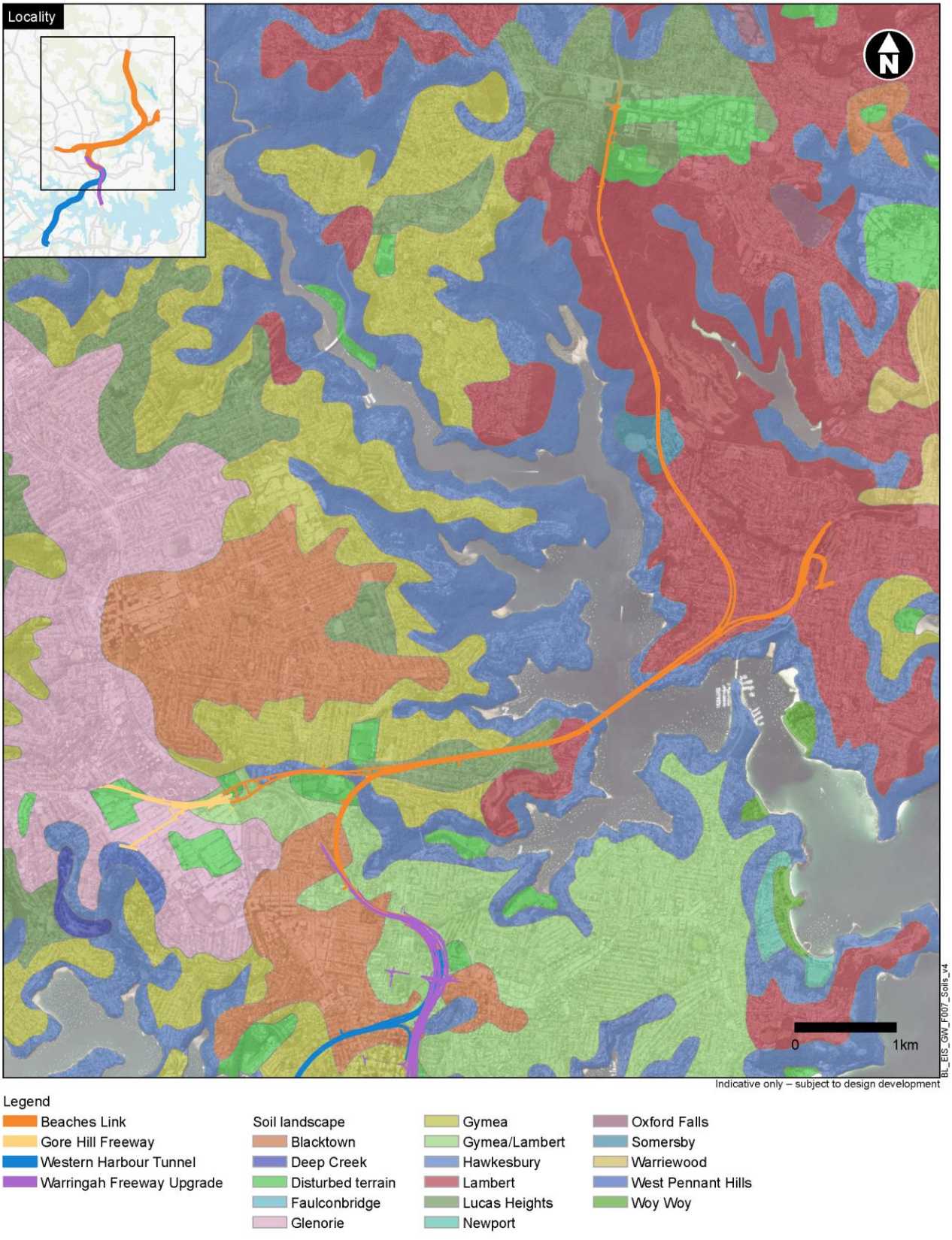


Figure 3-8: Soil landscapes

## 3.5 Soil erosion hazard

The surface areas overlying the project comprises heavily urbanised areas including buildings, roadways, hardstands and vegetated areas (ie gardens, grass, trees). Under current conditions, there are likely to be minimal areas of exposed soils within areas overlying the current project which would contribute to a substantial soil erosion hazard.

## 3.6 Acid sulfate soils risk

Acid sulfate soils (ASS) are the common name given to naturally occurring sediments and soils containing iron sulfides (principally iron sulfide or iron disulfide or their precursors). The exposure of the sulfide in these soils to oxygen by drainage or excavation leads to the generation of sulfuric acid. Areas of ASS can typically be found in low lying and flat locations which are often swampy or prone to flooding.

ASS risk maps from the CSIRO ASRIS database were reviewed to ascertain the probability of ASS being present across the project area. Based on this information, the generalised ASS classes and probability across the project area has been assessed as follows:

- Middle Harbour – (A) high probability/confidence unknown
- Cammeray to Naremburn – (B4) low probability/very low confidence
- Naremburn to Northbridge – (C4) extremely low probability/very low confidence
- Artarmon to Naremburn – (B4) low probability/very low confidence
- Seaforth to Balgowlah – (C4) extremely low probability/very low confidence.

A review of the ASS risk maps from the Willoughby Local Environmental Plan 2012 (NSW Government, 2012a) and the Manly Local Environmental Plan 2013 (NSW Government, 2013b) indicated that the project would be located within areas of Class 5 ASS risk or areas with no probable ASS risk (unclassified). The Mosman Local Environmental Plan 2012 (NSW Government, 2012b) identified areas underlying The Spit as an ASS area (land up to 5 metres AHD) but did not provide an ASS class for this area. The ASS risk maps from the Warringah Local Environmental Plan 2011 (NSW Government, 2011) did not classify the project area as an ASS risk. The North Sydney Local Environmental Plan 2013 (NSW Government, 2013a) does not contain ASS risk maps. The respective local environmental plans do not cover ASS risk within Middle Harbour.

Where relevant, the local environmental plans detail that development consent is required for the carrying out of the following work which may disturb, expose or drain ASS and cause environmental damage within the respective risk classes:

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

Probability of ASS occurrence (from ASRIS) along the alignment is presented on Figure 3-9.

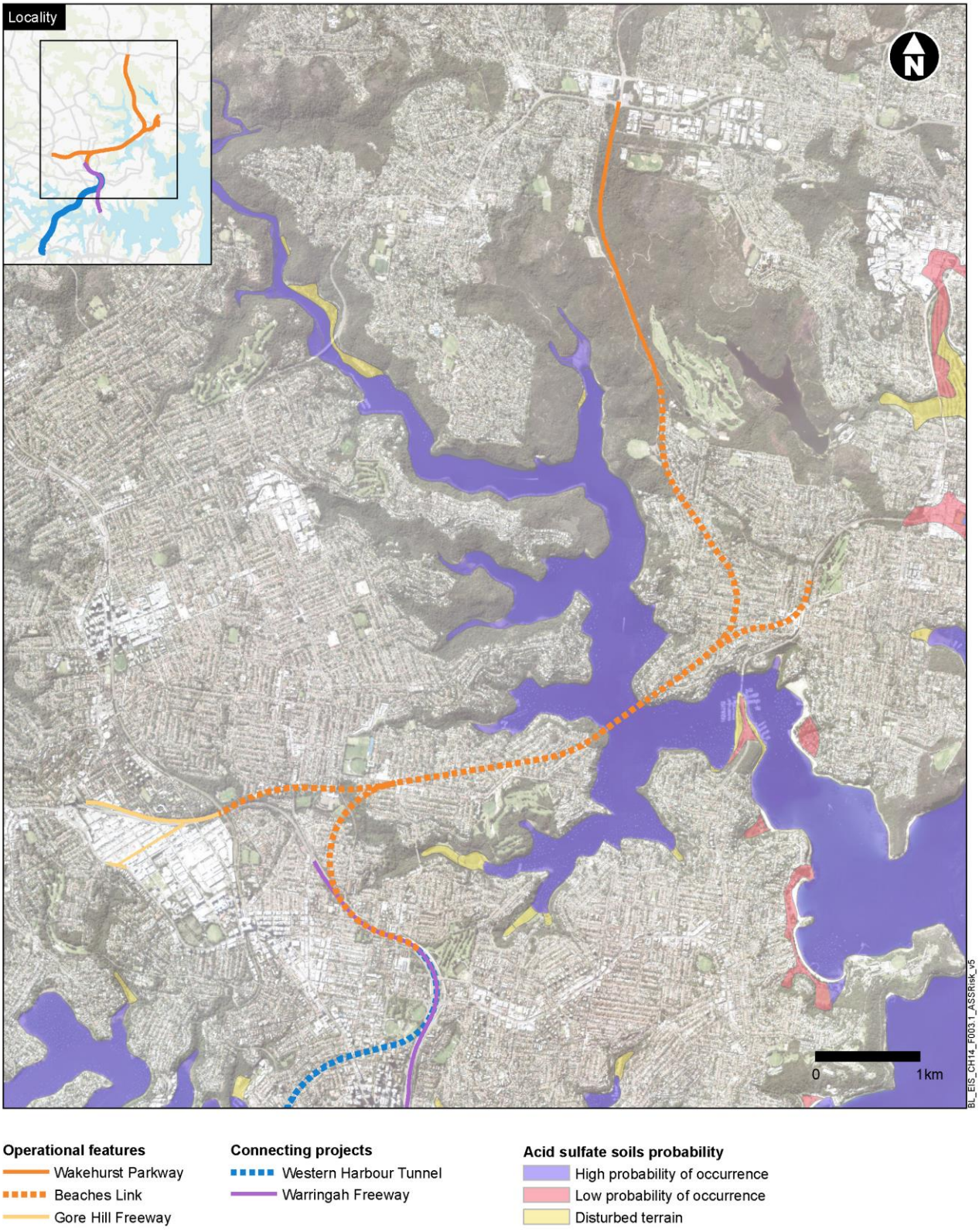


Figure 3-9: ASS probability (from ASRIS)

## 3.7 Soil salinity

With reference to the Department of Infrastructure, Planning and Natural Resources (2003) *Salinity Potential in Western Sydney 2002* map sheet, higher salinity risk in western Sydney is generally associated with residual soils overlying Wianamatta Group Bringelly Shales. Residual soils from this geological unit near drainage lines pose a higher salinity risk potential.

None of the soil landscapes within the project area document salinity as a limitation to the landscape type.

Based on available geological maps, Bringelly Shales are not present within the project area.

No council local environmental plans within the project area contain salinity risk maps.

## 3.8 Hydrogeology

Appendix N (Technical working paper: Groundwater) notes the regional water table across the project area is likely to mimic topography and would flow from areas of high topographic relief to areas of low topographic relief, ultimately discharging to waterways and harbours.

Depth to water table is likely to be highly variable and could range from close to ground surface below in low lying areas and at depth below elevated ridgelines. Localised perched water tables may also occur, as well as multiple water tables resulting from the highly stratified nature of the Hawkesbury Sandstone.

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

The direction of groundwater flow could not be definitively assessed based on current information, although the surrounding topography of the project area and location of water bodies suggests that groundwater would flow in the following directions near the above ground features of the project:

- Easterly direction towards Long Bay (Northbridge) from Cammeray, Naremburn, Willoughby and Artarmon
- Southerly direction towards Long Bay and easterly direction towards Middle Harbour from Northbridge
- Southerly and westerly direction towards Middle Harbour from Seaforth and Killarney Heights
- Southerly and south easterly direction towards Burnt Bridge Creek
- East and west from Wakehurst Parkway towards Manly Dam and Bantry Bay respectively.

The groundwater quality within the Hawkesbury sandstone is typically of high quality with low salinity of neutral to slightly acidic pH. This is due to the sandstone being dominated by clean quartz/feldspar sand grains. Groundwater contained within the Ashfield shale unit is generally of poorer quality than the Hawkesbury sandstone, due to its high clay mineral content, giving rise to a higher salinity.

### 3.8.1 Groundwater bore search

A search of the NSW Department of Planning, Industry and Environment (Regional NSW) groundwater database identified one registered groundwater well within a 500 metre radius of the project:

- GW108224.1.1 is located in St Leonards, about 480 metres from the alignment, and is reported as being used for water supply. The surface geology in the vicinity of GW108224.1.1 is Ashfield shale, however the bore is 132.4 metres deep and is inferred to be constructed in the Hawkesbury Sandstone.

It should also be noted that there are two bores (GW020065.1.1 and GW020067.1.1) located in Frenchs Forest situated approximately 520 metres from the northern end of the alignment. The bores are recorded as being 114.9 metres and 137.1 metres deep respectively and are inferred to exploit the Hawkesbury Sandstone.

## 3.9 Receiving environments

Based on the available information, receiving environments located near project elements which could be potentially impacted by contamination within the project area (if present) are detailed below:

- Long Bay – Potential impact from the surface work and construction of the following construction support sites located at Cammeray (Cammeray Golf Course construction support site (BL1)), Artarmon (Punch Street (BL3); Dickson Avenue (BL4); Barton Road (BL5); and Gore Hill Freeway Median (BL6) construction support sites) and Northbridge (Flat Rock Drive construction support site (BL2))
- Middle Harbour – Potential impact from the construction support sites located within Middle Harbour and the Spit West Reserve (ie Middle Harbour south cofferdam (BL7); Middle Harbour north cofferdam (BL8); and Spit West Reserve construction support site (BL9)). In addition, potential impact from the surface work and construction support sites located from Seaforth to Frenchs Forest (ie Wakehurst Parkway south (BL12; Wakehurst Parkway east (BL13); and Wakehurst Parkway north (BL14) construction support sites)
- Burnt Bridge Creek – Potential impact from the surface work and construction support sites located at Balgowlah (ie Balgowlah Golf Course (BL10) and Kitchener Street (BL11) construction support sites)
- Bantry Bay and Manly Dam – Potential impact from the surface work on the Wakehurst Parkway (between Seaforth and Frenchs Forest – Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13); and Wakehurst Parkway north (BL14) construction support sites)
- Beneficial users of groundwater down gradient from the respective sites (where present).

A search of the Groundwater Dependent Ecosystems Atlas (Bureau of Meteorology) carried out on 26 April 2018 identified the following locations with potential for groundwater dependent ecosystems:

- Upper reaches of Flat Rock Creek at Munro Park (Northbridge) and upper reaches of Quarry Creek, (Cammeray), located south east of the project alignment in the vicinity of the Willoughby Leisure Centre / Flat Rock Drive. Identified as 'moderate to high potential' for terrestrial groundwater dependent ecosystems (Coastal Sandstone Gully Forest, Sandstone Riparian Scrub and Coastal Sandstone Gully Forest)
- Bates Creek (Forestville), about 550 metres west of the project alignment (Wakehurst Parkway). Identified as 'moderate to high' potential for terrestrial groundwater dependent ecosystems (Estuarine Mangrove Forest, Seagrass Meadow and Coastal Sandstone Gully Forest)
- Manly Dam Reserve (Allambie Heights), about 650 metres east of the project alignment (Wakehurst Parkway). Identified as 'moderate' potential for terrestrial groundwater dependent ecosystems (Coastal Sandstone Gully Forest and Coastal Sandstone Plateau Heath).

## 3.10 Site inspection

A site inspection was conducted on 18 September 2017. The site inspection focused on surface areas above the tunnel alignment and all aboveground features of the project, as well as nearby land uses and potential AEIs. The site inspection was only carried out from areas within the project area which were publicly accessible. A second site inspection was carried out on 5 April 2019, however this only looked at additional aboveground project elements that were not covered in the first inspection (ie Sydney Water Reservoir located east of the Wakehurst Parkway at Killarney Heights, Flat Rock Reserve, Northbridge and the proposed location of the motorway control centre at Reserve Road, Artarmon) given then scheme designs.

At the time of the inspection, the project area consisted primarily of residential, business and commercial/industrial land uses. The land use surrounding the project was generally low to high density residential and commercial. Specific observations made during the site inspection are detailed below:

- In the south, the surface portals to the mainline tunnels are located along the existing Warringah Freeway, incorporating the Cammeray Golf Course and road verges and the mainline tunnels continue towards Naremburn and Northbridge

- The Gore Hill Freeway Connection is located within a primarily commercial/industrial land use zoning surrounded by low to medium density residential land use
- Punch Street is used as a roadway, carparking, landscaped areas and commercial/industrial premises
- The proposed motorway control centre was being used as the Freeway Hotel
- Willoughby Leisure Centre, Bicentennial Reserve (including the Baseball Diamond) and Halstrom Park were being used for recreational open space (sporting fields, swimming pool). The former incinerator building was being used as a restaurant
- Flat Rock Reserve was public open space comprising car parking, open space and walking trails. The western portion of the reserve is elevated (likely to be representative of final fill levels) with the eastern portion dropping steeply in elevation to Flat Rock Creek
- The land use of the suburbs of Willoughby and Northbridge is primarily low density residential
- The Spit West Reserve is currently recreational open space with a marina located within the northern portion of the reserve
- Balgowlah Golf Course is located between close to the corner of Sydney Road and Burnt Bridge Creek Deviation
- The land use of the suburbs of Seaforth, Balgowlah and North Balgowlah is primarily low density residential with increasing areas of bushland to the north of these suburbs (ie areas surrounding the Wakehurst Parkway)
- Possible incinerator chimney stack located at the corner of Corner Dalwood Avenue and Frenchs Forest Road at Seaforth
- Bantry Bay Reservoir comprises two above ground potable water reservoirs and associated infrastructure. The eastern portion of the site had been filled, presumably to facilitate construction of the reservoirs. General demolition materials were observed on the surface of the areas surrounding the eastern portion of this site
- The intersection of the Wakehurst Parkway and Warringah Road at Frenchs Forest is highly modified, associated with the construction of the Northern Beaches Hospital and associated road upgrades.

# 4. Information review

Several sources were investigated to determine the history of land use within and next to the project. The following list details the sources of historical information and a summary of information provided by each source:

- NSW Land and Property Management Authority, Land and Property Information Division: Historical aerial photographs (1930 to 2005)
- NSW EPA Contaminated Sites Register and Record of Notices
- Available aerial imagery services including Google Earth, SIX Maps and Metro Map
- Yellow Pages business directory.

## 4.1 Historical aerial photography

Historical aerial photographs from the Land and Property Information Division were reviewed for the years 1930, 1955, 1961, 1970, 1975, 1983/84, 1986, 1991, 1994, 1998, 2002 and 2005. The aerial photography review focused on the key land based and above ground construction support sites (detailed in Section 1.3) and surface work, specific AEIs and general land use that could be potentially impacted by the project construction work (refer to Chapter 6 (Construction work) of the environmental impact statement).

The findings of the review of historical aerial photographs are provided in Tables A.1 to A.10 in Annexure A. A summary is provided in Table 4-1.

Table 4-1: Summary of potential contamination issues - Historical aerial photography review

| Site | Potential contamination |
|---|---|
| **Construction support sites** | |
| Cammeray Golf Course (BL1) | ▪ Inappropriate handling and disposal of building materials during demolition of buildings for construction of the Warringah Freeway<br>▪ Filling with material of unknown quality during construction of the Warringah Freeway<br>▪ Particulate matter deposition from vehicles using the Warringah Freeway<br>▪ Chemical use and storage at golf course. |
| Flat Rock Drive (BL2) | ▪ Infilling with waste materials. |
| Punch Street (BL3) | ▪ Commercial/industrial use of site and surrounding areas<br>▪ Degradation of building materials used in bridge structure<br>▪ Inappropriate handling and disposal of building materials during demolition of bridge structure<br>▪ Filling with material of unknown quality during creek realignment<br>▪ Filling with material of unknown quality during construction of Gore Hill Freeway. |
| Dickson Avenue (BL4) | ▪ Commercial/industrial use of site and surrounding areas. |
| Barton Road (BL5) | ▪ Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of Gore Hill Freeway. |
| Gore Hill Freeway median (BL6) | ▪ Filling with material of unknown quality during redevelopment of quarry<br>▪ Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of the Gore Hill Freeway. |

| Site | Potential contamination |
|---|---|
| Spit West Reserve (BL9) | ▪ Land reclamation. |
| Balgowlah Golf Course (BL10) | ▪ Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of the Burnt Bridge Creek Deviation<br>▪ Chemical use and storage at golf course. |
| Kitchener Street (BL11) | ▪ Filling with material of unknown quality during construction of Burnt Bridge Creek Deviation. |
| Wakehurst Parkway south (BL12) | ▪ Contamination resulting from degradation of asphalt road surface<br>▪ Degradation of hazardous building materials from structures currently present on site. |
| Wakehurst Parkway east (BL13) | ▪ Contamination resulting from degradation of asphalt road surface<br>▪ Degradation of paint from use of the adjacent site as water reservoirs. |
| Wakehurst Parkway north (Bl14) | ▪ Stockpiling of material of unknown quality. |
| **Other surface sites** | |
| Gore Hill Freeway surface work | ▪ Commercial/industrial use of site and surrounding areas<br>▪ Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of Gore Hill Freeway. |
| Balgowlah connection surface work | ▪ Demolition - Inappropriate handling and disposal of building materials during demolition of buildings for construction of the Burnt Bridge Creek Deviation<br>▪ Filling with material of unknown quality during construction of Burnt Bridge Creek Deviation. |
| Wakehurst Parkway surface work | ▪ Contamination resulting from degradation of asphalt road surface.<br>▪ Potential illegal fly tipping of waste |
| Motorway Control Centre | ▪ Commercial/industrial use of site and surrounding areas. |

With respect to project design changes, additional review of historical aerial imagery was undertaken to ascertain historical land usage within and adjacent to the Balgowlah Connection surface works and the Wakehurst Parkway (between Seaforth and Frenchs Forest). The results of the additional review are provided below.

A review of the historical aerial imagery for the location where the Balgowlah Connection surface work would occur indicate that the site was generally occupied by residential development and bushland (riparian vegetation surrounding Burnt Bridge Creek) up until sometime between 1979 and 1983/84 when construction of the Burnt Bridge Creek deviation started. Areas next to the proposed Balgowlah Connection surface work location have remained generally as residential and open space (golf course) land use.

A review of the historical aerial imagery for the Wakehurst Parkway indicate that the road has been present since before 1930. The areas surrounding the Wakehurst Parkway have remained bushland since the 1930s. There was no observable evidence of extensive quarry or landfilling activities adjacent to the Wakehurst Parkway.

## 4.2 Other information sources

### 4.2.1 Aerial imagery services

Jacobs carried out a review of available aerial imagery services including Google Earth, SIX Maps and Metro Maps to ascertain current above ground activities and/or operations which could potentially represent contamination sources. The table below shows only current, above ground activities and/or operations which could potentially represent sources of contamination. Other potential sources of contamination, historical and/or those located underground, which cannot be observed from currently available aerial imagery services are discussed in the sections below. The results of the aerial imagery review are presented in Table 4-2.

### 4.2.2 Business directories

A Yellow Pages internet search was carried out to assess potential contamination risks associated with current activities and/or operations near the project area. The Yellow Pages internet search was based on matching business types (as best as possible) listed in the Yellow Pages with those activities that may cause contamination as outlined in Managing Land Contamination: Planning Guidelines SEPP 55 – Remediation of Land (Department of Urban Affairs and Planning & EPA, 1998). The Yellow Pages search was limited to the suburbs within and surrounding the project area including Cammeray, Crows Nest, Naremburn, Artarmon, Willoughby, Northbridge, Seaforth, Balgowlah, North Balgowlah and Frenchs Forest. The results of the business directory review are presented in Table 4-3.

Table 4-2: Potential contamination sources (current aerial imagery review)

| Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants |
|---|---|---|---|---|---|
| Unsealed areas next to Warringah Freeway – Eastern side (Cammeray Golf Course) at Cammeray | Within | Cammeray Golf Course construction support site (BL1) (surface) | Particulate matter deposition from vehicles | Surface | Heavy metals, hydrocarbons (mainly polycyclic aromatic hydrocarbons (PAH)), asbestos |
| Depot (possible council work depot) – Ernest Street at North Sydney | Nearby | Tunnel (depth) | Residuals from use as a work depot | Surface and depth (depth distribution associated with potential underground storage tanks) | Heavy metals, hydrocarbons, pesticides, asbestos |
| Unsealed areas next to Warringah Freeway – Eastern side (between freeway and Miller Street on ramp) at Cammeray | Within | Cammeray Golf Course construction support site (BL1) (surface) | Particulate matter deposition from vehicles | Surface | Heavy metals, hydrocarbons (mainly PAH), asbestos |
| Unsealed areas next to Warringah Freeway – Western side (between Miller Street and West Street) at Cammeray | Within | Cammeray Golf Course construction support site (BL1) (surface) | Particulate matter deposition from vehicles | Surface | Heavy metals, hydrocarbons (mainly PAH), asbestos |
| Unsealed areas next to Warringah Freeway – Western side (between West Street and Brook Street) at Crows Nest | Within | Cammeray Golf Course construction support site (BL1) (surface) | Particulate matter deposition from vehicles | Surface | Heavy metals, hydrocarbons (mainly PAH), asbestos |

| Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants |
|---|---|---|---|---|---|
| Unsealed areas next to Warringah Freeway – Eastern side (between Brook and Chandos Streets) at Crows Nest | Within | Tunnel (depth) | Particulate matter deposition from vehicles | Surface | Heavy metals, hydrocarbons (mainly PAH), asbestos |
| Unsealed areas next to Warringah Freeway – Western side (between Brook Street and Willoughby Road) at Naremburn | Within | Tunnel (depth) | Particulate matter deposition from vehicles | Surface | Heavy metals, hydrocarbons (mainly PAH), asbestos |
| Cemetery – West Street at Crows Nest | Nearby | Tunnel (depth) | Burials | Depth | Heavy metals, nutrients |
| Punch Street at Artarmon | Within | Punch Street construction support site (BL3) (surface) | Commercial/industrial use of site and surrounding areas (ie manufacturing, chemical use and storage etc). | Surface and depth (potentially 0–4.0 metres). | Heavy metals, hydrocarbons, volatile organic compounds (VOC) |
| Freeway Hotel, Reserve Road at Artarmon | Within | Motorway Control Centre (surface) | Commercial/industrial use of site and surrounding areas (ie manufacturing, chemical use and storage etc). | Surface and depth (potentially 0–4.0 metres). | Heavy metals, hydrocarbons, VOC |
| Service Station – Corner Artarmon and Willoughby Roads at Artarmon | At surface, not vertically above tunnel | Tunnel (depth) | Leaks and spills from underground petroleum storage infrastructure | Depth | Heavy metals, hydrocarbons |

| Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants |
|---|---|---|---|---|---|
| Sediments within Middle Harbour and adjacent to The Spit | Above | Tunnel (depth) | Contamination associated with harbour use and catchment inputs | Surface to recent (about 150 year) depositional extent | Heavy metals, hydrocarbons, pesticides, organotins, per- and poly-fluoroalkyl substances (PFAS) |
| Balgowlah Golf Course at Balgowlah | Adjacent | Balgowlah Golf Course construction support site (BL10) (surface) | Degradation of hazardous building materials from structures currently present on the site | Surface (potentially 0 to 0.1 metres) | Heavy metals, hydrocarbons, pesticides, asbestos |
| | | | Chemical use and storage at golf course | Surface (potentially 0 to 1.0 metres) | Heavy metals, hydrocarbons, VOC, pesticides |
| Residential properties, Dudley Street at Balgowlah | Within | Balgowlah Golf Course construction support site (BL10), new open space and recreation facilities and Balgowlah Connection (surface) | Degradation of hazardous building materials from structures currently present on the site | Surface | Heavy metals, hydrocarbons, pesticides, asbestos |
| Residential properties – Judith Street and Wakehurst Parkway at Seaforth | Within | Wakehurst Parkway south construction support site (BL12) (surface) | Degradation of hazardous building materials from structures currently present on the site | Surface | Heavy metals, hydrocarbons, pesticides, asbestos |
| Sydney Water Reservoir – Kirkwood Street at Seaforth | Nearby | Wakehurst Parkway east construction support site (BL13) (surface) | Deposition from the degradation of painted reservoir surfaces | Surface | Heavy metals |

| Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants |
|---|---|---|---|---|---|
| Wakehurst Parkway – Seaforth to Frenchs Forest | Within | Wakehurst Parkway surface work (surface) | Particulate matter deposition from vehicles and degradation of asphaltic road surface | Surface | Heavy metals, hydrocarbons (mainly PAH), asbestos |
| Wakehurst Parkway (north of Warringah Road) at Frenchs Forest | Adjacent | Wakehurst Parkway north construction support site (BL14) (surface) | Stockpiling | Surface (potentially 0 to 0.1 metres) | Heavy metals, hydrocarbons, pesticides, asbestos |

Table 4-3: Potential contamination sources (business directory review)

Next to construction footprint
Within 500 m of construction footprint
Greater than 500 m from construction footprint

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Acid/alkali plant and formulation | Acid production, chlorine and sodium hydroxide production | Acid (Acid) | No listings within surrounding suburbs | | | | | | | | | |
| Agricultural/ horticultural activities | Farming, cropping, market gardens, nurseries | Agricultural-chemicals (Agri-C), Nursery (Nurs), Market Gardens (Mark), Farms (Farm) | | | | | | | Peninsula Palms Indoor Plant Hire: 40 Judith Street, Seaforth (Nurs) | | | |
| Airports | Airports | Airports (Airp) | No listings within surrounding suburbs | | | | | | | | | |
| Asbestos production and disposal | Asbestos disposal sites | Asbestos Disposal (Asbe-D) | No listings within surrounding suburbs | | | | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Chemicals manufacture and formulation | Suppliers | Chemicals-industrial (Chem-I), Chemicals-manufacturing (Chem-M) | | | | | | | | | | Dow Chemical: 20 Rod-borough Road Frenchs Forest (Chem-M) |
| | | | | | | | | | | | | Australian Pharmaceutical: 14 Rod-borough Road Frenchs Forest (Chem-M) |
| Defence work | Bases, depots | Defence Force (Defe-F) | No listings within surrounding suburbs | | | | | | | | | |
| Drum re-conditioning work | Drum re-conditioners | Drum Re-conditioning (Drum-R) | No listings within surrounding suburbs | | | | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Dry cleaning establish-ments | Dry cleaners | Dry Cleaners (Dry-C) | | Blue and White Dry Cleaners: Cnr West and Falcon Streets Crows Nest (Dry-C) | Super Dry Clean and Laundry: 302 Willoughby Road Naremburn (Dry-C) | | High Centre Dry Cleaning and Laundrette: 178 Penshurst Street Willoughby (Dry-C) | Ultraclean Dry Cleaners: 69 Strath-allen Avenue North-bridge (Dry-C) | | Lawrence Dry Cleaners: Cnr Condamine Street and Sydney Road Balgowlah (Dry-C) | | Forestway Dry Cleaners: Cnr Warringah Road and Forest Way Frenchs Forest (Dry-C) |
| | | | | | | | Country Club Dry Cleaners: 333 Penshurst Street Willoughby (Dry-C) | | | Balgowlah Dry Cleaners: 343 Sydney Road Balgowlah (Dry-C) | | At Your Service Dry Cleaners: 71 Sorlie Road Frenchs Forest (Dry-C) |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Electrical manufacturing (transformers) | Sub-stations, switching and high voltage yards | Transformers (Tran), Transformer Manufacturers (Tran-M), Transformer Oil (Tran-O) | | | | | | | | | | Telectran and Ferguson Transformers: 12A Rod-borough Road Frenchs Forest (Tran, Tran-M) |
| Electroplating and heat treatment premises | Metal plating, galvanising, chrome plating | Electroplating (Elcp) | No listings within surrounding suburbs | | | | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Engine work | Mechanics | Engine Reconditioning (Eng-R), Mechanics (Eng-M) | | VAR: 190 West Street Crows Nest (Eng-M) | | Balmain Engineer-ing: 38 Punch Street Artarmon (Eng-R) | Marco Salmi Motors: 5 Nathan Lane Willoughby (Eng-M) | | | Balgowlah Automotive: 441 Sydney Road Balgowlah (Eng-M) | | L. Griffiths: 32 Caree-bong Road Frenchs Forest (Eng-M) |
| | | | | BMW Speciali st: 31 Atchiso n Street Crows Nest (Eng-M) | | Leons Engineer-ing Services: 94A Reserve Road Artarmon (Eng-R) | | | | Various mechanical services: 1-3 Paton Place Balgowlah (Eng-M) | | |
| | | | | Tower Motors: 72 Holter man Street Crows Nest (Eng-M) | | Sydney Auto Wreckers: 43 Whiting Street Artarmon (Eng-R) | | | | Sydney Road Service Centre: 439 Sydney Road Balgowlah (Eng-M) | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | Falcon Street Garage: 125 Falcon Street Crows Nest (Eng-M) | | Burton and Scerra: 7A Dickson Avenue Artarmon (Eng-M) | | | | Blasini & Davis Mechanical: 67 Kenneth Road Balgowlah (Eng-M) | | |
| | | | | Ultratune: 8 Alex-ander Street Crows Nest (Eng-M) | | Stirling and Reed Automotive: 74 Hotham Parade Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | Sydney Motor Auto Repairs : 97 West Street Crows Nest (Eng-M) | | North Shore Mechanical Repairs: 2A Whiting Street Artarmon (Eng-M) | | | | | | |
| | | | | Mobil Car Care: 27 Falcon Street Crows Nest (Eng-M) | | Mildren: 22 Cleg Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Jobsons Mechnical: 21 Hotham Parade Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | Don Houghton Automotive: 51 Whiting Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Cremorne Prestige Service: 39 Hotham Parade Artarmon (Eng-M) | | | | | | |
| | | | | | | Moto Technical: 98 Reserve Road Artarmon (Eng-M) | | | | | | |
| | | | | | | Artarmon Automotive Services: 63 Whiting Street Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | Arcus Auto Services: 52 Hotham Parade Artarmon (Eng-M) | | | | | | |
| | | | | | | Scuderia Servizio European: 8 Whiting Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Northside Autoworks: 27 Carlotta Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Pacific Automotive Services: 29 Dickson Avenue Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | NRMA Motorserve: 43 Herbert Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Artarmon Mazda: 3 Campbell Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Leaver Jaguar: 24 Whiting Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Phenix Industries: 19b Dickson Avenue Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | Simply Sports Cars: 17 Hotham Parade Artarmon (Eng-M) | | | | | | |
| | | | | | | Artarmon Auto and Mechanical Services: 50 Hotham Parade Artarmon (Eng-M) | | | | | | |
| | | | | | | Audcare: 11 Whiting Street Artarmon (Eng-M) | | | | | | |
| | | | | | | VW Repairers: 47 Whiting Street Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | Automedics: 2 Campbell Street Artarmon (Eng-M) | | | | | | |
| | | | | | | JNP Bodyworks: 28 Hotham Parade Artarmon (Eng-M) | | | | | | |
| | | | | | | Autoactive Car Services: 36 Hotham Parade Artarmon (Eng-M) | | | | | | |
| | | | | | | Chatswood Nissan: 555 Pacific Highway Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | Reliable Automotive Services: 15 Dickson Avenue Artarmon (Eng-M) | | | | | | |
| | | | | | | Northshore Tyres: 75 Dickson Avenue Artarmon (Eng-M) | | | | | | |
| | | | | | | Alto Land Rover: 65 Whiting Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Andrea Motori: 13 Whiting Street Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | E & A Motors: Cnr Cleg Street and Lambs Road Artarmon (Eng-M) | | | | | | |
| | | | | | | European Galleria: 36 Dickson Avenue Artarmon (Eng-M) | | | | | | |
| | | | | | | Five Ways Garage: 18 Lambs Road Artarmon (Eng-M) | | | | | | |
| | | | | | | Armstrong Automotive Services: 57 Whiting Street Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | Lambs Road Auto Repairs: 20 Lambs Road Artarmon (Eng-M) | | | | | | |
| | | | | | | G & F Motor Repairs: 23 Whiting Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Chatswood Toyota: 12 Marden Street Artarmon (Eng-M) | | | | | | |
| | | | | | | Alto Group: 387 Pacific Highway Artarmon (Eng-M) | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| | | | | | | 4.mance Automotive: 86 Hotham Parade Artarmon (Eng-M) | | | | | | |
| Explosives industry | Ammunition, fireworks | Explosives (Expl) | No listings within surrounding suburbs | | | | | | | | | |
| Gas work | Gas work | No listing | No listings within surrounding suburbs | | | | | | | | | |
| Iron and steel work | Smelters, foundries | Foundry (Fnd) | No listings within surrounding suburbs | | | | | | | | | |
| Landfill sites | Landfills | Landfills (Lnfl) | No listings within surrounding suburbs | | | | | | | | | |
| Metal treatment | | No listing | No listings within surrounding suburbs | | | | | | | | | |
| Mining and extractive industries | | Mining (Ming) | No listings within surrounding suburbs | | | | | | | | | |
| Oil production and storage | Refineries, recyclers | Lubricants (Oil-L), Refineries (Oil-Ref), Recyclers (Oil-Recyc), Reconditioners (Oil-Recon) | No listings within surrounding suburbs | | | | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Paint formulation and manufacture | Paint manu-facturers | Manufacturers (Pnt-M) | | | | Murobond Coatings: 81 Dickson Avenue Artarmon (Pnt-M) | | | | PPG Industries Australia: 206 Con-damine Street Balgowlah (Pnt-M) | | |
| Pesticide manufacture and formulation | Pesticide and chemical manufacture | Insecticides, herbicides and fungicides (Pest) | No listings within surrounding suburbs | | | | | | | | | |
| Power stations | | Power Station (Pows) | No listings within surrounding suburbs | | | | | | | | | |
| Railway yards | | No listing | No listings within surrounding suburbs | | | | | | | | | |
| Scrap yards | Recyclers | Metal Recyclers (Met-R) | No listings within surrounding suburbs | | | | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Service stations | Service Stations | Service Stations (Serv) | Cammeray Service Centre: 481 Miller Street Cammeray (Serv) | Caltex Wool-worths: 111-121 Falcon Street Crows Nest (Serv) | | BP Australia: 422 Pacific Highway Artarmon (Serv) | Coles Express: 616-626 Willoughby Road Willoughby (Serv) | | | | | |
| | | | Coles Express: Cnr Miller and Palmer Street Cammeray (Serv) | | | | | | | | | |
| Sheep and cattle dips | Sheep and cattle dips | Sheep dipping (Shdp) | No listings within surrounding suburbs | | | | | | | | | |
| Smelting and refining | See iron and steel work | See iron and steel work | No listings within surrounding suburbs | | | | | | | | | |
| Tanning and associated trades | Tanneries | Tanneries (Tann) | No listings within surrounding suburbs | | | | | | | | | |

| SEPP 55 activities | General activity description | Yellow Pages business description | Suburb | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Cammeray | Crows Nest | Naremburn | Artarmon | Willoughby | North-bridge | Seaforth | Balgowlah | North Balgowlah | Frenchs Forest |
| Waste storage and treatment | Transfer stations, waste treatment facilities | Waste Transfer Station (Wts) | No listings within surrounding suburbs | | | | | | | | | |
| Wood preservation | | Timber Preservation (Timb) | No listings within surrounding suburbs | | | | | | | | | |

## 4.3 NSW contaminated sites register

A search conducted on 30 April 2018 of NSW EPA Contaminated Sites Record of Notices (under section 58 of the Contaminated Land Management Act 1997 (CLM Act)) and the list of contaminated sites notified to NSW EPA (under section 60 of the CLM Act) indicated that there were seven sites registered with NSW EPA within 500 metres of the project that were either regulated (current notices) or had been notified.

The sites are shown in Figure 4-1 and summarised in Table 4-4.

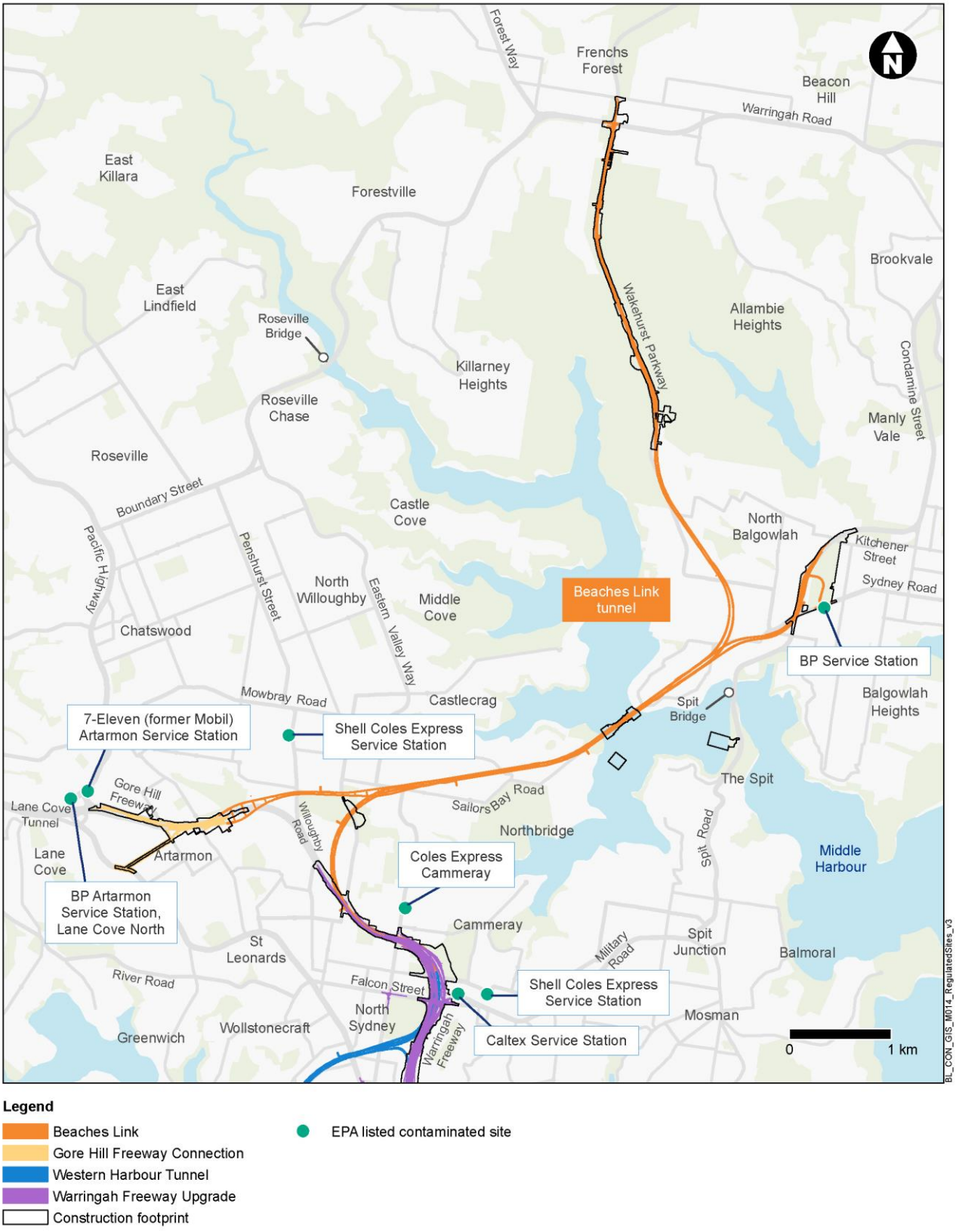


Figure 4-1: Regulated/notified sites within 500m of the project

Table 4-4: Regulated/notified sites within 500 metres of the project

| Site | Suburb | Regulated/ notified | Site address | Site activity | Contamination status | Location relative to project | Construction element |
|---|---|---|---|---|---|---|---|
| 1 | Neutral Bay | Notified (section 60) | 16–38 Military Road | Service Station | Regulation being finalised | About 150 metres south of the project | Cammeray Golf Course construction support site (BL1) |
| 2 | Neutral Bay | Notified (section 60) | 200–204 Ben Boyd Road | Service Station | Regulation under CLM Act not required | About 300 metres south east of the project | Cammeray Golf Course construction support site (BL1) |
| 3 | Cammeray | Notified (section 60) | 477–483 Miller Street | Service Station | Under assessment | About 300 metres north of the project | Tunnel |
| 4 | Artarmon | Notified (section 60) | 477 Pacific Highway | Service Station | Under assessment | About 200 metres north west of the project | Gore Hill Connection surface work |
| 5 | Artarmon | Notified (section 60) | 432 Pacific Highway / Lane Cove North | Service Station | Under assessment | About 300 metres west of the project | Gore Hill Connection surface work |
| 6 | Willoughby | Notified (section 60) | 616–626 Willoughby Road | Service Station | Regulation under CLM Act not required | About 500 metres north of the project | Flat Rock Drive construction support site (BL2) |
| 7 | Balgowlah | Notified (section 60) | Corner Sydney Road and Maretimo Street | Service Station | Regulation under CLM Act not required | Less than 100 metres south of the project | Balgowlah Golf Course construction support site (BL10) |

The contamination mechanisms associated with activities carried out on the above service station sites are likely to be associated with deeper contamination (ie potentially four to 10 metres below ground level – below underground storage tanks) from leaks from underground fuel infrastructure. In consideration of the contamination mechanisms associated with service station sites, the construction elements and distance from the project, contamination (if present) from these sites would pose a low risk to construction activities across the project.

Contamination exposure risk from service stations located near surface works and construction support sites is likely to be low (ie contamination, if present is likely to be below the depth of construction activities). Only one service station site is located near tunnel elements of the project (Cammeray – about 300 metres north of the project).

Considering the lateral and vertical separation between this service station and the tunnel and the hydrogeological conditions (sandstone and groundwater flow direction towards the east), contamination from the site (if present) is unlikely to pose a substantial risk to construction and operation of the tunnel.

## 4.4 Previous contamination site investigations

Information from the following reports was reviewed in preparation of this report:

- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Groundwater Monitoring Factual Report – Round One (Douglas Partners and Golder Associates (DPGA), 2017a)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Groundwater Monitoring Factual Report – Round Two (DPGA, 2017b)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Geotechnical Factual Report – Land Investigations (DPGA, 2017c)
- Northern Beaches Hospital Road Connectivity and Network Enhancements Project – Factual Baseline Water Quality Monitoring Report (24 months) (SMEC, 2017)
- Western Harbour Tunnel and Beaches Link – Geotechnical Investigations Factual Report (GFR1) (AECOM and Coffey (AEC), 2017)
- Western Harbour Tunnel and Beaches Link – Contamination Factual Report (CFR) (AECOM and Coffey, 2018)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Groundwater Monitoring Factual Report – Round Four (DPGA, 2018a)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Groundwater Monitoring Factual Report – Round Five (DPGA, 2018b)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Groundwater Monitoring Factual Report – Round Six (DPGA, 2018c)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Groundwater Monitoring Factual Report – Round Seven (DPGA, 2018d)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Groundwater Monitoring Factual Report – Round Eight (DPGA, 2018e)
- Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Contamination Factual Report – Marine Investigations (DPGA, 2018f)

  Western Harbour Tunnel and Beaches Link Geotechnical Investigation. Contamination Factual Report – Land Investigations (DPGA, 2018g)
- Western Harbour Tunnel and Beaches Link – Groundwater Monitoring Report 6 – September 2018 (AECOM, 2018)
- Western Harbour Tunnel and Beaches Link – Groundwater Monitoring Report 7 – October 2018 to March 2019 (AEC, 2019).

### 4.4.1 Harbour sediments

Sediment sampling was carried out within the proposed Middle Harbour crossing and construction support sites at Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and the Spit West Reserve construction support site (BL9) as part of the DPGA (2018f) investigation. Sediment samples were collected from a range of depths and analysed for particle size distribution, contaminant compounds including heavy metals, hydrocarbon compounds (total recoverable hydrocarbons (TRH), benzene / toluene / ethyl-benzene and xylenes (BTEX), PAH, tributyltin (TBT), organochlorine pesticides (OCP), polychlorinated biphenyls (PCB), per- and poly-fluoroalkyl substances (PFAS) and dioxins. The results of the laboratory analysis were compared against the following guideline criteria:

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

The results of the investigations indicated that the sediment closest to the shorelines comprised a gravelly, muddy sand while the sediment from the remainder of the crossing comprised a grey green mud with some layers of sand and shell. More elevated concentrations of contaminants were observed for the grey green mud up to one metre below the harbour bed.

The results of the geochemical testing were used to calculate the 95 per cent upper confidence limit (UCL) of the mean concentrations of contaminants for the two main material types observed at the crossing. The results indicated that the 95 per cent UCL of the mean concentrations for all contaminants were below guideline levels for the gravelly, muddy sand closest to the shoreline and for the grey green mud greater than one metre below harbour bed. Both these material types are considered suitable for offshore disposal.

For the grey green mud up to one metre below harbour bed, the 95 percent UCL of the mean concentrations of copper, lead, mercury and silver all exceeded the NAGD screening levels (and ISQG) triggering the need for Phase III testing (bioavailability and elutriate testing) in accordance with the NAGD to determine suitability of this material for offshore disposal. The results of the Phase III testing indicated that the heavy metals copper, lead and zinc may be bioavailable. Phase IV testing of the grey green mud up to one metre below the harbour bed would be required to determine its suitability for offshore disposal. If offshore disposal is not appropriate, land-based disposal of this material would be required.

Concentrations of lead and benzo(a)pyrene for the grey green mud up to one metre below the harbour bed, exceeded the specific contaminant concentration for waste classification without toxicity characteristics leaching procedure (TCLP) testing. These exceedances triggered the need for TCLP testing to allow a final waste classification. Following completion of the TCLP testing, the final waste classification of the grey green mud up to one metre below the harbour bed is general solid waste. However, as tributyltin was detected in the material, land-based disposal of the material would need to be in accordance with the NSW EPA chemical control order for organotin waste materials. Although dioxins were also detected in the material, the dioxins were at concentrations below the criteria triggering the chemical control order for dioxin contaminated waste materials.

Contaminant compounds exceeding the nominated criteria at the respective sediment sample locations are provided in Sediment tables.

The nominated guidelines (detailed above) do not include criteria for PFAS and dioxins. One PFAS compound (perfluorohexane sulfonic acid) and dioxins were detected above laboratory levels of reporting in sediment samples collected from Middle Harbour. PFAS and dioxin analysis was not carried out on sediment samples collected from The Spit.

Limited samples were collected for ASS testing as part of the DPGA (December 2018f) investigation. A review has been carried out of the analytical results in comparison to Table 4-4 of the *Acid Sulfate Soil Manual* (Acid Sulfate Soils Management Advisory Committee, 1998). The peroxide oxidisable sulfur results reported at location B119WA_VC-A (0.224 per cent) from Middle Harbour exceed the oxidisable sulfur action criteria of 0.03 per cent

Annexure C includes a memo which outlines sediment contamination levels and results of elutriate testing that was carried out by Royal HaskoningDHV (2020) subsequent to the investigations carried out by DPGA (2018f), for the purpose of assessing the suitability of dredged sediments for offshore disposal. Offshore disposal is an activity regulated by the Australian Government under the Environment Protection (Sea Dumping) Act 1981 (Cwlth). Determination of the offshore disposal permit(s) is subject to assessment and approval by the Commonwealth.

Royal HaskoningDHV (2020) results of elutriate testing indicate that water quality impacts at the dredging site due to dissolved contaminants would not be expected. For further information please refer to Annexure C.

### 4.4.2 Groundwater

Groundwater quality data has been reported from seven sampling events at up to four standpipe piezometers by DPGA (2017a, 2017b, 2018a, 2018b, 2018c, 2018d and 2018e). Details of the monitoring sites are shown in Table 4-5.

Table 4-5: Groundwater quality monitoring locations – DPGA, 2017a

| Bore ID | Location | Monitored formation | No. of samples | Comments |
|---|---|---|---|---|
| B114A | Artarmon | Hawkesbury Sandstone | 6 | N/A |
| B127A | North Balgowlah | Hawkesbury Sandstone | 7 | N/A |
| B134A | Bicentennial Reserve Baseball Diamond, Willoughby | Hawkesbury Sandstone | 7 | N/A |
| B238A | Northbridge | Hawkesbury Sandstone | 5 | Metals results considered unreliable due to high pH |

The DPGA (2017a) report indicated that groundwater sampling was carried out from wells B114A (Artarmon), B127A (North Balgowlah), B134A (Bicentennial Reserve, Willoughby) and B238A (Northbridge). Although present within the analytical tables, the location of well B238A was not identified on the figures contained within the report. Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and benzene, toluene, ethylbenzene and xylenes (BTEX). Table 4-6 details contaminant compounds detected above the respective water quality guidelines within the groundwater samples collected.

Table 4-6: Groundwater analytical results (DPGA, 2017a)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B114A | Artarmon | Cobalt, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B127A | North Balgowlah | Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B134A | Bicentennial Reserve, Willoughby | Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B238A | Northbridge | Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |

The DPGA (2017b) report indicated that groundwater sampling was carried out from wells B114A (Artarmon), B127A (North Balgowlah), B134A (Bicentennial Reserve, Willoughby) and B238A (Northbridge). Although present within the analytical tables, the location of well B238A was not identified on the figures contained within the report. Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and BTEX. Table 4-7 details contaminant compounds detected above the respective water quality guidelines within the groundwater samples collected.

Table 4-7: Groundwater analytical results (DPGA, 2017b)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B114A | Artarmon | Cobalt, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B127A | North Balgowlah | Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B134A | Bicentennial Reserve, Willoughby | Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B238A | Northbridge | Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Ammonia | ANZECC (2000) 95% species protection for marine ecosystems |

The DPGA (2018a) report indicated that groundwater sampling was carried out from wells B114A (Artarmon), B127A (North Balgowlah) and B134A (Bicentennial Reserve, Willoughby). Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and BTEX. Table 4-8 details contaminant compounds detected above the respective water quality guidelines within the groundwater samples collected.

Table 4-8: Groundwater analytical results (DPGA, 2018a)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B114A | Artarmon | Cobalt, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese, Nickel | NHMRC (2011) drinking water guidelines |
| B127A | North Balgowlah | Cobalt, Copper, Zinc, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Copper, Zinc | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Lead, Manganese, Nickel | NHMRC (2011) drinking water guidelines |
| B134A | Bicentennial Reserve, Willoughby | Cadmium, Copper, Manganese, Nickel, Zinc, Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Copper, Manganese, Zinc, Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Arsenic, Chromium, Lead, Manganese, Nickel | NHMRC (2011) drinking water guidelines |
| | | Lead | NHMRC (2008) recreational water guidelines |

The DPGA (2018b) report indicated that groundwater sampling was carried out from wells B114A (Artarmon), B127A (North Balgowlah) and B134A (Bicentennial Reserve, Willoughby). Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and BTEX.

Table 4-9 details contaminant compounds detected above the respective water quality guidelines within the groundwater samples collected.

Table 4-9: Groundwater analytical results (DPGA, 2018b)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B114A | Artarmon | Cobalt, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| B127A | North Balgowlah | Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B134A | Bicentennial Reserve, Willoughby | Nickel, Zinc, Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Nickel, Zinc, Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| | | Manganese | NHMRC (2008) recreational water guidelines |

The DPGA (2018c) report indicated that groundwater sampling was carried out from wells B114A (Artarmon), B127A (North Balgowlah), B134A (Bicentennial Reserve, Willoughby) and B238A (Northbridge). Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and BTEX. Table 4-10 details contaminant compounds detected above the respective water quality guidelines within the groundwater samples collected.

Table 4-10: Groundwater analytical results (DPGA, 2018c)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B114A | Artarmon | Zinc | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| B127A | North Balgowlah | Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B134A | Bicentennial Reserve, Willoughby | Cobalt, Nickel, Zinc, Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Nickel, Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| | | Manganese | NHMRC (2008) recreational water guidelines |
| B238A | Northbridge | Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Ammonia | ANZECC (2000) 95% species protection for marine ecosystems |

The DPGA (2018d) report indicated that groundwater sampling was carried out from wells B127A (North Balgowlah), B134A (Bicentennial Reserve, Willoughby) and B238A (Northbridge). Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and BTEX. Table 4-11 details contaminant compounds detected above the respective water quality guidelines within the groundwater samples collected.

Table 4-11: Groundwater analytical results (DPGA, 2018d)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B127A | North Balgowlah | Cobalt, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Cobalt | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B134A | Bicentennial Reserve, Willoughby | Cobalt, Manganese, Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese, Sulphate | NHMRC (2011) drinking water guidelines |
| B238A | Northbridge | Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Ammonia | ANZECC (2000) 95% species protection for marine ecosystems |

The DPGA (2018e) report indicated that groundwater sampling was carried out from wells B114A (Artarmon), B127A (North Balgowlah), B134A (Bicentennial Reserve, Willoughby) and B238A (Northbridge). Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and BTEX. Table 4-12 details contaminant compounds detected above the respective water quality guidelines within the groundwater samples collected.

Table 4-12: Groundwater analytical results (DPGA, 2018e)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B114A | Artarmon | Cobalt, Zinc | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| B127A | North Balgowlah | Zinc | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| B134A | Bicentennial Reserve, Willoughby | Cobalt, Nickel, Zinc, Ammonia, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Boron, Copper, Manganese, Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Sulphate | NHMRC (2011) drinking water guidelines |
| B238A | Northbridge | Ammonia | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Ammonia | ANZECC (2000) 95% species protection for marine ecosystems |

It is possible that the concentrations of contaminants above guideline levels may represent contamination, especially those reported in well B134A (heavy metals and ammonia) located in Bicentennial Reserve, Willoughby, which could be associated with historical landfilling next to the well location. It is noted that Appendix N (Technical Working Paper: Groundwater) indicated that the heavy metal results were considered unreliable because of high pH results.

Groundwater quality data has been reported from eight sampling events at up to six standpipe piezometers by AEC (2019). Details of the monitoring sites are shown in Table 4-13.

Table 4-13: Groundwater quality monitoring locations - AEC

| Bore ID | Location | Monitored formation | No. of samples | Comments |
|---|---|---|---|---|
| B128 | Balgowlah | Sandstone | 8 | N/A |
| B138 | Seaforth | Sandstone | 6 | N/A |
| B155 | Northbridge | Sandstone | 6 | N/A |
| B173 | Killarney Heights | Sandstone | 7 | N/A |
| B174 | Killarney Heights | Sandstone | 8 | N/A |
| B175 | Frenchs Forest | Clayey sand, sand and sandstone | 8 | N/A |

The AEC (2019) report indicated that groundwater sampling was carried out from wells B128 (Balgowlah), B138 (Seaforth), B155 (Northbridge), B173 (Killarney Heights), B174 (Killarney Heights) and B175 (Frenchs Forest). Groundwater samples were analysed for common contaminant compounds including heavy metals, nutrients, PAH, TRH and BTEX. The AEC (2019) report provided no assessment against groundwater quality criteria. Table 4-14 details contaminant compounds detected above the respective water quality guidelines (adopted from DPGA reports) within the groundwater samples collected.

Table 4-14: Groundwater analytical results (AEC, 2019)

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B128 | Balgowlah | Phosphorous (reactive), Total Phosphorous, Cobalt, Copper, Zinc | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Copper, Manganese, Zinc | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| B138 | Seaforth | Cobalt, Nickel, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese, Nickel | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| B155 | Northbridge | Nitrate, Phosphorous (reactive), Total Phosphorous, Cobalt | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Nitrate, Chromium | ANZECC (2000) 95% species protection for freshwater ecosystems |
| B173 | Killarney Heights | Chromium, Copper, Zinc | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Copper, Zinc | ANZECC (2000) 95% species protection for marine ecosystems |

| Bore ID | Location | Compound | Guideline exceedance |
|---|---|---|---|
| B174 | Killarney Heights | Boron, Copper, Manganese, Nickel, Zinc | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Cobalt, Copper, Nickel, Zinc, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |
| B175 | Frenchs Forest | Nitrate, Cobalt, Copper, Manganese, Nickel, Zinc | ANZECC (2000) 95% species protection for freshwater ecosystems |
| | | Nitrate, Copper, Nickel, Zinc, Total Phosphorous | ANZECC (2000) 95% species protection for marine ecosystems |
| | | Manganese | NHMRC (2011) drinking water guidelines |

It is possible that the concentrations of contaminants above guideline levels may represent contamination. It is noted that Appendix N (Technical working paper: Groundwater) indicated that some of the heavy metal results were considered unreliable because of high pH results.

The SMEC (2017b) monitoring report was carried out across the Northern Beaches Hospital Road Connectivity and Network Enhancements Project area and involved groundwater and surface water monitoring, sample collection and analysis for common contaminants compounds including heavy metals, TRH, BTEX, PAH and nutrients. Groundwater wells GW4 and GW9 were located near elements of the Beaches Link and Gore Hill Freeway Connection project.

The results of the monitoring indicated the following with respect to contamination:

- Selected heavy metals were detected at concentrations above the ANZECC (2000) 95 per cent species protection for freshwater ecosystems criteria at the majority of well locations. These heavy metal concentrations were considered to be low and representative of background conditions
- Wells GW1, GW3, GW4 and GW9 reported regular exceedances of the ANZECC (2000) 95 per cent species protection for freshwater ecosystems criteria for cadmium, copper, lead, nickel and zinc. These elevated concentrations could be associated with localised contamination
- TRH and benzene were detected at concentrations above the laboratory levels in wells GW2 and GW7. It was considered that the detection of these compounds could be associated with service station sites near these locations or introductions during the drilling program
- Elevated nitrate concentrations were detected with GW10. The elevated nitrate was considered to be associated with the use of fertiliser on nearby residential properties or within parkland areas.

Based on the results of the baseline monitoring, the SMEC (2017b) monitoring report concluded that groundwater quality showed no substantial existing contamination.

### 4.4.3 Soil

The AECOM and Coffey (2018) report indicated that soil sampling for contamination testing was carried out from the following boreholes and depths:

- B128 (at depths ranging from the surface to 0.6 metres) located at Balgowlah Golf Course
- B173 to B175, B362 to B368, B371 and B372 (at depths ranging from the surface to 2.28 metres) located along Wakehurst Parkway
- B354 and B358 (at depths ranging from 0.55 metres to 1.7 metres) located along Gore Hill Freeway
- B382 and B386 (at depths ranging from 0.05 metres to 1.2 metres) located at Balgowlah.

Soil samples were analysed for common contaminant compounds including heavy metals, PAH, TRH, BTEX, OCP, and organophosphate pesticides with selected samples additionally analysed for phenols, volatile and semi-volatile organic compounds, cyanide, PCB and asbestos (presence/absence). The results of the sampling and analysis were compared against guidelines for the protection of ecological and human (investigation and screening levels) receivers under open space and commercial/industrial land usage. The analytical results compared to adopted guidelines are detailed below. Where no discussion is provided, results were less than the respective guidelines:

- Nickel concentrations ranged from below detection limits to 140 milligrams per kilogram and exceeded the adopted open space ecological investigation level (35 milligrams per kilogram) in three samples B175_0.25-0.35 (137 milligrams per kilogram), B354_0.55-0.75 (136 milligrams per kilogram) and QC510 (duplicate of B354_0.55-0.75) (140 milligrams per kilogram)
- Concentrations of benzo(a)pyrene toxicity equivalency quotient – carcinogenic PAHs ranged from no detection to 13.4 milligrams per kilogram and were below the adopted open space HIL (3 milligrams per kilogram) for all samples analysed except for sample B371_0.08- 0.10 (13.4 milligrams per kilogram)
- Benzo(a)pyrene concentrations ranged from no detection to 8.9 milligrams per kilogram and were below the adopted open space ecological screening level (0.7 milligrams per kilogram) for all samples analysed except for B371_0.08-0.10 (8.9 milligrams per kilogram)
- Benzo(a)pyrene concentrations were below the adopted commercial/industrial ecological screening level (1.4 milligrams per kilogram) except for B371_0.08-0.10 (8.9 milligrams per kilogram)
- TRH concentrations were below the adopted open space ecological screening levels except for TRH C16 – C34 which exceeded the ecological screening level (300 milligrams per kilogram) in B371_0.080-0.10 (630 milligrams per kilogram).

The DPGA (2018g) report indicated that soil sampling for contamination testing was carried out from borehole locations B114A (Artarmon), B127A and B129A (North Balgowlah) and B242A (Balgowlah). Soil samples were analysed for common contaminant compounds including heavy metals, PAH, TRH, BTEX, OCP and organophosphate pesticides. The investigation criteria applied to the soil results were residential land use and areas ecological significance. These investigation criteria are likely to be overly conservative and not applicable for land use associated with the project (predominantly tunnel, roadways and construction support sites).

The AECOM and Coffey (2018) investigation indicated contamination (ie concentrations above adopted open space and commercial/industrial land use guidelines protective of ecological and human health) in several samples. The highest risk of contamination exposure would be those samples containing concentrations above human health guidelines. Exceedances of the human health guidelines were reported for benzo(a)pyrene in surface soils at Wakehurst Parkway.

The DPGA (2017c) and AECOM and Coffey (2017) geotechnical factual reports indicated that buried waste materials were encountered at the following locations:

- B337 (Cammeray Golf Course) – 4.13 metres of fill material containing some concrete and PVC
- B340 (Cammeray Golf Course) – 1.8 metres of fill containing some sandstone and concrete
- B176 (Bicentennial Reserve) – 30 metres of landfill material
- B177 (Flat Rock Reserve) – 11 metres of fill (potential – limited observation because hole was wash bored).

## 4.5 Local knowledge

The following information is based on the author's experience in carrying out previous investigations within and next to the project area and knowledge of local areas (refer to Robert F McKillop (2012) Managing our Waste: An environmental history of Flat Rock Creek and the Willoughby Incinerator 1900-2011). The local knowledge information is focused on activities and contamination sources which may represent a potential contamination risk to the construction and operation of the project.

The results of the local knowledge assessment are presented in Table 4-15.

Table 4-15: Potential contamination sources (anecdotal information)

| Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants |
|---|---|---|---|---|---|
| Willoughby Leisure Centre and Bicentennial Reserve – Small Street at Willoughby | Adjacent | Tunnel (depth) | Infilling and incinerator operations | Surface and depth (depth distribution associated with depth of infilling. Infilling materials could comprise historical residential, industrial and furnace waste from the on-site incinerator) | Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos |
| Flat Rock Reserve at Northbridge | Within | Construction support site and decline tunnel portal (surface and depth) | Infilling – Following the construction of Flat Rock Drive in 1968, areas to the east were filled (up until 1981) raising the valley floor by a maximum of approximately 30 metres. Prior to 1971, filling comprised putrescible materials. Filling after 1971 comprised of mostly building waste | Surface and depth (depth distribution associated with depth of infilling). Infilling materials could comprise putrescible materials (at the base of the infilling profile) | Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos |

# 5. Contamination investigation findings

## 5.1 Potential areas of environmental interest

Several potential AEIs were identified during the information review and site inspection.

Based on the information contained within the preceding sections of this report, Table 5-1 outlines the potential AEIs located near the project area and their associated comparative risks to environmental receivers, construction limitations and site users in consideration of the potential for contamination and proposed construction activities.

The comparative risk has been assessed based on the following metrics shown in Figure 5-1.

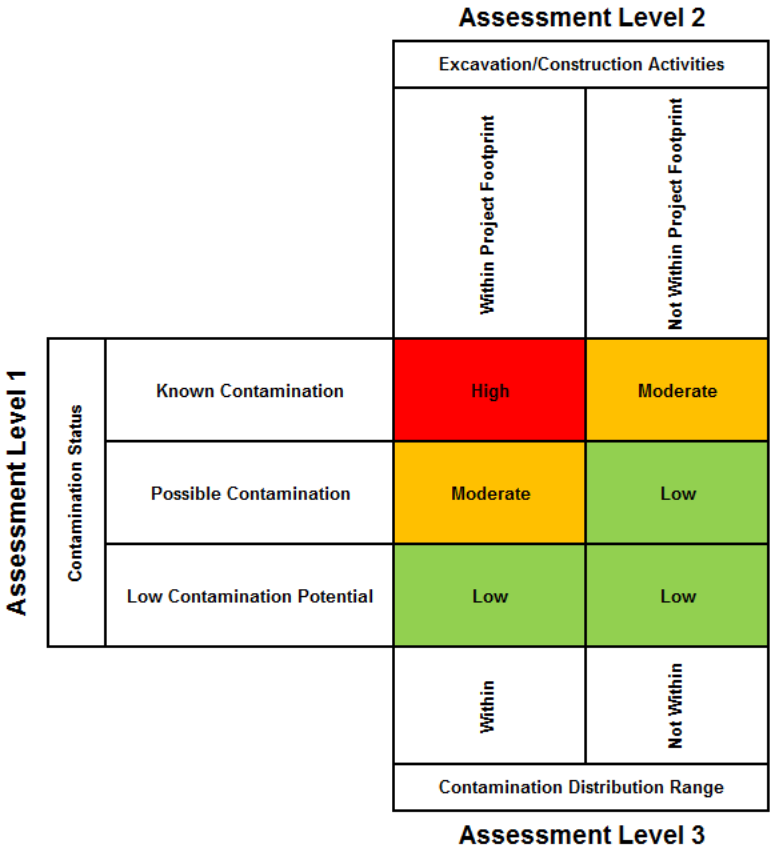


Figure 5-1: Comparative risk assessment matrix

Identified AEIs with assigned moderate to high exposure risk rankings are presented in Table 5-1 and shown in Figure 5-2.

Table 5-1: Potential areas of environmental interest

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B1 | Unsealed areas next to Warringah Freeway – Eastern side (Cammeray Golf Course) at Cammeray | Within footprint of construction support site | Cammeray Golf Course construction support site (BL1) (surface) | Deposition of particulate matter | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| | | | | Inappropriate handling and disposal of building materials during demolition of buildings for construction of Warringah Freeway | Surface (potentially 0–1.0 metres) | Heavy metals, hydrocarbons, pesticides, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| | | | | Chemical use and storage at golf course | Surface (potentially 0–1.0 metres) | Heavy metals, hydrocarbons, VOC, pesticides | **Low**<br>• Low contamination potential<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| | | | | Filling with material of unknown quality during construction of the Warringah Freeway | Surface and depth (depth distribution associated with depth of filling) (potentially 0–2.0 metres). | Heavy metals, hydrocarbons, pesticides, PCB, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| B2 | Unsealed areas next to Warringah Freeway – Eastern side (between freeway and Miller Street on ramp) at Cammeray | Within footprint of construction support site | Cammeray Golf Course construction support site (BL1) (surface) | Deposition of particulate matter | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos | **Moderate**<br>• Possible contamination with widespread distribution<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B3 | Unsealed areas next to Warringah Freeway – Western side (between Miller Street and West Street) at Cammeray | Above tunnel and within footprint of construction support site | Tunnel (surface and depth) | Deposition of particulate matter | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically – surface work only)<br>• Potential contamination distribution unlikely to impact upon tunnelling (based on depth to tunnel). |
| B4 | Unsealed areas next to Warringah Freeway – Western side (between West Street and Brook Street) at Crows Nest | Above tunnel and within footprint of construction support site | Tunnel (surface and depth) | Deposition of particulate matter | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically – surface work only)<br>• Potential contamination distribution unlikely to impact upon tunnelling (based on depth to tunnel). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B5 | Unsealed areas next to Warringah Freeway – Eastern side (between West Street and Brook Street) at Crows Nest | Above tunnel and within footprint of construction support site | Tunnel (surface and depth) | Deposition of particulate matter | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically – surface work only)<br>• Potential contamination distribution unlikely to impact upon tunnelling (based on depth to tunnel). |
| B6 | Unsealed areas next to Warringah Freeway – Western side (between Brook Street and Willoughby Road) at Naremburn | Tunnel (laterally, not vertically) | Tunnel (depth) | Deposition of particulate matter | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| N/A | Cemetery – West Street at Crows Nest | Tunnel (laterally, not vertically) | Tunnel (surface and depth) | Burials | Depth (potentially > 2 metres) | Heavy metals, nutrients | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (roadworks only)<br>• Substantial contamination risk from burials is low and unlikely to impact upon tunnelling. |
| B7 | Punch Street at Artarmon | Within footprint of construction support site | Punch Street construction support site (BL3) (surface) | Historical hazardous building materials (bridge) and filling | Surface and depth (depth distribution associated with depth of filling) (potentially 0–2.0 metres) | Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| | | | | Commercial/industrial use of site and surrounding areas (ie manufacturing, chemical use and storage etc) | Surface and depth (potentially 0–4.0 metres) | Heavy metals, hydrocarbons, VOC | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B8 | Freeway Hotel, Reserve Road at Artarmon | Within footprint of Motorway Control Centre | Motorway Control Centre (surface) | Commercial/industrial use of site and surrounding areas (ie manufacturing, chemical use and storage etc) | Surface and depth (potentially 0–4.0 metres) | Heavy metals, hydrocarbons, VOC | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| B9 | Flat Rock Reserve at Northbridge | Within footprint of construction site and access decline portal | Flat Rock Drive construction support site (BL2), access decline portal (approximately 7 metres below site surface level) | Infilling | Surface and depth (depth distribution associated with depth of infilling). Infilling materials could comprise putrescible materials | Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos, landfill gas | **Moderate**<br>• Known contamination adjacent to site/possible contamination beneath site<br>• Excavation activities within compound and access portal<br>• Excavation activities within potential contamination distribution range (laterally and vertically). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B10 | Willoughby Leisure Centre and Bicentennial Reserve at Willoughby | Above tunnel and adjacent to footprint of construction support site and tunnel portal | Tunnel (depth) | Infilling | Surface and depth (depth distribution associated with depth of infilling). Infilling materials could comprise historical residential, industrial and furnace waste from the on-site incinerator) (potentially 0 to > 30 metres in depth) | Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos, landfill gas | **High**<br>• Known contamination beneath site<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (vertically). |
| N/A | Service Station – Corner Artarmon and Willoughby Roads at Artarmon | Adjacent to tunnel (laterally, not vertically) | Tunnel (depth) | Leaks and spills from underground petroleum storage infrastructure | Depth (potentially > 4.0 metres) | Heavy metals, hydrocarbons | **Low**<br>• Possible contamination<br>• No excavation activities for tunnel within site footprint<br>• Potential contamination distribution unlikely to impact upon tunnelling (based on depth to tunnel). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B11 | Reclamation of land – Spit West Reserve at Mosman | Within footprint of construction support site | Spit West Reserve construction support site (BL9) (surface) | Reclamation of land with material of unknown quality | Surface and depth (distribution associated with depth of infilling) (potentially > 2.0 metres) | Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, organotins, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| B12 | Sediments within Middle Harbour and adjacent to the Spit | Above tunnel and within footprint of construction support site | Middle Harbour south cofferdam (BL7), Middle Harbour north cofferdam (BL8) and Spit West Reserve construction support site (BL9) and tunnel (surface and depth) | Contamination associated with harbour use and catchment inputs | Surface to recent (about 150 years) depositional extent | Heavy metals, hydrocarbons (mainly PAH), pesticides, PCB, PFAS, organotins | **High**<br>• Known contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range. |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| N/A | Kitchener Street at Balgowlah | Adjacent to construction support site footprint | Kitchener Street construction support site (BL11) (surface) | Filling during road construction | Surface and depth (potentially 0–2.0 metres) | Heavy metals, hydrocarbons, pesticides, asbestos | **Low**<br>• Low contamination potential<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically). |
| B13 | Balgowlah Golf Course at Balgowlah | Adjacent to construction support site footprint | Balgowlah Golf Course construction support site (BL10), new open space and recreation facilities and Balgowlah Connection (surface) | Inappropriate handling and disposal of building materials during demolition of buildings for construction of the Burnt Bridge Creek Deviation | Surface (potentially 0–1.0 metres) | Heavy metals, hydrocarbons, pesticides, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| | | | | Filling with material of unknown quality during construction of the Burnt Bridge Creek Deviation | Surface and depth (depth distribution associated with depth of filling) (potentially 0–2.0 metres) | Heavy metals, hydrocarbons, pesticides, PCB, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| | | | | Degradation of hazardous building materials from structures currently present on the site | Surface (potentially 0–0.1 metres) | Heavy metals, hydrocarbons, pesticides, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| | | | | Chemical use and storage at golf course | Surface (potentially 0–1.0 metres) | Heavy metals, hydrocarbons, VOC, pesticides | **Low**<br>• Low contamination potential<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (surface work only). |
| B14 | Residential properties, Dudley Street at Balgowlah | Within footprint of construction support site | Balgowlah Golf Course construction support site (BL10), new open space and recreation facilities and Balgowlah Connection surface works | Degradation of hazardous building materials from structures currently present on the site | Surface (potentially 0–0.1 metres) | Heavy metals, hydrocarbons, pesticides, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically)<br>• Potential contamination distribution unlikely to affect tunnelling below surface levels (based on depth to tunnel). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| N/A | Incinerator Site – Corner Dalwood Avenue and Frenchs Forest Road at Seaforth | Adjacent to tunnel (laterally, not vertically) | Tunnel (depth) | Incinerator operations | Surface (furnace waste from on-site incinerator) (potentially 0–0.5 metres) | Heavy metals, hydrocarbons (mainly PAH), asbestos | **Low**<br>• Low contamination potential<br>• No excavation activities for tunnel within site footprint<br>• No excavation activities within potential contamination distribution range (depth). |
| B15 | Residential properties – Judith Street/Kirkwood Street and Wakehurst Parkway at Seaforth | Above tunnel and within footprint of construction support site | Wakehurst Parkway south construction (BL12) support site | Degradation of hazardous building materials from structures currently present on the site | Surface (potentially 0–0.1 metres) | Heavy metals, hydrocarbons, pesticides, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically)<br>• Potential contamination distribution unlikely to affect tunnelling below surface levels (based on depth to tunnel). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B16 | Sydney Water Reservoir site (and surrounds) – Kirkwood Street at Seaforth | Adjacent to construction support site footprint and tunnel (laterally, not vertically) | Wakehurst Parkway East construction support site (BL13), roadwork and tunnel (surface and depth) | Deposition from the degradation of painted reservoir surfaces | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities for construction compound and roadwork within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically)<br>• Potential contamination distribution unlikely to affect tunnelling (based on depth to tunnel). |
| | Areas surrounding the Sydney Water Reservoir site – Kirkwood Street, Seaforth | Within construction support site footprint and tunnel (laterally, not vertically) | Wakehurst Parkway East construction support site (BL13), roadwork and tunnel (surface and depth) | Deposition from the degradation of painted reservoir surfaces and the presence of demolition wastes | Surface (potentially 0–0.1 metres) | Heavy metals hydrocarbons, pesticides asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities for construction compound and roadwork within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically)<br>• Potential contamination distribution unlikely to affect tunnelling (based on depth to tunnel). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| B17 | Wakehurst Parkway – Seaforth to Frenchs Forest | Above tunnel and within footprint of construction support site | Wakehurst Parkway south construction support site (BL12) | Degradation of asphaltic road surface | Surface (potentially 0–0.1 metres) | Heavy metals (mainly lead), hydrocarbons (mainly PAH) | **High**<br>• Known contamination<br>• Excavation activities for construction compound and roadwork within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically)<br>• Potential contamination distribution unlikely to affect tunnelling below surface levels (based on depth to tunnel). |
| | | | | Illegally dumped waste | Surface (potentially 0–0.1 metres) | Heavy metals, hydrocarbons, pesticides, asbestos | **Moderate**<br>• Possible contamination<br>• Excavation activities for roadwork within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| N/A | Wakehurst Parkway (north of Warringah Road) at Frenchs Forest | Adjacent to construction support site footprint | Wakehurst Parkway north construction support site (BL14) (surface) | Stockpiling | Surface (potentially 0–0.1 m) | Heavy metals, hydrocarbons, pesticides, asbestos | **Low**<br>• Low contamination potential<br>• Excavation activities for construction compound within site footprint<br>• Excavation activities within potential contamination distribution range (laterally and vertically)<br>• Site currently sealed compound. |
| N/A | Dry Cleaners – Northbridge | Adjacent to tunnel (laterally, not vertically) | Tunnel (depth) | Leaks and spills of solvents | Depth (potentially > 1.0 metre) | VOC | **Low**<br>• Possible contamination<br>• No excavation activities for tunnel within site footprint<br>• Potential contamination distribution unlikely to affect tunnelling (based on depth to tunnel). |
| N/A | Mechanics – Dickson Avenue and Reserve Road at Artarmon | Adjacent to construction support site footprint and roadworks | Dickson Avenue construction support site (BL4) and roadwork (surface) | Leaks and spills from underground storage infrastructure | Surface and depth (potentially 0 to > 4 metres) | Heavy metals, hydrocarbons | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| N/A | Farming, cropping, market gardens, nurseries – Seaforth | Adjacent to tunnel (laterally, not vertically) | Tunnel (depth) | Pesticide and fertiliser use | Surface (potentially 0–0.5 metres) | Pesticides, nutrients | **Low**<br>• Possible contamination<br>• No excavation activities for tunnel within site footprint<br>• No excavation activities within potential contamination distribution range (depth). |
| N/A | Dry Cleaners – Naremburn | Adjacent to surface works | Warringah Freeway Upgrade surface work (surface) | Leaks and spills of solvents | Depth (potentially > 1.0 metres) | VOC | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |
| N/A | Mechanics – Crows Nest | Adjacent to surface works | Warringah Freeway Upgrade surface work (surface) | Leaks and spills from underground storage infrastructure | Depth (potentially > 4.0 metres) | Heavy metals, hydrocarbons, VOC | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| N/A | Mechanics – Artarmon | Adjacent to construction support site footprint and roadworks | Dickson Avenue construction support site (BL4) and roadwork (surface) | Leaks and spills from underground storage infrastructure | Depth (potentially > 4.0 metres) | Heavy metals, hydrocarbons, VOC | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |
| N/A | Mechanics – Willoughby | Adjacent to tunnel (laterally, not vertically) | Tunnel (depth) | Leaks and spills from underground storage infrastructure | Depth (potentially > 4.0 metres) | Heavy metals, hydrocarbons, VOC | **Low**<br>• Possible contamination<br>• No excavation activities for tunnel within site footprint<br>• Potential contamination distribution unlikely to affect tunnelling (based on depth to tunnel). |
| N/A | Mechanics – Balgowlah | Adjacent to construction support site footprint and roadworks | Balgowlah Golf Course construction support site (BL10) and roadwork (surface) | Leaks and spills from underground storage infrastructure | Depth (potentially > 4.0 metres) | Heavy metals, hydrocarbons, VOC | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |

| Figure 5-2 reference | Site | Location relative to alignment | Construction element and anticipated depth | Potential contamination source | Potential contamination distribution | Potential contaminants | Risk ranking |
|---|---|---|---|---|---|---|---|
| N/A | Paint Manufacturers – Artarmon | Adjacent to construction support site footprint and roadworks | Dickson Avenue construction support site (BL4) and roadwork (surface) | Leaks and spills | Depth (potentially > 1.0 metres) | Heavy metals, hydrocarbons, VOC | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |
| N/A | Service Station – Cammeray | Adjacent to surface works | Warringah Freeway Upgrade surface work (surface) | Leaks and spills from underground petroleum storage infrastructure | Depth (potentially > 4.0 metres) | Heavy metals, hydrocarbons | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |
| N/A | Service Station – Artarmon | Adjacent to roadworks | Gore Hill Freeway roadwork (surface) | Leaks and spills from underground petroleum storage infrastructure | Depth (potentially > 4.0 metres) | Heavy metals, hydrocarbons | **Low**<br>• Possible contamination<br>• No excavation activities within site footprint<br>• No excavation activities within potential contamination distribution range (surface work only). |

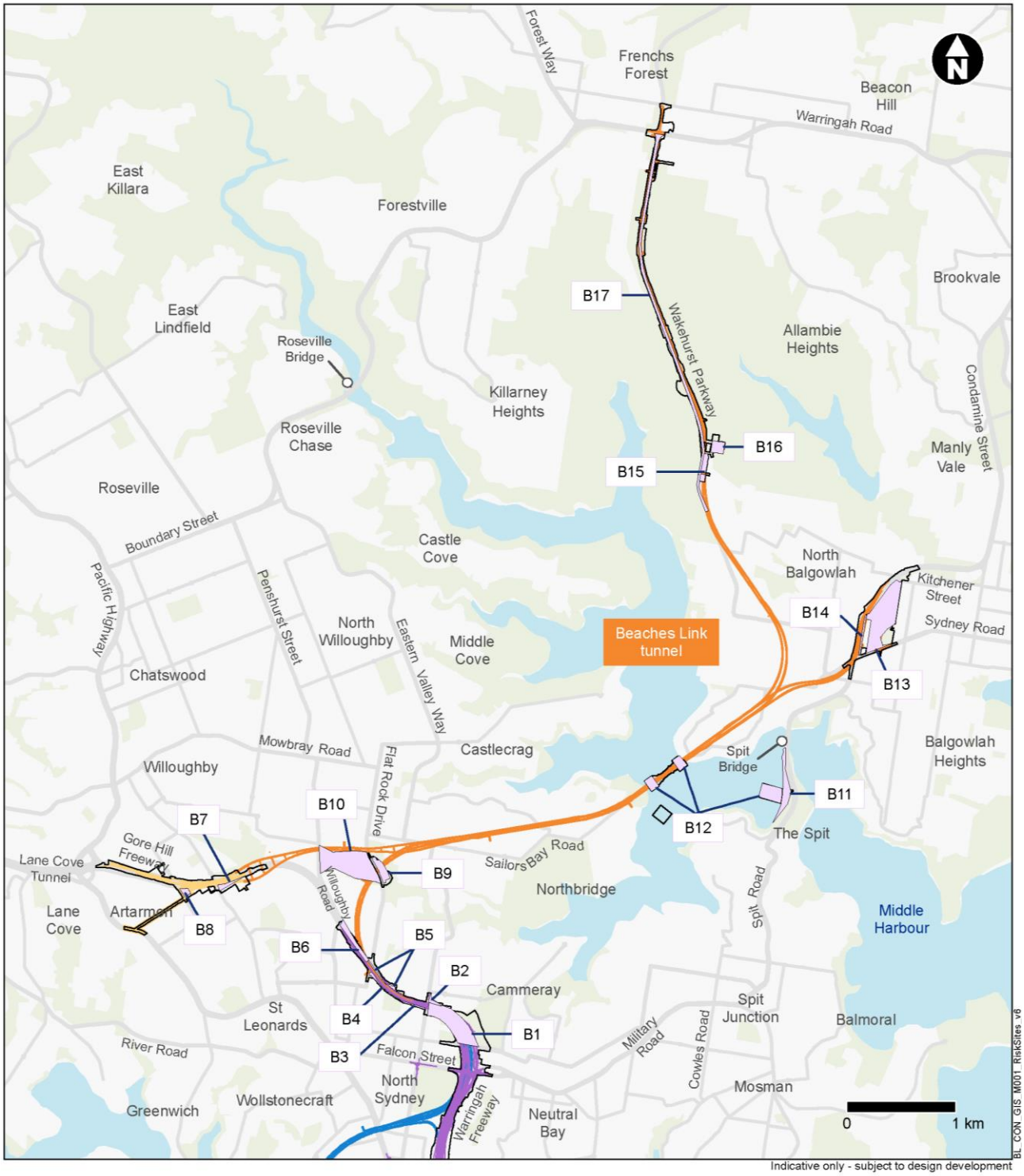


Figure 5-2: AEIs with assigned moderate to high exposure risk rankings

## 5.2 Summary of areas of environmental interest exposure risk

Based on the results of the information review and site inspection, several sites within and or next to the project area are considered to represent a low contamination risk. No further consideration of contamination risk has been provided for these sites.

A summary of the identified AEIs with assigned moderate to high exposure risk rankings is provided below:

- Potentially contaminated soils may be present within unsealed areas next to the Warringah Freeway. The contamination could be associated with the inappropriate handling and disposal of building materials or filling of some of these areas with material of unknown quality, during the construction of the Warringah Freeway. The contamination could also be potentially from particulate matter deposition from large volume traffic flows using the Warringah Freeway since its opening. These areas pose a moderate contamination risk to construction given that contamination is potentially present within soils which are likely to be excavated and exposed during the carrying out of surface works and construction of the construction support site at the Cammeray Golf Course construction support site (BL1)
- Punch Street at Artarmon, including the area proposed to become Punch Street construction support site (BL3), has the potential for the presence of contaminated soil and fill materials. The presence of the potential contamination could be associated with the degradation of hazardous building materials possibly contained within the old bridge structure and the potential inappropriate demolition and waste disposal practices used during the demolition of the bridge. In addition, potential contamination could be associated with possible infilling of the site with material of unknown quality during construction of the Gore Hill Freeway. This area poses a moderate contamination risk to construction considering the potential presence of soil contamination and that soils are likely to be excavated and exposed during construction activities at the Punch Street construction support site (BL3)
- The current and historical commercial/industrial use of the area proposed to become the Motorway Control Centre (Freeway Hotel site) and the adjoining properties at Reserve Road at Artarmon could mean the possible presence of contamination. This area poses a moderate contamination risk to construction considering the potential presence of soil contamination and that soils are likely to be excavated and exposed during construction of the Motorway Control Centre and Reserve Road ramp
- The proposed Flat Rock Drive construction support site (BL2) is located in Flat Rock Reserve at Northbridge. The historical landfill activities carried out within the areas surrounding the Willoughby Leisure Centre, Bicentennial Reserve and part of Flat Rock Reserve could contain soil, groundwater and landfill gas contamination associated with the historic buried waste mass
    - Soils/ wastes: Building type wastes are situated in the upper layers of the former landfill at Flat Rock Reserve, with the possible presence of putrescible materials located at greater depths of the waste mass. Soils/wastes in the area may be contaminated with a variety of contaminant compounds, including asbestos. Therefore, there is a moderate contamination risk associated with the potential presence of contamination beneath the Flat Rock Drive construction support site (BL2) which is likely to be exposed during construction of the access decline tunnel and other associated works to establish the construction support site
    - Landfill gas: It is possible that the waste mass beneath Flat Rock Drive construction support site (BL2) and the adjacent Willoughby Leisure Centre and Bicentennial Reserve may present a source of landfill gas. With specific regard to the possible presence of landfill gas beneath the site and the adjacent Willoughby Leisure Centre and Bicentennial Reserve, should the landfill gas be present, there is the potential for it to migrate towards the proposed Flat Rock Drive construction support site (BL2) as a result of formation pressure gradients due to ground disturbance from construction activities associated with the project. The Flat Rock Drive road embankment is an engineered and compacted fill which was formed up to 30 metres high to build the new road in 1968. This embankment forms a distinct separation between areas of historical landfill to the west and to the east of Flat Rock Drive. It is not known whether the road embankment restricts gas flow (if any) between the two areas. Sub-surface structures (where present) beneath the road embankment between the two areas may act as conduits for gas movement (if gas is present). The geotechnical investigation boreholes installed in

and around the Willoughby Leisure Centre as part of this project have not been specifically tested for landfill gas (i.e. concentrations and flow). As part of the drilling, lower explosive limit (LEL) monitoring was carried out in accordance with drilling protocols. The LEL monitoring which was carried out is a broad screening (not specific to landfill gas) which assess explosion potential based on all gases (not landfill gas specific) and oxygen concentrations.

- Groundwater contamination: There is a moderate contamination risk associated with the potential presence of groundwater contamination beneath Flat Rock Drive construction support site (BL2), which is likely to be encountered during construction of the access decline tunnel. Also, known groundwater contamination in adjoining areas (Willoughby Leisure Centre and Bicentennial Reserve) could migrate to the main tunnel works which travel under Willoughby and Northbridge and represents a high contamination risk to the tunnel in this area

- Spit West Reserve at Mosman is partially located on reclaimed land, and soils used as part of the reclamation works could be potentially contaminated. This area poses a moderate contamination risk to construction given the potential for contamination to be present within soil, which is likely to be excavated and exposed during construction of the Spit West Reserve construction support site (BL9)
- Contamination has been reported in sediments present within Middle Harbour and west of Spit West Reserve. Contamination is likely to be associated with inputs from the surrounding urbanised catchments and general maritime use within the harbour. The sediments pose a high contamination risk to construction given that contamination is known to be present within sediments which are likely to be excavated and exposed during the construction of the cofferdams in Middle Harbour, Middle Harbour south cofferdam construction support site (BL7) during installation of the immersed tube tunnel and associated dredging and piling work and Middle Harbour north cofferdam (BL8) as well as the construction of the Spit West Reserve construction support site (BL9) itself where piling would also be required to establish construction support site wharf structures
- Soil contamination could be present within soils adjacent to the Balgowlah Golf Course. The potential contamination could be associated with the inappropriate demolition and waste disposal practices of structures historically present within this area as well as the unknown quality of fill used in the construction of the Burnt Bridge Creek Deviation. Further contamination risks could be associated with the degradation of hazardous building materials which may have potentially been used in structures currently or formerly situated in the area. This area poses a moderate contamination risk during construction given that soils are expected to be excavated and exposed during creation of the Balgowlah Golf Course construction support site (BL10), new open space and recreation facilities and the Balgowlah connection surface works
- Potential soil contamination may be present within surface soils adjacent to the former residential premises located along Dudley Street at Balgowlah. The potential contamination could be associated with the degradation of hazardous building materials which may have potentially been used in these structures. The potential contamination risk is not presented in the structures themselves, but in the surrounding soils. These areas pose a moderate contamination risk to construction given the potential for contamination and that soils are expected to be excavated and exposed during construction of the Balgowlah Golf Course construction support site (BL10) and the Balgowlah connection surface works
- Potential soil contamination may be present within surface soils adjacent to the existing residential premises located at the corners of Judith Street and Kirkwood Street with Wakehurst Parkway at Seaforth. The potential contamination could be associated with the degradation of hazardous building materials which may have potentially been used in these structures. The potential contamination risk is not presented in the structures themselves, but in the surrounding soils. These areas pose a moderate contamination risk to construction given the potential for contamination and that soils are expected to be excavated and exposed during construction of the Wakehurst Parkway south construction support site (BL12) at Seaforth/Killarney Heights
- There is the potential for possible contaminated soils at the Sydney Water Reservoir site at Seaforth from the deposition of degraded materials from the surface of the reservoir. These areas pose a moderate contamination risk to construction given the potential for contamination and that soils are expected to be excavated and exposed during construction of the Wakehurst Parkway east construction support site (BL13)

- Potential soil contamination may be present within surface soils next to the Sydney Water Reservoir site located at Seaforth. The potential contamination could be associated with the deposition of degraded materials from the surface of the reservoir, windblown deposition of degraded materials onto adjoining areas and the presence of demolition wastes in areas surround the reservoir site. These areas pose a moderate contamination risk to construction given the potential for contamination and that soils are expected to be excavated and exposed during construction of the Wakehurst Parkway east construction support site (BL13) at Killarney Heights
- Isolated contamination has been reported in surface soils adjacent to the Wakehurst Parkway (Seaforth to Frenchs Forest). The contamination is likely to be associated with the degradation of asphaltic road surfaces. The absence of formalised kerb and guttering along some sections of the Wakehurst Parkway may have caused asphalt to enter surface soils along these sections. These areas pose a high contamination risk to construction given the presence known soil contamination and that soils are expected to be excavated and exposed during the upgrade works to Wakehurst Parkway and adjacent construction of the Wakehurst Parkway south construction support site (BL12) at Seaforth/Killarney Heights and Wakehurst Parkway north construction support site (BL14) at Frenchs Forest
- In consideration of the non-urbanised (i.e. non-populated) nature of the areas immediately surrounding the Wakehurst Parkway, the area may have been subject to illegal fly tipping of waste. If present, illegally dumped wastes pose a moderate contamination risk to construction given the potential for contamination and that soils/wastes are expected to be excavated and exposed during the upgrade works to the Wakehurst Parkway
- It is possible that structures and/or buildings located within the project area contain hazardous building materials. Refer Section 9 for proposed management measures proposed for any structures and/or buildings that require demolition to enable construction.

# 6. Assessment of construction impacts

The following information details potential impacts to construction of the project from soil and contamination constraints identified as part of this investigation.

## 6.1 Soil erosion hazard

Construction of the project has the potential to increase erodibility and transport of soils through surface disturbance and vegetation removal and the potential destabilizing slopes in the study area. Increased erosion could result in sedimentation within and around waterways down gradient from surface work locations associated with the project.

Uncompacted or unconsolidated materials (such as excavated and stockpiled soils) have the potential to be transported from construction areas during rain (through surface water runoff) causing downstream sedimentation and during periods of dry and windy conditions (as dust). Sedimentation in natural waterways can result in reduced water quality, flow and degradation of aquatic ecosystems. Dust has the potential to cause general aesthetic issues and deposit on sealed surfaces to be eventually washed into waterways during rainfall events.

The highest potential for soil erosion would be associated with the disturbance of soils on existing slopes during construction. Soil disturbance is only likely to occur at the construction support sites and work zones as detailed in Section 1.3. These construction support sites and work zones are, however, not located in areas with steep terrain, reducing the potential for erosion. Higher soil erosion impact potential would be associated with surface work construction sites located adjacent to more environmentally sensitive areas (eg Garigal National Park and Manly Dam Reserve).

## 6.2 Acid sulfate soils

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

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

Based on the information reviewed, the risk of ASS being present within the project area is low to negligible, except for soils within Spit West Reserve and sediments within Middle Harbour. Although not identified within any of the information reviewed, there is the possibility of potential ASS being present in sediments within The Spit.

## 6.3 Salinity

Salinity impacts occur when salts naturally present in soil or groundwater are concentrated at the surface or in shallow soils generally through transport by rising groundwater associated with the removal of deep rooted vegetation or other activities which could raise the groundwater table above normal seasonal levels. Salts can accumulate to a level which can damage structures and the environment. If present, salinity impacts could potentially occur during construction of the project as a result of soil disturbance during earthworks (namely vegetation removal).

Construction activities are more likely to lower the groundwater table rather than raising it above seasonal levels.

Based on the information reviewed and an understanding on how saline soils are formed, the risk of areas of saline soils being present within the project area are low to negligible. With the unlikely presence of saline soils within the project area, salinity is unlikely to represent a risk to surface water and/or groundwater during construction of the project.

## 6.4 Contamination – soil

Based on the information reviewed, several moderate to high risk potential AEIs have been identified which contain contaminated and potentially contaminated soils.

If contamination risks are not quantified at these AEIs and appropriately managed, construction activities may expose workers, the public and environmental receivers to contaminated soil. Potential impacts as a result of disturbance of contaminated soil without appropriate remediation and/or management may include:

- Contaminant exposure risk to project personnel and the general public
- Contaminant exposure to environmental receivers
- Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds
- Contamination of previously clean areas.

AEIs containing contaminated and potentially contaminated soils which may be exposed, or impacted, during construction activities include:

- Unsealed areas next to the Warringah Freeway
- Proposed Punch Street construction support site (BL3) at Artarmon
- Proposed Motorway Control Centre site located at the Freeway Hotel site, Reserve Road at Artarmon
- Flat Rock Reserve at Northbridge
- Willoughby Leisure Centre and Bicentennial Reserve at Willoughby
- Spit West Reserve at Mosman
- Middle Harbour and The Spit
- Balgowlah Golf Course at Balgowlah
- Residential premises located at Dudley Street at Balgowlah
- Residential premises located at the intersection of Judith Street and Kirkwood Street with the Wakehurst Parkway at Seaforth
- Areas adjacent to the Sydney Water Reservoir site at Killarney Heights
- Wakehurst Parkway between Seaforth and Frenchs Forest.

## 6.5 Contamination – sediments

Contaminated sediments have been identified within Middle Harbour and The Spit. The sediments in Middle Harbour and The Spit would potentially pose a high contamination risk to construction due to the contamination associated with the historical industrial use (over 150 years) of the harbour and the addition of polluted stormwater runoff originating from nearby urbanised catchments.

Contaminated sediments are likely to be disturbed during the installation of the immersed tube tunnel and associated dredging and piling work. Piling would also be required to establish construction support site wharf structures at Spit West Reserve construction support site (BL9) and the immersion pontoon in Middle Harbour.

Potential impacts as a result of disturbance of contaminated sediment without appropriate remediation and/or management may include:

- Contaminant exposure risk to project personnel
- Contaminant exposure risk and sedimentation to marine receivers
- Cross contamination associated with the incorrect handling or disposal of spoil/unexpected finds
- Accidental spills during the transportation of spoil across Sydney and Middle Harbours.

Contaminated exposure risks to workers and the environment would depend on the level of sediment disturbance associated with the dredging methodology (refer to Appendix P (Technical working paper: Hydrodynamic and dredge plume monitoring) (Royal HaskoningDHV, 2020)).

Annexure C includes a memo which outlines sediment contamination levels and results of elutriate testing that was carried out by Royal HaskoningDHV (2020) subsequent to the investigations carried out by DPGA (2018), for the purpose of assessing the suitability of dredged sediments for offshore disposal. Offshore disposal is an activity regulated by the Australian Government under the *Environment Protection (Sea Dumping) Act 1981* (Cwlth). Determination of the offshore disposal permit(s) is subject to assessment and approval by the Commonwealth.

Royal HaskoningDHV (2020) results of elutriate testing indicate that water quality impacts at the dredging site due to dissolved contaminants would not be expected. For further information please refer to Annexure C.

## 6.6 Contamination – groundwater

Contaminated groundwater may be encountered during construction activities, namely during excavation dewatering and tunnelling in the vicinity of potential AEIs. If groundwater contamination is not assessed and appropriately managed, construction activities may expose workers, the public and environmental receivers to contaminated groundwater via direct contact or discharge to surface waters. Potential impacts as a result of contact with or discharge of contaminated groundwater may include:

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

Based on the information reviewed, some groundwater monitoring has been carried out at selected locations within the project area. The monitoring data indicated that groundwater contamination was present beneath/surrounding the Willoughby Leisure Centre and Bicentennial Reserve and could be migrating towards Flat Rock Reserve. Elevated ammonia concentrations were reported in groundwater samples collected from beneath/surrounding these sites. The ammonia impacted groundwater could impact upon the construction of the tunnel located beneath this area and the construction of the access decline tunnel located adjacent to this area (within Flat Rock Reserve) if not appropriately managed. The sampling and analysis carried out within this area included a suite of general contaminant compounds. Based on the historical landfilling carried out within this area, other contaminant compounds may be present within groundwater.

## 6.7 Contamination – landfill gas

Landfill gas can be generated during the degradation/breakdown of total organic carbon present within organic compounds present in buried wastes. If present within and/or adjacent to the project, landfill gas could accumulate within below ground excavations and enclosed structures associated with the project at concentrations which could represent an asphyxiation or explosion risk.

Waste burial areas and potential landfill gas sources were identified at Willoughby Leisure Centre and Bicentennial Reserve and possibly beneath Flat Rock Reserve. Stage 2 investigations will involve additional boreholes which will assess further for potential contamination and landfill gas.

# 7. Assessment of operational impacts

The following information details potential impacts to operation of the project from soil and contamination constraints identified as part of this investigation.

## 7.1 Soil erosion hazard

After reinstatement of construction support sites and other areas of soil disturbance following construction of the project and installation of stormwater drainage systems, soil erosion hazards are unlikely to result during the operation of the project.

## 7.2 Acid sulfate soils

Groundwater drawdown during the operation of the tunnel could cause the lowering of the groundwater table in the vicinity of ASS which could cause the oxidation of sulfidic compounds within these soils which in turn could generate acid run off, leachate and mobilise other contaminants (namely heavy metals) into the environment Acidic run off, leachate and contaminant mobilisation could potentially impact upon the following:

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

Based on the information reviewed, soils within Spit West Reserve could be ASS. However, information from Appendix N (Technical working paper: Groundwater) indicated that groundwater drawdown during tunnel operation is unlikely to extend to Spit West Reserve, and soils beneath this area are unlikely to be affected by significant lowering of the groundwater table associated with project operation.

## 7.3 Salinity

Based on the information reviewed and an understanding on how saline soils are formed, the risk of areas of saline soils being present within the project area are low to negligible. With the unlikely presence of saline soils within the project area, salinity is unlikely to represent a risk to structures and/or surface water (via discharge of groundwater ingress in tunnels) during operation of the project.

## 7.4 Contamination – soil

Where existing soil contamination is identified within the operational areas of the project and is to be managed on site, appropriate environmental management plans would need to be prepared and implemented during the operational phase of the project. Implementation of appropriate environmental management plans would reduce the potential impacts from contaminated soil associated with the operation of the project.

Potential contamination of soils within and directly adjacent to the project could occur as a result of spills and leaks of hydrocarbons from vehicles, deposition of vehicle particulates and accidents during operation.

## 7.5 Contamination – sediments

Following construction, the operation of the project would not continue to disturb sediments.

Potential contamination of sediments directly adjacent to the project could occur as a result of spills and leaks of hydrocarbons from vehicles, deposition of vehicle particulates and accidents during operation.

## 7.6 Contamination – groundwater

Where existing groundwater contamination is identified within and/or adjacent to the operational areas of the project, appropriate engineering controls (for example tunnel linings) would need to be installed to either remove the risk of contaminated groundwater ingress into below ground structures (namely tunnels) or manage the risk to receivers via appropriate treatment prior to discharge or reuse. Implementation of appropriate engineering controls would reduce the potential impacts from contaminated groundwater to the operation of the project and receptors from discharge.

Potential contamination of groundwater within and directly adjacent to the project could occur as a result of spills and leaks of hydrocarbons from vehicles and accidents during operation.

## 7.7 Contamination – ground gas

Where existing ground gas is identified within the operational areas of the project, appropriate engineering controls would need to be installed to reduce the ongoing risk of gas ingress during operation of the project. Engineering controls could include surface or sub surface extraction or tanked tunnel construction. Implementation of appropriate engineering controls would reduce the potential impacts from ground gas to the operation of the project.

# 8. Cumulative impacts

Chapter 27 (Cumulative impacts) of the environmental impact statement outlines a list of other infrastructure projects that are currently being carried out, committed to, or proposed in the surrounding areas during the period in which the Beaches Link and Gore Hill Freeway Connection project is being constructed. The key projects in relation to potential cumulative impacts with the Beaches Link and Gore Hill Freeway Connection regarding contamination are:

- Western Harbour Tunnel and Warringah Freeway Upgrade
- Sydney Metro City & Southwest (Chatswood to Sydenham).

Both projects involve underground tunnelling and in relation to the Beaches Link and Gore Hill Freeway Connection project, both will include surface works in close proximity to each other.

Further, it has been assumed that construction of the proposed Channel 9 site staged residential development (14 Artarmon Road, Willoughby) would occur at the same time as construction of the project and, in particular, the development of the Flat Rock Drive construction support site (BL2). Both projects include significant earthworks with the potential for exposure of contaminated soils in close proximity to each other.

Potential cumulative impacts were considered for assessment based on the likely interactions of this project with other concurrent projects. Potential cumulative impacts could occur where the impacts of the different project combine to increase, decrease, or change potential contamination impacts and risks to human and environmental receptors.

Potential cumulative impacts would be dependent on a variety of factors including the presence of contamination, the type of potentially affected media (eg soil, groundwater), the nature and timing of construction disturbance, as well as the exposure pathways for contamination to human and/or environmental receptors.

For the above projects, the key activities that might have the potential to result in cumulative contamination impacts include:

- Excavation activities and liberation of contamination (as dust or fibres) that could deposit on adjacent land and be transported by surface water flows to surrounding areas
- Dewatering activities and discharge of contaminated water to adjacent land and waterways.

Provided that the strategies outlined in Section 9 are implemented to manage contamination within AEIs and potential exposure pathways, the potential for the project to results in cumulative impacts with adjacent projects is considered to be minimal.

# 9. Environmental management measures

The following table details recommended environmental management measures to mitigate potential environmental (soil erosion, ASS, soil salinity) and contamination risks identified associated with the construction and operation (where applicable) of the project.

Table 9-1: Recommended environmental management measures during construction and operation

| Impact | Mitigation and management measure |
|---|---|
| **Design and Operation** | |
| Contamination – groundwater | The potential for inflow of contaminated groundwater into the tunnel should be considered during detailed design. If inflow of contaminated groundwater into the tunnel is likely, the potential risks associated with exposure of the environment and community should be addressed. This might include limiting inflows (for example with tunnel linings), design of the groundwater collection system to minimise leakage and treatment of the collected groundwater to an appropriate standard prior to discharge. |
| **Construction** | |
| Soil erosion and sedimentation | Erosion and sediment measures should be implemented at all work sites in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction*, Volume 1 (Landcom, 2004) and Volume 2D (NSW Department of Environment, Climate Change and Water, 2008), commonly referred to as the 'Blue Book'. |
| Impacts from disturbance of acid sulfate soils | Prior to any excavation in Middle Harbour or ground disturbance at The Spit/Spit West Reserve, testing should be carried out to determine the presence of ASS.<br>If ASS are identified in any bed sediments within Middle Harbour or soils at The Spit/Spit West Reserve that would be excavated as a part of the project, an appropriate ASS management plan should be developed and implemented prior to disturbance in accordance with *Acid Sulfate Soil Manual* (ASSMAC, 1998). The ASS management plan should also detail appropriate measures to manage ASS wastes (where generated) in accordance with *Waste Classification Guidelines* (NSW EPA, 2014).<br>If ASS are encountered elsewhere, they should be managed in accordance with the *Acid Sulfate Manual* (ASSMAC, 1998). |
| Contamination – soils | Based on the information reviewed, a number of moderate to high risk potential AEIs have been identified, including the Flat Rock drive construction support site (BL2), Balgowlah Golf Course (BL10) and surface works and construction support site locations along the Wakehurst Parkway (BL12, BL13 and BL14). Where extensive investigations have not been carried out, potentially contaminated areas directly affected by the project should be investigated and managed in accordance with the requirements of guidance endorsed under section 105 of the *Contaminated Land Management Act 1997.*<br>Any contaminated material disturbed during construction should be separated from uncontaminated material on site to prevent cross contamination. Contaminated material should be encapsulated on site where appropriate, and in accordance with relevant regulatory requirements. Any material that is not suitable for encapsulation should be loaded into sealed and covered trucks for disposal at a suitably licensed |

| Impact | Mitigation and management measure |
|---|---|
| | facility. Further site investigations during the further design development and construction planning phases would inform contamination management including determining where encapsulation is appropriate.<br>Where contaminated soils and other materials are to be encapsulated on-site, encapsulation should be designed in accordance with the requirements detailed in the *Guidelines for the Assessment of On-site Containment of Contaminated Soil* (ANZECC, 1999). |
| Contamination – sediments | Appropriate construction methodology has been developed to remove or suitably reduce the contamination risks from contaminated sediments during construction activities as detailed in Chapter 6 (Construction work) and Appendix P (Technical working paper: Hydrodynamic and dredge plume modelling) (Royal HaskoningDHV, 2020) of the environmental impact statement).<br>Where bed sediments within Middle Harbour require excavation and removal to facilitate construction, there are two options for the disposal of sediments. These include:<br>▪ Offshore disposal – The appropriateness of the offshore disposal option would need to be assessed in accordance with *National Assessment Guidelines for Dredging* (Commonwealth of Australia, 2009)<br>▪ Landfill disposal – Sediments not suitable for offshore disposal and requiring disposal to landfill would be assessed in accordance with the *Waste Classification Guidelines (*NSW EPA, 2014). Landfill disposal is likely to be appropriate for both clean and contaminated sediments.<br>Excavated bed sediments to be disposed to landfill (ie not suitable for offshore disposal) are likely to require some initial treatment at an onshore transfer point to reduce water content (ie achieve a spadable condition), reduce odours and neutralise ASS (if present) before transport to a suitable licensed landfill facility.<br>Additional investigations should be required to determine the extent (laterally and vertically) and separation of clean and contaminated bed sediments to facilitate disposal. Appropriate management measures should be developed to remove or suitably reduce the contamination risks from sediments during construction activities. Where sediments are disturbed as part of construction activities, sediment transport and distribution within the water column should be appropriately managed so as not to cause harm to benthic and marine ecosystems and/or adversely reduce water quality. |
| Contamination – groundwater | To further quantify the risk associated with groundwater contamination and construction and operation of the project (including dewatering), further groundwater investigations should occur in the vicinity of landfilled areas at the Willoughby Leisure Centre, Bicentennial Reserve and Flat Rock Reserve. |

| Impact | Mitigation and management measure |
|---|---|
| Contamination – ground gas | Stage 2 contamination studies should include landfill gas investigations in the vicinity of the Willoughby Leisure Centre, Bicentennial Reserve and Flat Rock Reserve to assess the potential presence or absence of gas which could affect construction and/or operation of the project. Ground gas investigations should be carried out (where applicable) in accordance with the following guidance:<br>▪ *Guideline for the Assessment and Management of Sites Impacted by Hazardous Ground Gases* (NSW EPA, 2012)<br>▪ *Assessing Risks Posed by Hazardous Ground Gases to Buildings Report* (C665) (Wilson et al., 2007). |
| Contamination | A NSW Environment Protection Authority-accredited Site Auditor will be engaged where contamination is complex to review applicable contamination reports and evaluate the suitability of sites for a specified use as part of the project. |
| Building demolition | Should any structures and/or buildings require demolition to enable construction, hazardous building materials (where present) should be managed to ensure appropriate handling and waste disposal to reduce the potential for contamination of soil in the vicinity. In accordance with Australian Standard (AS 2601-2001), *The demolition of structures*, a hazardous building materials audit would be required before the demolition of any structure and/or building. |
| **Operation** | |
| Contamination – ground gas | If ground gas risks to the operation of the project (namely tunnels, subsurface and enclosed structures) are established, appropriate design (eg tanking, gas drainage) and/or management (eg ventilation) measures should be developed and implemented to remove or suitably reduce the associated risk. |

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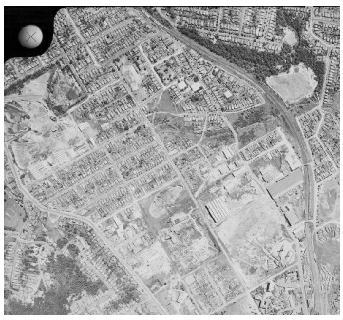
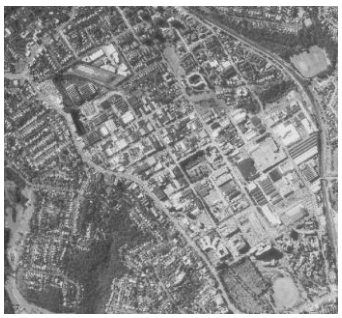
# Annexure A. Historical aerial photography

Table A-1: Historical aerial photography review – Gore Hill Freeway Connection

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 | No image available | | |
| 1955 |  | The Gore Hill Freeway Connection surface work site is located within an area comprising residential and commercial developments, open space and a quarry. | The surrounding area comprises established low density residential with increased commercial/industrial use to the south. Main visible industry comprises quarries and brick work. |
| 1961 | No image available | | |
| 1970 | No image available | | |
| 1975 |  | Quarry identified with the north-western corner of the Gore Hill Freeway Connection surface work site in the 1955 imagery has been filled/developed for commercial/industrial. Increased commercial/industrial development has occurred. | Increased commercial/industrial land use is present to the south of the Gore Hill Freeway Connection surface work. |
| 1983/84 |  | Further commercial/industrial development has occurred in the north-western corner of the Gore Hill Freeway Connection surface work. Other areas are generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1986 |  | Site is generally unchanged from the 1983/84 imagery. | Surrounding area is generally unchanged from the 1983/84 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1991 |  | The majority of the Gore Hill Freeway Connection surface work site is highly modified associated with the construction of the Gore Hill Freeway. | Surrounding area is generally unchanged from the 1986 imagery with the exception of the demolition of residential and commercial premises and clearing of areas of bushland to assist construction of the Gore Hill Freeway Connection. |
| 1994 | No image available | | |
| 1998 |  | The majority of the Gore Hill Freeway Connection surface work site is occupied by the Gore Hill Freeway. Areas to the north of the freeway are generally residential and to the south commercial/industrial. | Surrounding area is generally unchanged from the 1991 imagery. |
| 2002 |  | Gore Hill Freeway Connection surface work site is generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Gore Hill Freeway Connection surface work site is generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-2: Historical aerial photography review – Cammeray Golf Course (BL1)

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Cammeray Golf Course (BL1) appears to be a vacant parcel of land (golf course and associated facilities not yet constructed). The Warringah Freeway has not been constructed. Possible tennis courts present within the south-eastern corner of the site. | The surrounding area comprises established low density residential. Residential dwellings are present within the current footprint of the Warringah Freeway. |
| 1955 | Not visible | | |
| 1961 |  | Cammeray Golf Course (BL1) is part of the Cammeray golf course. The Warringah Freeway has not been constructed. | The surrounding area comprises established low density residential. Residential dwellings are present within the current footprint of the Warringah Freeway. |
| 1970 |  | The majority of Cammeray Golf Course (BL1) is occupied by the Cammeray golf course. The Warringah Freeway is constructed/being constructed in areas to the south-west of the site. | The surrounding area comprises established low density residential. Some areas of open space and residential land use identified in the 1961 imagery have been resumed by the construction of the Warringah Freeway. |
| 1975 |  | Cammeray Golf Course (BL1) is generally unchanged from the 1970 imagery. | Surrounding area is generally unchanged from the 1970 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1979 |  | Cammeray Golf Course (BL1) is generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1986 |  | Cammeray Golf Course (BL1) is generally unchanged from the 1979 imagery. | Surrounding area is generally unchanged from the 1979 imagery. |
| 1991 |  | Cammeray Golf Course (BL1) is generally unchanged from the 1986 imagery. | Surrounding area is generally unchanged from the 1986 imagery. |
| 1994 |  | Cammeray Golf Course (BL1) is generally unchanged from the 1991 imagery. | Surrounding area is generally unchanged from the 1991 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1998 |  | Cammeray Golf Course (BL1) is generally unchanged from the 1994 imagery. | Surrounding area is generally unchanged from the 1994 imagery. |
| 2002 |  | Cammeray Golf Course (BL1) is generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Cammeray Golf Course (BL1) is generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-3: Historical aerial photography review – Flat Rock Drive (BL2)

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Flat Rock Drive (BL2) is occupied by vacant land (bushland) next to a creek. | Area is predominantly established low density residential. Halstrom Park, Willoughby Leisure Centre and Bicentennial Reserve are occupied vacant bushland next to a creek. A potential industrial facility is located on the corner of Willoughby and Artarmon Roads. A large cleared area is located to the south of Artarmon Road (current location of Channel 9 studios). The Warringah Freeway and Flat Rock Drive have not been constructed. |
| 1955 |  | Flat Rock Drive (BL2) is generally unchanged from the 1930 imagery.<br>Infilling of Flat Rock Drive (BL2) has started. The incinerator building is visible along the northern boundary of the site. | Area is predominantly established low density residential. Infilling of Halstrom Park, Willoughby Leisure Centre and Bicentennial Reserve has commenced. The incinerator building is visible along Small Street. An area of industrial premises is located on the corner of Willoughby and Artarmon Roads. A large cleared area is located to the south of Artarmon Road (current location of Channel 9 studios). The Warringah Freeway and Flat Rock Drive have not been constructed. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1961 |  | Flat Rock Drive (BL2) is generally unchanged from the 1955 imagery. Infilling activities encroaching on the western boundary of BL2.<br>Infilling of Flat Rock Drive (BL2) has started. The incinerator building is visible along the northern boundary of the site. | Area is predominantly established low density residential. Infilling of Willoughby Leisure Centre and Bicentennial Reserve continues. Incinerator still visible. Halstrom Park appears to be a rectangular sports field. A stack is visible in the south-eastern corner of the infilling operations. An area of industrial premises is located on the corner of Willoughby and Artarmon Roads. Channel 9 studios have been constructed. The Warringah Freeway and Flat Rock Drive have not been constructed. |
| 1970 |  | BL2 has been subject to ground disturbance likely to have been associated with the construction of Flat Rock Drive. | Surrounding area is generally unchanged from the 1961 imagery with the exception of continued infilling to the east of the site extending to Tunks Park.<br>Infilling of Willoughby Leisure Centre and Bicentennial Reserve. Incinerator still visible. Flat Rock Drive has been constructed. The stack identified in the 1961 imagery within the south-eastern corner has been demolished. |
| 1975 |  | BL2 has been subject to continued ground disturbance (potentially large scale filling and removal of bushland). | Surrounding area is generally unchanged from the 1970 imagery with the exception of the demolition of the industrial facility located on the corner of Willoughby and Artarmon Roads. The TV transmitter tower on the Channel 9 site is visible. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1983/84 |  | Ground disturbance at BL2 appears to have been completed.<br>Flat Rock Drive (BL2) is generally unchanged from the 1975 imagery with the exception of some ancillary buildings next to the incinerator that have been demolished. Carpark and building constructed within the northern portion of the site. | Surrounding area is generally unchanged from the 1975 imagery with the exception of the construction of medium to high density residential buildings on the corner of Willoughby and Artarmon roads. Some ancillary buildings next to the incinerator have been demolished. A carpark and building have been constructed within the footprint of the Willoughby Leisure Centre site. |
| 1986 |  | Flat Rock Drive (BL2) is generally unchanged from the 1983/84 imagery. | Surrounding area is generally unchanged from the 1983/84 imagery. |
| 1991 |  | A carpark has been constructed within the northern portion of Flat Rock Drive (BL2). Remainder of BL2 is generally unchanged from the 1986 imagery. | Surrounding area is generally unchanged from the 1986 imagery with the exception of ongoing substantial changes including new sporting fields, sealed netball courts, baseball diamond, aquatic centre and car parking for the Willoughby Leisure Centre and Bicentennial Reserve. Incinerator building is still present to the west of the Willoughby Leisure Centre.<br>The Gore Hill Freeway has been constructed to the south-west of the site. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1994 |  | Flat Rock Drive (BL2) is generally unchanged from the 1991 imagery. | Surrounding area is generally unchanged from the 1991 imagery with the exception of the Gore Hill Freeway located to the south-west of the site. |
| 1998 |  | Flat Rock Drive (BL2) is generally unchanged from the 1994 imagery with the exception of minor disturbance works across the majority of the site (potential construction of Flat Rock Gully Reserve). | Surrounding area is generally unchanged from the 1994 imagery with the exception of development (possibly residential) to the south of the site. Additional netball courts have been constructed to the south of the Willoughby Centre. |
| 2002 |  | Flat Rock Drive (BL2) is generally unchanged from the 1998 imagery with the exception of additional vegetative cover. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Flat Rock Drive (BL2) is generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-4: Historical aerial photography review – Punch Street (BL3)

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Punch Street (BL3) appears to be a vacant parcel of land next to a creek. Low density residential premises are located across Punch Street (to the south-east). A bridge structure is observable to the west of the site. Access tracks are visible across the site. | The surrounding area comprises established low density residential to the north of the railway line) with increased commercial/industrial use to the south of the railway line. Main visible industry comprises quarries, brick work and market gardens. |
| 1955 |  | Punch Street (BL3) remains a vacant parcel of land. The nearby creek has been realigned. Low density residential premises are located across Punch Street (to the south-east). The Hampden Road/Herbert Street bridge has been constructed. | The surrounding area comprises established low density residential to the north of the railway line) with increased commercial/industrial use to the south of the railway line. Main visible industry comprises quarries and brick work. Artarmon Reserve has been formalised as open space. |
| 1961 | No image available | | |
| 1970 |  | Punch Street (BL3) remains a vacant parcel of land. Trees observed across the western portion of the site in the 1955 imagery have been removed. | Surrounding area is generally unchanged from the 1955 imagery with the exception of the demolition of residential premises and construction of industrial buildings to the south of the site. |
| 1975 |  | Punch Street (BL3) is generally unchanged from the 1970 imagery. | Surrounding area is generally unchanged from the 1970 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1983/84 |  | Punch Street (BL3) is generally unchanged from the 1975 imagery with the exception of a section of disturbed ground in the north-eastern portion of the site. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1986 |  | Punch Street (BL3) is generally unchanged from the 1983/84 imagery. | Surrounding area is generally unchanged from the 1983/84 imagery. |
| 1991 |  | Punch Street (BL3) is highly modified associated with the construction of the Gore Hill Freeway. | Surrounding area is generally unchanged from the 1986 imagery with the exception of demolition of residential and commercial premises and clearing of areas of bushland to assist construction of the Gore Hill Freeway. |
| 1994 |  | Punch Street (BL3) is a vacant portion of land next to the constructed and operational Gore Hill Freeway. | Surrounding area is generally unchanged from the 1991 imagery with the exception of the presence of the Gore Hill Freeway. |
| 1998 |  | Punch Street (BL3) remains vacant. Site contains established vegetation. | Surrounding area is generally unchanged from the 1994 imagery. |

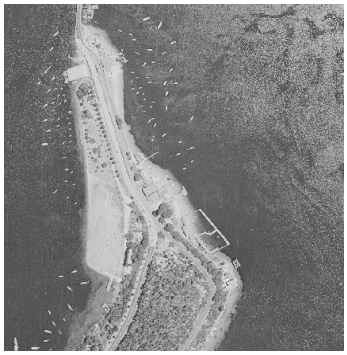
| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 2002 |  | Punch Street (BL3) is generally unchanged from the 1998 imagery with the exception of further establishment of on-site vegetation. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Punch Street (BL3) has been cleared of vegetation. | Surrounding area is generally unchanged from the 2002 imagery with the exception of some clearing in areas to the north of the site. |

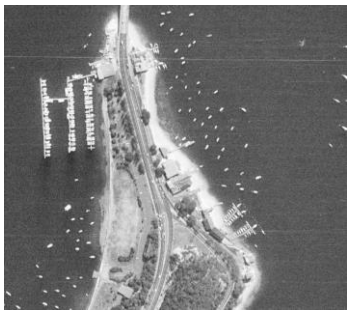
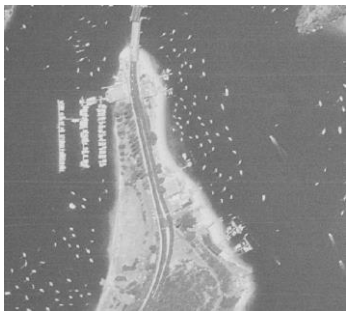
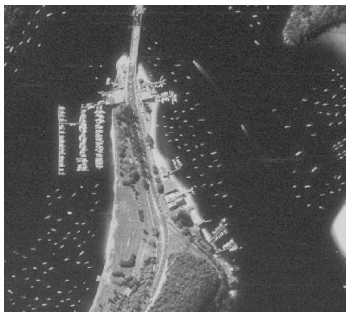
Table A-5: Historical aerial photography review – Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) construction support sites

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 | No image available | | |
| 1955 |  | Gore Hill Freeway median (BL6) is located within a quarry. Dickson Avenue (BL4) and Barton Road (BL5) are located on sites occupied by residential buildings. | The surrounding area comprises established low density residential with increased commercial/industrial use to the south. Main visible industry comprises quarries and brick work. |
| 1961 | No image available | | |
| 1970 | No image available | | |
| 1975 |  | Quarry identified at Gore Hill Freeway median (BL6) in the 1955 imagery has been filled/developed for commercial/industrial. Barton Road (BL5) appears to be occupied by residential buildings. Dickson Avenue (BL4) appears to be occupied by commercial/industrial operations (small workshops). | Increased commercial/industrial land use is present to the south of the sites. |
| 1983/84 |  | Further commercial/industrial development has occurred near Gore Hill Freeway median (BL6). Dickson Avenue (BL4) and Barton Road (BL5) are generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1986 |  | Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) are generally unchanged from the 1983/84 imagery. | Surrounding area is generally unchanged from the 1983/84 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1991 |  | Barton Road (BL5) and Gore Hill Freeway median (BL6) are highly modified associated with the construction of the Gore Hill Freeway. Both sites appear to be within the construction footprint of the freeway. Dickson Avenue (BL4) is generally unchanged from the 1986 imagery. | Surrounding area is generally unchanged from the 1986 imagery with the exception of the demolition of residential and commercial premises and clearing of areas of bushland to assist construction of the Gore Hill Freeway. |
| 1994 | No image available | | |
| 1998 |  | Gore Hill Freeway median (BL6) is part of the Gore Hill Freeway footprint. Barton Road (BL5) appears to be a vacant parcel of land between residential buildings and the freeway. Dickson Avenue (BL4) is generally unchanged from the 1991 imagery. | Surrounding area is generally unchanged from the 1991 imagery. |
| 2002 |  | Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) are generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Dickson Avenue (BL4), Barton Road (BL5) and Gore Hill Freeway median (BL6) are generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-6 Historical aerial photography review – Spit West Reserve (BL9) construction support site

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Spit West Reserve (BL9) is occupied by possible area of land reclamation on the southern side of the Spit bridge and to the west of Spit Road. | Area has generally scattered and isolated low density residential dwellings with increased low density residential dwellings to the south. The majority of the surrounding area appears to be vacant bushland. A bridge structure is present connecting the Spit to Seaforth. |
| 1955 |  | Spit West Reserve (BL9) is a vacant portion of land (possible reserve). Reclamation work observed in 1930 appears to have been completed. | The surrounding area has established low density residential premises. |
| 1961 |  | Spit West Reserve (BL9) is generally unchanged from the 1955 imagery. | Surrounding area is generally unchanged from the 1955 imagery with the exception of road upgrades at the intersection of Parriwi and Spit roads. |
| 1970 |  | Spit West Reserve (BL9) is generally unchanged from the 1961 imagery with the exception of the construction of a marina to the north of the site. | Surrounding area is generally unchanged from the 1961 imagery with the exception of marina construction on the eastern side of the Spit. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1975 |  | Spit West Reserve (BL9) is generally unchanged from the 1970 imagery. | Surrounding area is generally unchanged from the 1970 imagery. |
| 1979 |  | Spit West Reserve (BL9) is generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1983/84 |  | Spit West Reserve (BL9) is generally unchanged from the 1979 imagery. | Surrounding area is generally unchanged from the 1979 imagery. |
| 1986 |  | Spit West Reserve (BL9) is generally unchanged from the 1983/84 imagery. | Surrounding area is generally unchanged from the 1983/84 imagery. |
| 1991 |  | Spit West Reserve (BL9) is generally unchanged from the 1986 imagery. | Surrounding area is generally unchanged from the 1986 imagery. |

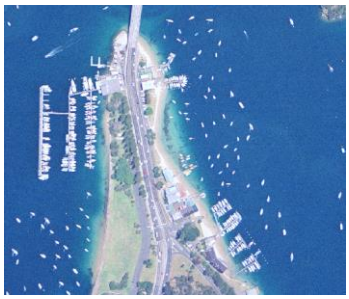
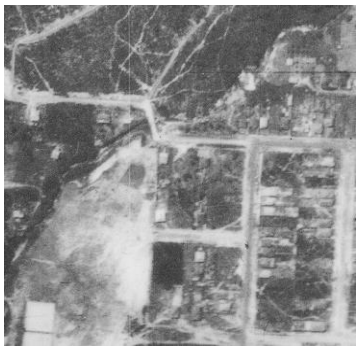
| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1994 |  | Spit West Reserve (BL9) is generally unchanged from the 1991 imagery. | Surrounding area is generally unchanged from the 1991 imagery. |
| 1998 |  | Spit West Reserve (BL9) is generally unchanged from the 1994 imagery. | Surrounding area is generally unchanged from the 1994 imagery. |
| 2002 |  | Spit West Reserve (BL9) is generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Spit West Reserve (BL9) is generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-7: Historical aerial photography review – Balgowah Golf Course (BL10) construction support site

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Balgowlah Golf Course (BL10) is occupied by vacant land next to a creek (Burnt Bridge Creek). The Burnt Bridge Creek Deviation has not been constructed. | The surrounding area comprises predominantly established low density residential with areas of vacant land and bushland. Ground disturbance visible to the south-west of the site near the current Balgowlah Golf Course site. |
| 1955 |  | Balgowlah Golf Course (BL10) is occupied by vacant land next to a creek (Burnt Bridge Creek). The Burnt Bridge Creek Deviation has not been constructed. | The surrounding area comprises increased low density residential. |
| 1961 |  | Balgowlah Golf Course (BL10) is occupied by vacant land next to a creek (Burnt Bridge Creek). The Burnt Bridge Creek Deviation has not been constructed. | The surrounding area comprises low density residential. |
| 1970 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 1961 imagery. | Surrounding area is generally unchanged from the 1961 imagery. |
| 1975 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 1970 imagery. | Surrounding area is generally unchanged from the 1970 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1979 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1983/84 |  | Balgowlah Golf Course (BL10) has undergone substantial change associated with the construction of the Burnt Bridge Creek Deviation. | Surrounding area is generally unchanged from the 1975 imagery with the exception of demolition of residential premises and clearing of areas of bushland to assist construction of the Burnt Bridge Creek Deviation. |
| 1986 |  | Balgowlah Golf Course (BL10) is a cleared portion of land next to the Burnt Bridge Creek Deviation and the Kitchener Street overpass. | Surrounding area is generally unchanged from the 1983/84 imagery with the exception of construction and operation of the Burnt Bridge Creek Deviation. |
| 1991 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 1986 imagery. Storage of materials on-site observed in imagery. | Surrounding area is generally unchanged from the 1986 imagery. |
| 1994 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 1991 imagery. Sealed access track constructed into the site. | Surrounding area is generally unchanged from the 1991 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1998 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 1994 imagery. | Surrounding area is generally unchanged from the 1994 imagery. |
| 2002 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Balgowlah Golf Course (BL10) is generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-8: Historical aerial photography review – Kitchener Street (BL11) construction support site

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Kitchener Street (BL11) is located on an area of ground disturbance visible near the current Balgowlah Golf Course site. | Surrounding area is predominantly established low density residential. Sydney Road is visible. |
| 1955 |  | Kitchener Street (BL11) is located on the established Balgowlah Golf Course site. | Surrounding area is predominantly established low density residential. Sydney Road is visible. Balgowlah Boys High School is present to the south of the site. |
| 1961 |  | Kitchener Street (BL11) is generally unchanged from the 1955 imagery, with the exception of extension of the clubhouse car park. | Surrounding area is generally unchanged from the 1955 imagery. |
| 1970 |  | Kitchener Street (BL11) is generally unchanged from the 1961 imagery. | Surrounding area is generally unchanged from the 1961 imagery with the exception of medium to high density residential premises constructed to the east of the site fronting Sydney Road. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1975 |  | Kitchener Street (BL11) is generally unchanged from the 1970 imagery. | Surrounding area is generally unchanged from the 1970 imagery with the exception of the completion of Balgowlah Oval located to the south-east of the site. |
| 1979 |  | Kitchener Street (BL11) is generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1983/84 |  | Kitchener Street (BL11) is generally unchanged from the 1979 imagery with the exception of demolition of residential premises to assist construction of the Burnt Bridge Creek Deviation next to the western boundary of the site. | Surrounding area is generally unchanged from the 1979 imagery with the exception of demolition of residential premises and clearing of areas of bushland to the north-west, north and north-east of the site to assist construction of the Burnt Bridge Creek Deviation. |
| 1986 |  | Kitchener Street (BL11) is generally unchanged from the 1983/84 imagery with the exception of the construction and operation of the Burnt Bridge Creek Deviation next to the western boundary of the site. | Surrounding area is generally unchanged from the 1983/84 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1991 |  | Kitchener Street (BL11) is generally unchanged from the 1986 imagery. | Surrounding area is generally unchanged from the 1986 imagery. |
| 1994 |  | Kitchener Street (BL11) is generally unchanged from the 1991 imagery. | Surrounding area is generally unchanged from the 1991 imagery. |
| 1998 |  | Kitchener Street (BL11) is generally unchanged from the 1994 imagery. | Surrounding area is generally unchanged from the 1994 imagery. |
| 2002 |  | Kitchener Street (BL11) is generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery. |

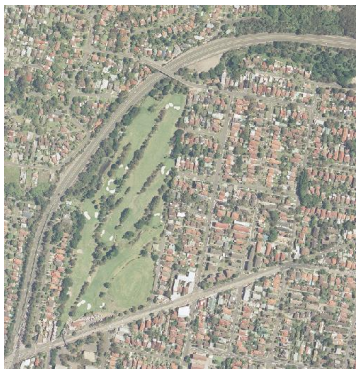
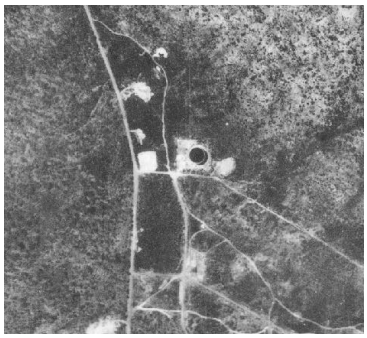
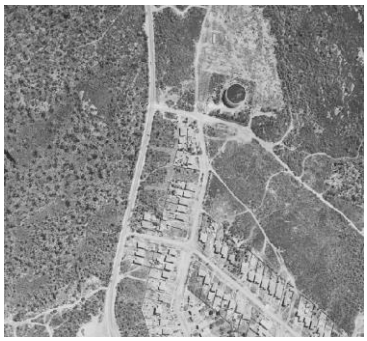
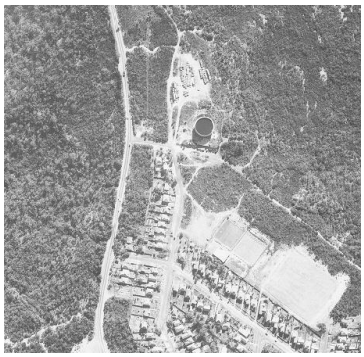
| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 2005 |  | Kitchener Street (BL11) is generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-9: Historical aerial photography review – Wakehurst Parkway south (BL12) and Wakehurst Parkway east (BL13) construction support sites

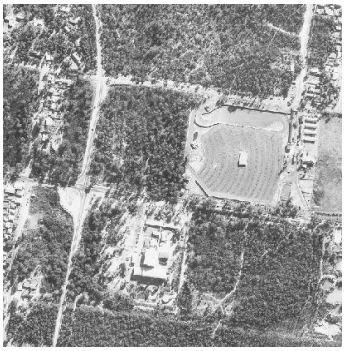
| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Wakehurst Parkway south (BL12) is located within an area of bushland with isolated pockets of ground disturbance.<br>Wakehurst Parkway east (BL13) is located within an area surrounded by bushland. One reservoir in present within the central portion of land. | Surrounding area is predominantly bushland and a single residential premises. Wakehurst Parkway is visible. |
| 1955 |  | Wakehurst Parkway south (BL12) is a combination of bushland and residential development.<br>Wakehurst Parkway east (BL13) is located within an area surrounded by bushland with the exception of the northern and eastern portions of the site which have been cleared. One reservoir in present within the central portion of land. | Areas to the north and west comprise bushland. Areas to the east and south comprise low density residential dwellings. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1961 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1955 imagery.<br>Wakehurst Parkway east (BL13) is located within an area surrounded by bushland with the exception of the northern portion of the site which is subject to clearing activities. One reservoir in present within the central portion of land. | Surrounding area is generally unchanged from the 1955 imagery with the exception of extensive clearing to the east of the BL12 site. |
| 1970 |  | Bushland between residential premises and Wakehurst Parkway (BL12 site) has been cleared.<br>Wakehurst Parkway east (BL13) has been subjected to clearing activities. The second reservoir has been constructed within the central portion of land. | Bowling club and greens appear to have been constructed on areas of extensive clearing identified in 1961 imagery. Golf course construction is being carried out to the north-east of the sites. |
| 1975 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1970 imagery.<br>Reservoir construction in the land centrally located within Wakehurst Parkway east (BL13) has been completed. | Surrounding area is generally unchanged from the 1970 imagery. |
| 1979 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1975 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |

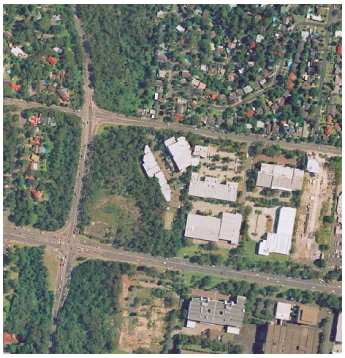
| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1983/84 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1979 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 1979 imagery. | Surrounding area is generally unchanged from the 1979 imagery. |
| 1986 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1983/84 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 1983/84 imagery. | Surrounding area is generally unchanged from the 1983/84 imagery. |
| 1991 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1986 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 1986 imagery with the exception of clearing activities to the north of the site. | Surrounding area is generally unchanged from the 1986 imagery. |
| 1994 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1991 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 1991 imagery with the exception of the area of clearing to the north of the site now being re-established. | Surrounding area is generally unchanged from the 1991 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1998 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1994 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 1994 imagery. | Surrounding area is generally unchanged from the 1994 imagery. |
| 2002 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 1998 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery. |
| 2005 |  | Wakehurst Parkway south (BL12) is generally unchanged from the 2002 imagery.<br>Wakehurst Parkway east (BL13) is generally unchanged from the 2002 imagery. | Surrounding area is generally unchanged from the 2002 imagery. |

Table A-10: Historical aerial photography review – Wakehurst Parkway north (BL14) construction support site

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1930 |  | Wakehurst Parkway north (BL14) is located in an area of predominantly bushland with some nearby open space. Orchards are present between Warringah Road and Frenchs Forest Road | Surrounding area predominantly bushland. Wakehurst Parkway, Warringah Road and Frenchs Forest Road visible. Some potential quarrying activities to the south of Warringah Road. |
| 1955 |  | Wakehurst Parkway north (BL14) is located in an area of predominantly bushland with some small areas of ground disturbance on the north-eastern side of the corner of Warringah Road and Wakehurst Parkway. | Surrounding area comprises bushland, open space and low density residential premises. |
| 1961 |  | Wakehurst Parkway north (BL15) is located in an area of predominantly bushland. | Surrounding area comprises bushland, drive-in cinema (to the east), commercial/industrial premises (to the south), quarry (to the south-west) and areas of open space and low density residential premises. |
| 1970 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1961 imagery with the exception of a walled car park area present within the south-western corner of the site. | Surrounding area is generally unchanged from the 1961 imagery with the exception of the construction of high voltage electrical transmission lines to the north and east of the site. |
| 1975 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1970 imagery. | Surrounding area is generally unchanged from the 1970 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1979 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1975 imagery. | Surrounding area is generally unchanged from the 1975 imagery. |
| 1983/84 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1979 imagery. | Surrounding area is generally unchanged from the 1979 imagery. |
| 1986 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1983/84 imagery with the exception of portions of Wakehurst Parkway north (BL14) being used for stockpiling. | The drive-in cinema has been demolished. Property to the north-east of the site has been developed for commercial/industrial use. |
| 1991 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1986 imagery. | The former drive-in cinema site has been developed in industrial/commercial units. |
| 1994 |  | Wakehurst Parkway north (BL15) is generally unchanged from the 1991 imagery. | Surrounding area is generally unchanged from the 1991 imagery. |

| Date of aerial photography | | Site | Surrounding area |
|---|---|---|---|
| 1998 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1994 imagery. | Surrounding area is generally unchanged from the 1994 imagery. |
| 2002 |  | Wakehurst Parkway north (BL14) is generally unchanged from the 1998 imagery. | Surrounding area is generally unchanged from the 1998 imagery with the exception of the demolition of commercial/industrial premises to the south (across Warringah Road) of the site. |
| 2005 |  | Portion of Wakehurst Parkway north (BL14) is being used for vehicle parking. | Surrounding area is generally unchanged from the 2002 imagery with the exception of some commercial/industrial development to the south (across Warringah Road) of the site. |

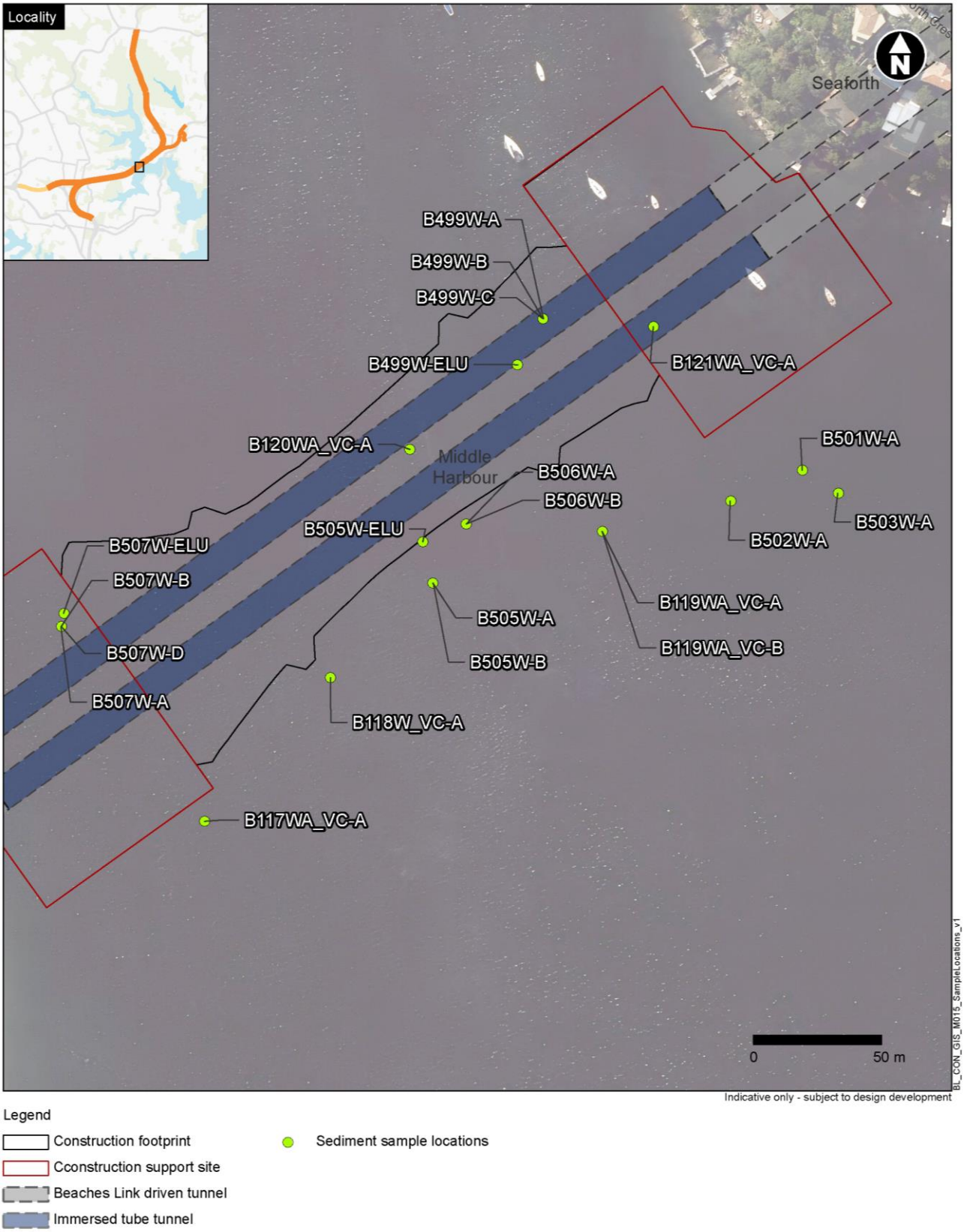
# Annexure B. Sediment tables

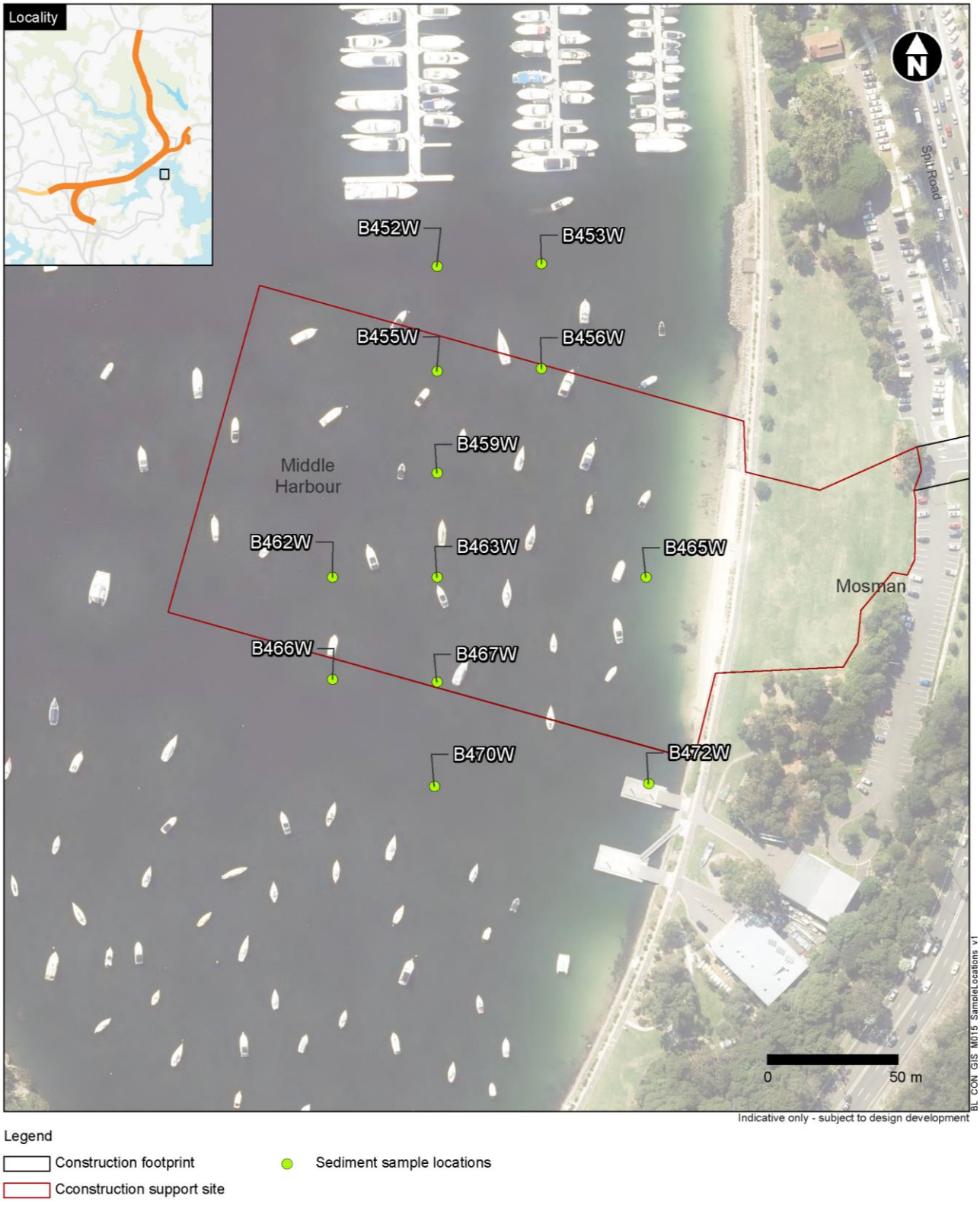
Table B-1: Beaches Link and Gore Hill Freeway Connection - Sediment Tables

| Location | Compound | ISGC (high) | ISGC (low) | NAGD |
|---|---|---|---|---|
| **Middle Harbour** | | | | |
| B117WA_VC-A | Heavy Metals | | x | |
| | TRH | | | x |
| B118W_VC-A | Heavy Metals | | x | |
| | PAH | | x | |
| B119WA_VC-A | TBT | | x | |
| | Heavy Metals | | x | |
| | Mercury | x | | |
| | TRH | | | x |
| | PAH | | x | x |
| | OCP | | | x |
| B119WA_VC-B | Heavy Metals | | x | |
| | Mercury | x | | |
| | TRH | | | x |
| | PAH | x | x | x |
| B120WA_VC-A | Heavy Metals | | x | |
| | Mercury | x | | |
| | Lead | x | | |
| | Silver | x | | |
| | TRH | | | x |
| | OCP | | x | |
| | PAH | | x | x |
| B120WA_VC-A | PAH | | x | |
| B121WA_VC-A | TBT | | x | |
| B499W-A | Heavy Metals | | x | |
| | Mercury | x | | |
| | PAH | x | x | x |
| B499W-B | Heavy Metals | | x | |
| | Mercury | x | | |
| | Silver | x | | |
| | TRH | | | x |
| | PAH | | x | x |
| B499W-C | Heavy Metals | | x | |
| | Mercury | x | | |

| Location | Compound | ISGC (high) | ISGC (low) | NAGD |
|---|---|---|---|---|
| B499W-ELU | PAH | | x | |
| B501W-A | Heavy Metals | | x | |
| | Mercury | x | | |
| | TRH | | | x |
| | PAH | | x | |
| B502W-A | Heavy Metals | | x | |
| | Mercury | x | | |
| | PAH | | x | |
| B503W-A | TRH | | | x |
| | PAH | | x | |
| B505W-A | Heavy Metals | | x | |
| | Mercury | x | | |
| | Lead | x | | |
| | Silver | x | | |
| | Zinc | x | | |
| | TRH | | | x |
| | OCP | | x | |
| | PAH | x | x | x |
| B505W-B | PAH | | x | |
| B505W-ELU | Heavy Metals | | x | |
| | PAH | | x | |
| B506W-A | Heavy Metals | | x | |
| | Mercury | x | | |
| | TRH | | | x |
| | OCP | | x | |
| | PAH | x | x | |
| B506W-B | PAH | | x | |
| B507W-A | Heavy Metals | | x | |
| | PAH | | x | |
| B507W-B | PAH | | x | |
| B507W-D | Heavy Metals | | x | |
| B507W-ELU | PAH | | x | |

| Location | Compound | ISGC (high) | ISGC (low) | NAGD |
|---|---|---|---|---|
| **The Spit** | | | | |
| B452W | Mercury | | x | NP |
| B453W | Mercury | | x | NP |
| B455W | Mercury | | x | NP |
| B456W | Mercury | | x | NP |
| B459W | Mercury | | x | NP |
| B462W | Lead | | x | NP |
| | Mercury | | x | NP |
| | PAH | | x | NP |
| B463W | Mercury | | x | NP |
| B465W | PAH | | x | NP |
| B466W | Lead | | x | NP |
| | Mercury | | x | NP |
| | PAH | | x | NP |
| B467W | Mercury | | x | NP |
| B470W | Mercury | | x | NP |
| B472W | Mercury | | x | NP |


Locality
Seaforth
B499W-A
B499W-B
B499W-C
B499W-ELU
B121WA_VC-A
B120WA_VC-A
Middle Harbour
B501W-A
B506W-A
B506W-B
B503W-A
B502W-A
B505W-ELU
B507W-ELU
B507W-B
B119WA_VC-A
B505W-A
B507W-D
B119WA_VC-B
B505W-B
B507W-A
B118W_VC-A
B117WA_VC-A
0
50 m
BL_CON_GIS_M015_SampleLocations_v1
Indicative only - subject to design development
Legend
Construction footprint
Cconstruction support site
Beaches Link driven tunnel
Immersed tube tunnel
Sediment sample locations


Locality
B452W
B453W
B455W
B456W
B459W
Middle Harbour
B462W
B463W
B465W
Mosman
B466W
B467W
B470W
B472W
Spit Road
N
0
50 m
Indicative only - subject to design development
BL_CON_GIS_M015_SampleLocations_v1
Legend
Construction footprint
Cconstruction support site
Sediment sample locations

# Annexure C. Results of elutriate testing of harbour sediments

# Memo

| | | |
|---|---|---|
| Project Name | : | Beaches Link and Gore Hill Freeway Connection |
| Date | : | 27 November 2020 |
| Our reference | : | PA1694-102-104-N008F01-20201127 |
| **Subject** | **:** | Contaminant levels and results of elutriate testing of sediments associated with dredging at Middle Harbour for installation of the immersed tube tunnel units |

## Introduction

This memo sets out the contaminant levels and results and interpretation of elutriate testing carried out on sediments to be dredged for installation of the immersed tube tunnel (IMT) units across Middle Harbour as part of the Beaches Link and Gore Hill Freeway Connection project. This memo is an Attachment to the environmental impact statement Technical working paper: Contamination.

The resuspension of sediments during dredging can potentially result in the introduction of contaminants into the dissolved phase of the water column by releasing contaminants from the sediment pore water and by desorption of contaminants from suspended sediment particles. Once in the dissolved phase, released contaminants can be subject to migration, by tidal currents for example, and can therefore result in different exposures and risks compared to the release of contaminants attached to suspended sediment particles. Suspended sediment particles settle back to the bed of the harbour and can also be restricted in migration by environmental control measures such as silt curtains.

Elutriate testing provides an indication of the potentially soluble contaminants that are susceptible to migration and assesses the risk to the environment from these soluble contaminants.

## 1.0 Background

Key features of the Beaches Link and Gore Hill Freeway Connection project are shown in **Figure 1**. The crossing of Middle Harbour is located upstream of The Spit between the suburbs of Northbridge and Seaforth.

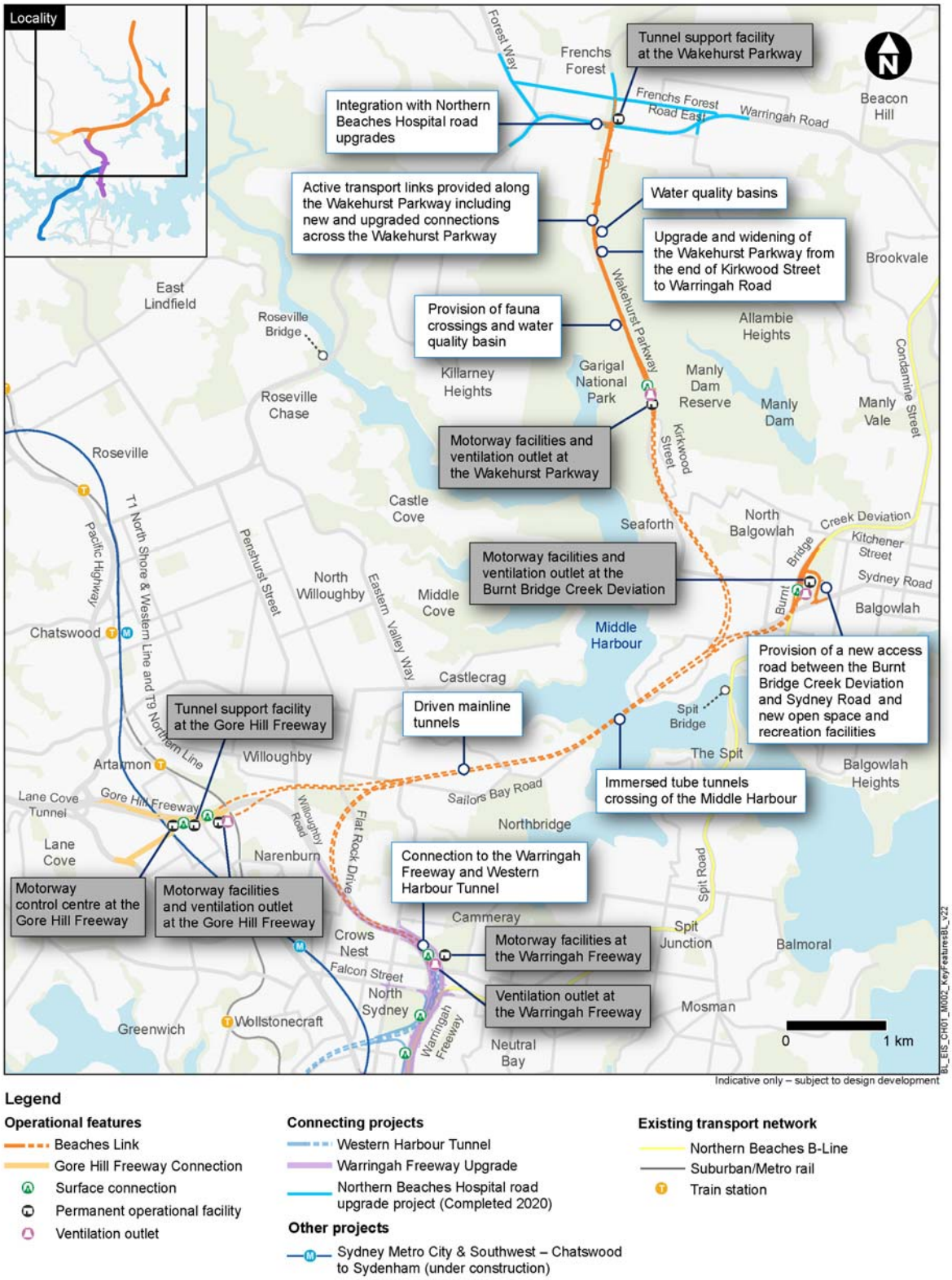



*Figure 1 Key features of the Beaches Link and Gore Hill Freeway Project*

The proposed IMT alignment and dredging footprint, as shown in **Figure 2** involves a 370m long underwater crossing. The water depths along the alignment are relatively deep, varying from 15m to 30m below Australia Height Datum (AHD), which is approximately present day mean sea level.

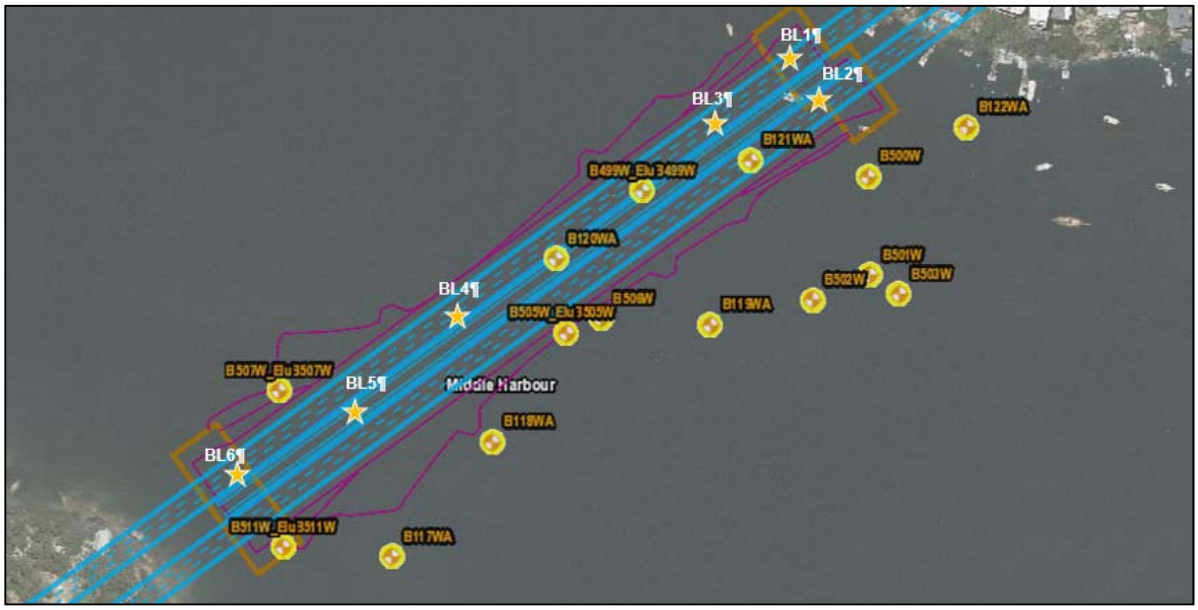



*Figure 2 Alignment (blue) and dredge footprint (magenta) for the Middle Harbour crossing. The locations of sediment samples are also shown (discussed below).*

The material that will be encountered during dredging of the crossing is shown in **Figure 3** and comprises:

- gravelly, muddy sand near the shoreline (shaded green and referenced in the legend to **Figure 3** as colluvium)
- grey green coloured muds[1] (shaded orange)
- sandstone (shaded grey).

As described in Section 4.4.1 of Technical working paper: Contamination of the environmental impact statement, the muds exhibit elevated levels of contaminants and were the focus for elutriate testing. These materials would be dredged by a backhoe dredger (BHD) equipped with a special closed bucket (environmental clamshell) and loaded into transport barges for disposal.

Two rounds of sampling and testing of the muds have been carried out, namely Douglas Partners and Golder Associates (2018) as reported in Technical working paper: Contamination of the environmental impact statement, and then subsequent investigation by Royal HaskoningDHV. The purpose of the Royal HaskoningDHV investigation was to assess the suitability of dredged sediments for offshore disposal, an activity regulated under the Commonwealth *Environment Protection (Sea Dumping) Act 1981*. The regulator for offshore disposal at the nominated disposal ground (Sydney Offshore Spoil Ground) is the Commonwealth Department of Agriculture, Water and Environment (DAWE).

It is a requirement of the Sea Dumping Act to assess potential impacts and put forward appropriate management and monitoring measures for consideration by the DAWE when determining an application and its suitability for offshore disposal. The sediment sampling and assessment carried out by Royal HaskoningDHV was commissioned to satisfy Commonwealth requirements, as part of Transport for NSW's

[1] *Muds comprise silts and clays (sediments finer than 63 microns in size)*

application for offshore disposal. Determination of the offshore disposal permit(s) is subject to determination of the application by the DAWE. Notwithstanding, a summary of the Royal HaskonigDHV investigations to date is included below.

In **Figure 2** the yellow circles depict the Douglas Partners and Golder Associates sampling locations, whereas the yellow stars depict the sampling locations in the subsequent Royal HaskoningDHV investigation. In addition, Royal HaskongDHV re-sampled at three of the Douglas Partners and Golder Associates locations in the central section of the IMT crossing.

It is noted that an adjustment of the IMT alignment was made subsequent to the Douglas Partners and Golder Associates (2018) sampling and testing. For this reason, a number of the sampling locations fall outside the current dredge footprint.

Sampling of pore waters was not carried out as part of the sediment investigations due to the difficulties of insitu sampling of pore water and obtaining sufficient samples for analysis, and the possibility of geochemical transformation of the pore water during processing of the samples[2].

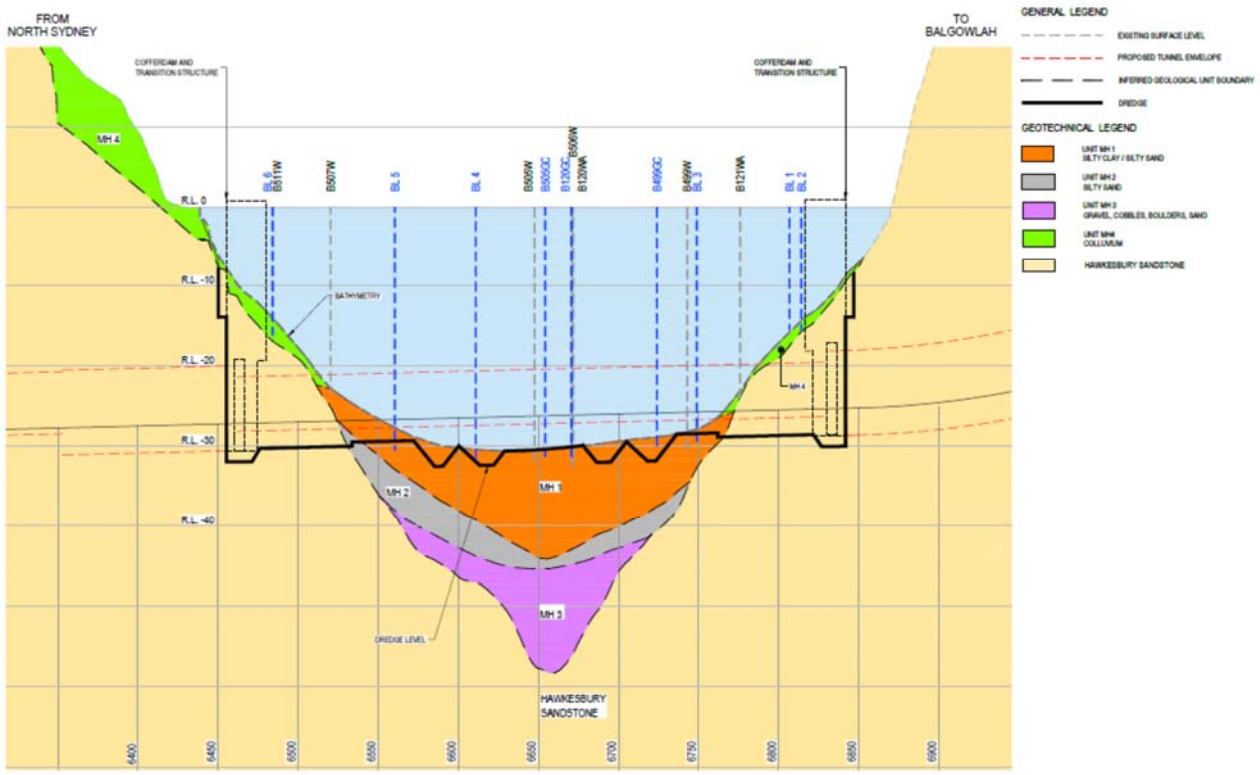



*Figure 3 View looking upstream showing the main types of material to be dredged*

[2] *Refer to discussion in Part II Section 2.3 of Simpson, Batley and Chariton (2013), wherein it is stated that:*

- *all pore water isolation methods have been shown to alter pore water chemistry and affect metal contaminant bioavailability and toxicity; and*
- *because pore waters will generally contain very low dissolved oxygen concentrations, and often having high concentrations of easily oxidizable species, maintaining these properties following isolation from sediment is practically impossible.*

## 2.0 Contaminant Levels in the Sediments

Information on sediment contamination from the Douglas Partners and Golder Associates (2018) sampling and testing is included in Technical working paper: Contamination of the environmental impact statement. A summary table comparing contaminant levels to Interim Sediment Quality Guidelines (ISQG) ISQG-High and ISQG-Low values is included in **Attachment A**.

Sediment contaminant information from the investigation by Royal HaskoningDHV is set out in Table 1 (95% upper confidence level (UCL) of the mean contaminant concentration), for three groups of sediments:

- gravelly, muddy sand near the shoreline
- grey green mud 0-1.0m below the bed of the harbour
- grey green mud greater than 1.0m below the bed of the harbour.

Bearing in mind the purpose of the Royal HaskoningDHV investigation (being consideration of the suitability of dredged material for offshore disposal) the contaminant levels were assessed in accordance with the sediment quality guidelines included in the *National Assessment Guidelines for Dredging* (NAGD) (Commonwealth of Australia, Canberra, 2009). These guidelines are identical to the guideline values in Simpson, Batley and Chariton (2013), as noted in Part II Section 3.8 of Simpson, Batley and Chariton (2013). Specifically, the contaminants levels were assessed against a Screening Level (SL). This is the level of a contaminant in the sediment below which toxic effects on organisms are not expected (NAGD, 2009).

*Table 1 Summary of the 95% UCL of mean contaminant concentrations in Royal HaskoningDHV investigation*

| | | | **gravelly, muddy sand near shoreline** | **grey green mud 0-1.0m below the harbour bed** | **grey green mud greater than 1.0 m below the harbour bed** |
|---|---|---|---|---|---|
| **Parameter** | **Units** | **SL** | **95% UCL of MEAN** | **95% UCL of MEAN** | **95% UCL of MEAN** |
| Tributyltin* | ug/kg | 9 | 3.46 | 6.17 | 1.07 |
| Arsenic | mg/kg | 20 | 7.07 | 14.53 | 8.16 |
| Cadmium | mg/kg | 1.5 | <0.05 | 1.22 | 0.41 |
| Chromium | mg/kg | 80 | 8.85 | 59.88 | 30.93 |
| Copper | mg/kg | 65 | 17.28 | 89.39 | 18.12 |
| Lead | mg/kg | 50 | 29.09 | 162.90 | 44.77 |
| Mercury | mg/kg | 0.15 | 0.13 | 1.81 | 0.12 |
| Nickel | mg/kg | 21 | 1.72 | 11.02 | 9.82 |
| Silver | mg/kg | 1 | 0.33 | 2.27 | 0.59 |
| Zinc | mg/kg | 200 | 42.19 | 207.70 | 24.39 |
| TPH* | mg/kg | 550 | 126.10 | 159.60 | 69.43 |
| DDD* | mg/kg | 0.002 | <0.001 | <0.001 | <0.001 |
| DDE* | mg/kg | 0.0022 | <0.001 | <0.0018 | <0.001 |
| DDT* | mg/kg | 0.0016 | <0.001 | <0.001 | <0.001 |
| Total PAH* | mg/kg | 10 | 5.34 | 6.40 | 3.67 |
| PCDD/Fs Total TEQ WHO-TEQ2 (0.5 LOR) | pg/g | -- | 8.65 | 48.32 | 20.69 |

* normalised to 1% TOC (Total Organic Carbon)

The key findings of the Royal HaskoningDHV investigation are outlined below:

- the gravelly, muddy sand near the shoreline is suitable for offshore disposal
- the top 1m of grey green mud along the majority of the Middle harbour crossing tunnel alignment is not suitable for offshore disposal. Based on the available sediment data, the top 1m of sediment would need to be disposed to land and would be classified as general solid waste
- contaminant concentrations in the grey green mud reduce with depth. Sediment below 1m depth is suitable for offshore disposal.

## 3.0 Elutriate Test Method

The elutriate test method is a commonly adopted test in dredging projects. It is referred to, for example, in NAGD (2009).

The test involves shaking a sediment sample with four times the volume of seawater at room temperature for 30 minutes, then allowing the samples to settle for one hour[3]. The supernatant (elutriate) is then centrifuged or filtered (0.45µm) within 60 minutes and analysed. The seawater used for the elutriate test is also analysed by the same methods, so that the results for the elutriate can be corrected for contaminant levels in the seawater.

The elutriate test is recognised in Simpson, Batley and Chariton (2013) as an option to provide an indication of potentially soluble contaminants, having regard to the sampling and geochemical transformation issues referred to earlier (see Simpson, Batley and Chariton, 2013, Part I, Section 3.3.1).

## 4.0 Elutriate Test Results and Interpretation

Douglas Partners and Golder Associates (2018) carried out elutriate testing of the grey green muds as part of their marine contamination investigations for the project. Royal HaskoningDHV also carried out elutriate testing of the grey green muds, as part of the assessment of the suitability of the dredged sediments for offshore disposal.

When considering the results of elutriate testing, in addition to correcting the results for contaminant levels in the seawater used in the test, it is also necessary to consider the natural dilution which would occur at the dredging site. This is because the natural dilution is typically well in excess of the dilution adopted in the elutriate test (1:4) hence the elutriate test results themselves will greatly overestimate the water quality impacts[4].

A 95 per cent species protection level is considered appropriate for Middle Harbour on the basis of it being a slightly to moderately disturbed system.

For the Douglas Partners and Golder Associates (2018) elutriate testing, four surface samples of the mud (0.0–0.5m depth) were selected for elutriate testing. The results from the testing, corrected for seawater concentrations, are set out in Table 2. The sample locations are shown in **Figure 2**.

[3] *The elutriate test hence uses a dilution of 1:4, wet sediment:seawater.*

[4] *In the NAGD document, for example, the natural dilution which is achieved after a four-hour period is taken into account before elutriate results are compared to water quality guideline values. In the open ocean, dilutions of the order of a hundred times or more (and often much more) would normally be expected after four hours (NAGD, 2009).*

*Table 2 Elutriate test results from Douglas Partners and Golder Associates (2018)*

| Sample location and depth (m) | Copper | Lead | Zinc | Silver | Mercury | Total TCDD |
|---|---|---|---|---|---|---|
| | µg/L | µg/L | µg/L | µg/L | µg/L | pg/L |
| | ANZG 95% Species Protection | | | | | |
| GUIDELINE | 1.3 | 4.4 | 15 | 1.4 | 0.1[5] | - |
| B505 (0.0-0.5) | <1 | 1.1 | <5 | <0.1 | <0.1 | <4.7 |
| B511 (0.0-0.5) | <1 | 1.2 | <5 | <0.1 | <0.1 | <4.7 |
| B499 (0.0-0.5) | 24 | 11.9 | 87 | 1.6 | 0.7 | <4.7 |
| B507 (0.0-0.5) | <1 | 1.7 | <5 | <0.1 | <0.1 | <4.7 |

'-' denotes no criteria in the referenced guideline.

In the subsequent Royal HaskoningDHV investigation, three surface samples of the mud (0.0–0.5m) were selected for elutriate testing. The results from the testing, corrected for seawater concentrations, are set out in Table 3. The sample locations are shown in **Figure 2**.

*Table 3 Elutriate test results from the ROYAL HASKONINGDHV elutriate testing*

| Sample location and depth (m) | Copper | Lead | Zinc | Silver | Mercury | Total TCDD |
|---|---|---|---|---|---|---|
| | µg/L | µg/L | µg/L | µg/L | µg/L | pg/L |
| | ANZG 95% Species Protection | | | | | |
| GUIDELINE | 1.3 | 4.4 | 15 | 1.4 | 0.1 | - |
| B12OWA (0-0.5) | <0.1 | 0.7 | 24 | <1 | <0.1 | 9.1 |
| BL3 (0-0.5) | <0.1 | 1.4 | 14 | <1 | <0.1 | 7.0 |
| BL4 (0-0.5) | <0.1 | 1.3 | 14 | <1 | <0.1 | 8.0 |

'-' denotes no criteria in the referenced guideline.

The following comments can be made from the results of the project elutriate testing:

- in relation to metals:
  - in most cases the elutriate test results were either below laboratory detection or below the ANZG (2018) water quality trigger values for marine water (95 per cent species protection level) without applying any further dilution
  - in the Douglas Partners and Golder Associates (2018) investigation the concentrations of copper, lead, zinc and mercury in the elutriate for sample B499 (0.0-0.5m) exceeded the adopted guideline criteria
  - in the Royal HaskoningDHV elutriate testing there was a single exceedance in the elutriate for zinc for sample B120WA (0.0-0.5m) (less than two times)
  - sample B499 (0.0-0.5m) had the highest noted exceedance (approximately six times for Zinc) and on the basis there is already a 1:4 dilution in the elutriate test, a minimum natural dilution of approximately 1:24 would be required to satisfy the 95 per cent species protection level.

- in relation to TCCD[6]:
  - in the Douglas Partners and Golder Associates (2018) elutriate testing all concentrations were below laboratory detection (4.7pg/L)

[5] To account for the bioaccumulation nature of mercury, the ANZG recommends that the 99% species protection level is used for slightly to moderately disturbed systems

[6] *TCDD is 2, 3, 7, 8 – Tetrachlorodibenzo-p-dioxin.*

- in the subsequent Royal HaskoningDHV testing, measurable concentrations of TCDD in the elutriate were observed, in the range 8-10pg/L
- there is no ANZG (2018) water quality trigger values for dioxins. ANZG (2018) notes that the toxicity data reviewed by USEPA (as referenced in the NAGD, 2009) were not in a suitable form to derive guideline values for aquatic life. USEPA did not derive a guideline figure but considered that water concentrations > 10pg/L TCDD could lead to excessive levels of dioxin in fish and shellfish for human consumption, assuming a bioconcentration factor (BF) > 5000. The concentrations of TCDD in the elutriates are of the same magnitude as the concentration referred to by USEPA. On the basis there is already a 1:4 dilution in the elutriate test, a minimum natural dilution of 1:4 would be required to satisfy the USEPA figure.

Based on the above comments of the elutriate test results for metals and TCDD, a minimum required natural dilution of 1:24 would be required. Hence the question arises as to whether the natural dilution at the dredging site would exceed 1:24. This is discussed further below.

A simple approach to assessing the natural dilution that would be expected at the dredging site over a period of, say, four hours (consistent with the time period in the NAGD, 2009) would be to estimate the volume of dredged material released into the water column during this period, ie not captured in the dredging process, and compare this to a 'control volume' of water.

The volume of dredged material released into the water column during dredging can be estimated based on the production rate of the dredging equipment and the so-called 'source term', which is the percentage of material 'lost' into the water column. The source term is a function of factors such as the method of dredging and properties of the material being dredged.

As noted earlier, dredging of the sediments with elevated contaminants would be undertaken by BHD using a closed bucket (environmental clamshell). The production rate for the BHD would be approximately 300m$^3$ insitu per hour. The source term for this activity is estimated to be 1.5%. Accordingly, over a period of four hours the volume of dredged material released into the water column would be approximately 18m$^3$ (300m$^3$/hr x 4hrs x 1.5 per cent).

The column of water adopted for calculation purposes as the control volume can be taken to be the area within which the BHD bucket would operate, around 15m by 15m, and the depth of water at the dredging site of, say, typically 20m. This would give a water volume of 4,500m$^3$. This value in practice would be expected to be an underestimate (conservative) since it ignores mixing and advection within the waterway due to tidal currents even though these currents would be moderated in the dredging area by deployment of silt curtains.

The above approach would give an initial dilution (the ratio of wet sediment to seawater) exceeding 200. This is well in excess of the required initial dilution of 24 to satisfy the 95 per cent species protection level in the ANZG.

Based on the elutriate test results and the assessed available natural dilution, water quality impacts at the dredging site due to dissolved contaminants would not be expected.

## 5.0 Management Measures during Dredging

Technical Working Paper: Hydrodynamics and dredge plume modelling of the environmental impact statement discusses the environmental controls and management measures recommended to be used during dredging operations. The outcomes of the elutriate testing results were considered in the development of these management measures.

Details regarding the management of dredging operations and dredge material during the construction period would be included in a Dredge Management Plan, which would form part of the construction environmental management plan.

**References**

ANZG (2018), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Governments and Australian state and territories governments, Canberra, ACT, Australia.

Commonwealth of Australia (2009). National Assessment Guidelines for Dredging.

Douglas Partners and Golder Associates (2018), *Western Harbour Tunnel and Beaches Link Geotechnical Investigation, Contamination Factual Report – Marine Investigations.*

Simpson, Batley and Chariton (2013). *Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines*, CSIRO Land and Water Science Report 08/07.

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**Attachment A** – Sediment contamination information from Douglas Partners and Golders Associates (2018)

| | | | TOC | Tributyltin normalised | Radionuclides sum gross alpha & beta | Antimony | Arsenic | Cadmium | Chromium | Copper | Lead | Mercury | Nickel | Silver | Zinc | TPH normalised | TRH normalised | DDD | DDE | DDT | Dieldrin | Endrin | Lindane | Chlordane | Total PAH normalised | Total PCB |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Units | % | mg/kg | Bq/g | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg | mg/kg |
| | | LOR | 0.02 | 0.0005 | 0.5 | 0.018 | 0.02 | 0.001 | 0.002 | 0.002 | 0.006 | 0.00004 | 0.003 | 0.002 | 0.005 | 3 | 3 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.0005 | 0.00025 | 0.00025 | 0.004 | 0.005 |
| ISGC-High | Sample | Sample | | 0.07 | -- | 25 | 70 | 10 | 370 | 270 | 220 | 1 | 52 | 3.7 | 410 | | | 0.02 | 0.027 | 0.046 | 0.008 | 0.008 | 0.001 | 0.006 | 45 | |
| ISGC-Low (NAGD SL) | Date | Depth | | 0.005 | 35 | 2 | 20 | 1.5 | 80 | 65 | 50 | 0.15 | 21 | 1 | 200 | 550 | 550 | 0.002 | 0.0022 | 0.0016 | 0.00002 (0.28) | 0.00002 (0.01) | 0.00032 | 0.0005 | 10 | 0.023 |
| B117WA_VC-A | 20/05/17 | 0-0.5 | 2.81 | 0.0010 | 0.54 | <0.5 | 11.1 | 0.1 | 32.1 | 39 | **94.5** | **0.67** | 7.9 | **1.4** | 168 | 280.78 | 336.65 | <0.0005 | 0.00143 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 3.267 | <0.0062 |
| B117WA_VC-B | 20/05/17 | 0.5-1.0 | 1.51 | ND | <0.5 | <0.5 | 5.99 | <0.1 | 18.4 | 3.7 | 9.4 | 0.03 | 6.3 | 0.2 | 23.8 | 34.44 | 39.74 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.215 | <0.005 |
| B117WA_VC-C | 20/05/17 | 1.0-1.5 | 1.59 | ND | <0.5 | <0.5 | 7.16 | 0.1 | 19.3 | 3 | 7.2 | 0.03 | 7 | 0.4 | 19.4 | 22.64 | 28.30 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.100 | <0.005 |
| B117WA_VC-D | 20/05/17 | 1.5-2.0 | 0.76 | 0.0032 | <0.5 | <0.5 | 5.63 | 0.1 | 10.8 | 1.9 | 5.1 | <0.01 | 3.9 | 0.2 | 10.8 | 32.89 | 44.74 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.114 | <0.005 |
| B118WA_VC-A | 22/05/17 | 0-0.5 | 3.10 | 0.0002 | <0.5 | <0.5 | 8.06 | 0.1 | 28.4 | 20.9 | 48.1 | **0.37** | 8.7 | 0.6 | 84.9 | 72.58 | 84.84 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 1.568 | - |
| B118WA_VC-B | 22/05/17 | 0.5-1.0 | 3.05 | 0.0003 | 0.55 | <0.5 | 9.04 | 0.2 | 28.8 | 4.8 | 10.4 | 0.01 | 11.7 | 0.4 | 25.6 | 24.59 | 33.11 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.052 | - |
| B118WA_VC-C | 22/05/17 | 1.0-1.5 | 2.92 | ND | <0.5 | <0.5 | 7.26 | 0.2 | 28.3 | 4.4 | 10.3 | 0.01 | 11.4 | 0.1 | 24.4 | 26.71 | 34.93 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.027 | - |
| B118WA_VC-D | 22/05/17 | 1.5-2.0 | 3.03 | ND | <0.5 | <0.5 | 9.86 | 0.3 | 27.2 | 4.8 | 9.5 | 0.01 | 11 | <0.1 | 24.5 | 29.37 | 40.59 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.024 | - |
| B118WA_VC-E | 22/05/17 | 2.0-2.5 | 2.85 | ND | 0.53 | <0.5 | 10.6 | 0.4 | 26.5 | 4.8 | 9.9 | 0.01 | 11 | <0.1 | 25 | 8.07 | 11.23 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | ND | - |
| B119WA_VC-A | 18/05/17 | 0-0.5 | 3.60 | 0.0019 | 0.69 | <0.5 | 14.7 | 0.2 | **85.3** | **142** | **205** | **1.96** | 11.5 | **2.6** | **368** | 128.89 | 157.78 | <0.0005 | **0.00366** | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 2.972 | <0.0062 |
| B119WA_VC-B | 18/05/17 | 0.5-1.0 | 3.40 | 0.0003 | <0.5 | <0.5 | 12.9 | 0.2 | 48.8 | 41.8 | **112** | **1.45** | 8.8 | **1.6** | 191 | 245.59 | 278.24 | <0.0005 | 0.0019 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 4.382 | <0.0062 |
| B119WA_VC-C | 18/05/17 | 1.0-1.5 | 2.77 | ND | 0.56 | <0.5 | 8.66 | 0.1 | 30 | 8 | 21.8 | 0.15 | 9.1 | 0.2 | 39.4 | 14.80 | 19.49 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.477 | <0.0062 |
| B119WA_VC-D | 18/05/17 | 1.5-2.0 | 2.66 | ND | <0.5 | <0.5 | 7.21 | <0.1 | 30.6 | 3.8 | 8.9 | 0.02 | 9.9 | <0.1 | 20.7 | 26.69 | 31.95 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.041 | <0.0062 |
| B120WA_VC-A | 18/05/17 | 0-0.5 | 3.36 | 0.0009 | 0.6 | <0.5 | 15.3 | 0.4 | **97** | **103** | **234** | **2.57** | 12.9 | **4** | **397** | 248.81 | 300.60 | 0.00191 | **0.00666** | **0.0045** | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 3.601 | - |
| B120WA_VC-B | 18/05/17 | 0.5-1.0 | 2.96 | ND | 0.53 | <0.5 | 10.1 | 0.1 | 36.2 | 15.5 | 42.6 | **0.43** | 15.3 | 0.9 | 77.4 | 41.55 | 47.97 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 1.693 | - |
| B120WA_VC-C | 18/05/17 | 1.0-1.5 | 3.06 | ND | 1.06 | <0.5 | 7.39 | 0.1 | 31.9 | 4.2 | 9.5 | 0.03 | 9.7 | 0.2 | 22.6 | 14.71 | 18.30 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.054 | - |
| B120WA_VC-D | 18/05/17 | 1.5-2.0 | 3.35 | ND | 1.1 | <0.5 | 9.92 | 0.1 | 38.1 | 4.6 | 9.5 | 0.02 | 11.1 | <0.1 | 23.6 | ND | ND | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | ND | - |
| B121WA_VC-A | 17/05/17 | 0-0.5 | 0.70 | 0.0194 | 0.54 | <0.5 | 6.15 | <0.1 | 19.1 | 27.8 | **57.8** | **0.43** | 2.7 | 0.5 | 103 | 145.71 | 167.14 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 3.057 | <0.005 |
| B122WA_VC-A | 18/05/17 | 0-0.5 | 0.77 | ND | <0.5 | <0.5 | 3.37 | <0.1 | 4.1 | 6.3 | 19.2 | 0.07 | <1 | <0.1 | 26.8 | 18.18 | 23.38 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.312 | - |
| B499W-A | 18/05/17 | 0-0.5 | 3.04 | 0.0002 | 0.76 | <0.5 | 14.9 | 0.2 | 61.2 | 64.4 | **148** | **1.47** | 10.3 | **2.5** | **252** | 154.28 | 176.97 | <0.0005 | 0.00055 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 5.362 | <0.0062 |
| B499W-B | 18/05/17 | 0.5-1.0 | 2.97 | 0.0015 | <0.5 | <0.5 | 15.4 | 0.2 | 78.4 | **109** | **198** | **1.92** | 11.7 | **4.8** | **325** | 159.93 | 197.31 | <0.0005 | 0.00108 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 4.175 | <0.0062 |
| B499W-C | 18/05/17 | 1.0-1.5 | 3.17 | 0.0005 | 0.67 | <0.5 | 11.8 | 0.2 | 46.2 | 35.6 | **95.6** | **1.19** | 8.9 | **2** | 168 | 50.16 | 58.68 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.763 | <0.0062 |
| B499W-D | 18/05/17 | 1.5-2.0 | 2.70 | ND | 0.68 | <0.5 | 6.68 | 0.2 | 30.2 | 6.2 | 12.6 | 0.06 | 8.3 | 0.2 | 27 | ND | ND | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.103 | <0.005 |
| B499W-E | 18/05/17 | 2.0-2.5 | 3.33 | ND | 0.67 | <0.5 | 8.71 | 0.2 | 38.8 | 4.6 | 10.1 | 0.02 | 10.6 | <0.1 | 25.4 | 10.21 | 13.51 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | ND | <0.005 |
| B500W-A | 17/05/17 | 0-0.5 | 0.87 | 0.0018 | <0.5 | <0.5 | 7.09 | <0.1 | 24.3 | 27.3 | **58.3** | **0.62** | 3.7 | 0.8 | 102 | 182.76 | 219.54 | <0.0005 | 0.00086 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 2.851 | - |
| B500W-B | 17/05/17 | 0.5-1.0 | 0.63 | ND | <0.5 | <0.5 | 5.91 | <0.1 | 12.2 | 3.1 | 8.9 | 0.06 | 2.8 | 0.1 | 15.6 | 77.78 | 88.89 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 3.302 | - |
| B500W-C | 17/05/17 | 1.0-1.5 | 0.51 | ND | 0.51 | <0.5 | 6.38 | <0.1 | 13.3 | 1.8 | 5.6 | 0.02 | 3.4 | 0.1 | 10 | 11.76 | 29.41 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.096 | - |
| B501W-A | 17/05/17 | 0-0.5 | 3.14 | 0.0003 | 0.68 | <0.5 | 14 | 0.2 | 47.2 | 35.8 | **108** | **1.41** | 8.4 | **1.4** | 194 | 183.76 | 214.01 | <0.0005 | **0.00241** | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 2.551 | <0.0062 |
| B501W-B | 17/05/17 | 0.5-1.0 | 2.14 | ND | 0.62 | <0.5 | 6.96 | <0.1 | 25.7 | 3.5 | 7.8 | 0.02 | 8.3 | 0.3 | 19.4 | 8.41 | 11.68 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.040 | <0.005 |
| B501W-C | 17/05/17 | 1.0-1.5 | 2.52 | ND | 1.21 | <0.5 | 8.77 | 0.2 | 37.6 | 5.1 | 10.6 | 0.03 | 12.1 | <0.1 | 26.9 | 18.25 | 23.02 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.040 | <0.0062 |
| B501W-D | 17/05/17 | 1.5-2.0 | 3.01 | ND | 0.5 | <0.5 | 8.21 | 0.1 | 34.9 | 4.5 | 9.6 | 0.02 | 10.2 | 0.1 | 24.7 | 4.65 | 6.31 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | | <0.005 |
| B501W-E | 17/05/17 | 2.0-2.5 | 1.63 | ND | <0.5 | <0.5 | 9.46 | 0.1 | 29.3 | 3 | 7.4 | 0.01 | 8.8 | <0.1 | 21.3 | 20.25 | 26.99 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.002 | <0.005 |
| B502W-A | 17/05/17 | 0-0.5 | 2.50 | 0.0014 | <0.5 | <0.5 | 13.7 | 0.2 | 52.9 | 56.2 | **119** | **1.39** | 9.4 | **1.8** | **208** | 128.80 | 153.60 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 2.124 | - |
| B502W-B | 17/05/17 | 0.5-1.0 | 2.43 | ND | <0.5 | <0.5 | 7.85 | 0.1 | 28.7 | 3.6 | 8.6 | 0.02 | 8.3 | 0.3 | 20.2 | 16.87 | 20.16 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.075 | - |
| B502W-C | 17/05/17 | 1.0-1.5 | 2.68 | ND | 1.06 | <0.5 | 8.37 | 0.1 | 37.5 | 7.7 | 14.8 | 0.09 | 10.5 | 0.2 | 33.2 | 11.94 | 16.42 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.053 | - |
| B502W-D | 17/05/17 | 1.5-2.0 | 3.37 | ND | <0.5 | <0.5 | 8.04 | 0.1 | 39.2 | 5.6 | 11.7 | 0.04 | 11.7 | 0.7 | 28.3 | 5.64 | 8.31 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.028 | - |
| B502W-E | 17/05/17 | 2.0-2.5 | 1.52 | ND | <0.5 | <0.5 | 8.88 | 0.1 | 29.9 | 3 | 7.4 | 0.02 | 8.5 | 0.2 | 24.4 | 18.42 | 23.03 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.006 | - |
| B503W-A | 18/05/17 | 0-0.5 | 3.74 | 0.0002 | 0.63 | <0.5 | 12 | 0.1 | 37.8 | 24 | **61.8** | **0.63** | 8.9 | 0.8 | 102 | 125.13 | 150.53 | <0.0005 | **0.00251** | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 2.168 | <0.0062 |
| B503W-B | 18/05/17 | 0.5-1.0 | 2.47 | ND | <0.5 | <0.5 | 7.27 | 0.2 | 26.1 | 4.2 | 9.6 | 0.04 | 7.6 | 0.2 | 20.5 | 25.10 | 30.77 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.046 | <0.005 |
| B503W-C | 18/05/17 | 1.0-1.5 | 2.57 | ND | 1.07 | <0.5 | 10.2 | 0.2 | 38.3 | 4.8 | 10 | 0.02 | 12 | 0.1 | 25.1 | 26.07 | 35.02 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.015 | <0.0062 |
| B503W-D | 18/05/17 | 1.5-2.0 | 3.17 | ND | 1.36 | <0.5 | 10.5 | 0.2 | 36.3 | 4.7 | 9.7 | 0.02 | 10.5 | <0.1 | 24.2 | 16.09 | 21.14 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.00025 | 0.004 | <0.005 |
| B505W-A | 19/05/17 | 0-0.5 | 3.61 | 0.0022 | 0.56 | <0.5 | 16.8 | 0.4 | 78.2 | **106** | **230** | **2.06** | 13 | **5.3** | **416** | 296.40 | 332.41 | <0.0005 | **0.0046** | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 5.042 | <0.0062 |
| B505W-B | 19/05/17 | 0.5-1.0 | 3.02 | ND | 0.56 | <0.5 | 8.37 | 0.1 | 26 | 5.6 | 12 | 0.11 | 10.5 | <0.1 | 28.5 | 42.72 | 49.67 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 1.781 | <0.0062 |
| B505W-C | 19/05/17 | 1.0-1.5 | 2.92 | ND | <0.5 | <0.5 | 8.34 | 0.1 | 25.6 | 4.1 | 9 | 0.01 | 9.9 | <0.1 | 21.7 | 19.52 | 25.00 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.058 | <0.0062 |
| B505W-D | 19/05/17 | 1.5-2.0 | 2.80 | ND | 0.53 | <0.5 | 8.2 | 0.1 | 28 | 5.2 | 10.7 | 0.03 | 10.8 | <0.1 | 26.5 | 11.43 | 15.36 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.047 | <0.005 |
| B506W-A | 19/05/17 | 0-0.5 | 3.60 | 0.0006 | 0.53 | <0.5 | 16.9 | 0.3 | 59.6 | **76** | **194** | **2.2** | 11.9 | **3.6** | **358** | 286.11 | 319.44 | <0.0005 | **0.0026** | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 7.361 | - |
| B506W-B | 19/05/17 | 0.5-1.0 | 2.79 | ND | <0.5 | <0.5 | 9.19 | 0.1 | 26.5 | 8.7 | 21.6 | <0.01 | 10.3 | 0.2 | 42.9 | 35.48 | 42.65 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 2.735 | - |
| B506W-C | 19/05/17 | 1.0-1.5 | 2.80 | ND | <0.5 | <0.5 | 8.99 | 0.1 | 24.6 | 4.2 | 9.7 | 0.08 | 10.4 | <0.1 | 23.9 | 15.00 | 19.29 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.065 | - |
| B506W-D | 19/05/17 | 1.5-2.0 | 2.77 | ND | 0.62 | <0.5 | 7.02 | 0.1 | 26.7 | 4.4 | 10.2 | 0.04 | 10.6 | 0.2 | 24.7 | 13.00 | 16.97 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.045 | - |
| B506W-E | 19/05/17 | 2.0-2.5 | 3.29 | ND | <0.5 | <0.5 | 7.31 | 0.2 | 30.3 | 4.9 | 10.8 | 0.02 | 12.7 | 0.1 | 27.1 | 18.54 | 24.92 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 0.020 | - |
| B507W-A | 22/05/17 | 0-0.5 | 1.02 | 0.0007 | <0.5 | <0.5 | 6.5 | <0.1 | 19.8 | 38.4 | **74** | **0.49** | 4 | 0.7 | 133 | 96.08 | 115.69 | 0.0007 | 0.00094 | 0.00087 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 5.392 | <0.005 |
| B507W-B | 22/05/17 | 0.5-1.0 | 0.42 | ND | <0.5 | <0.5 | 4.16 | <0.1 | 8.3 | 4.5 | 15.3 | 0.13 | 2.2 | 0.1 | 28.8 | 52.38 | 64.29 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 5.214 | <0.005 |
| B507W-C | 22/05/17 | 1.0-1.5 | 0.79 | 0.0016 | <0.5 | <0.5 | 2.67 | <0.1 | 5.4 | 4.1 | 9.9 | 0.07 | 1.4 | 0.1 | 18.9 | 63.29 | 78.48 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 2.241 | <0.005 |
| B507W-D | 22/05/17 | 1.5-2.0 | 0.88 | 0.0023 | <0.5 | <0.5 | 5.07 | <0.1 | 15.9 | 27.3 | **60.8** | **0.4** | 3.5 | 0.6 | 103 | 154.55 | 187.50 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 4.682 | <0.005 |
| B511W-A | 19/05/17 | 0-0.5 | 0.47 | ND | <0.5 | <0.5 | 6.25 | <0.1 | 5.8 | 8.3 | 16.9 | 0.09 | 1.4 | <0.1 | 21.5 | 61.70 | 74.47 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.0005 | <0.00025 | <0.0005 | 1.070 | <0.005 |