Appendix

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Appendix O

Surface water quality and hydrology

January 2020

Roads and Maritime Services

Western Harbour Tunnel and Warringah Freeway Upgrade

Technical working paper: Surface water quality and hydrology

January 2020

Prepared for

Roads and Maritime

Prepared by

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Glossary of terms and acronyms

Term	Definition
Ammonia	The most reduced form of inorganic nitrogen available, preferentially used by plants and aquatic micro-organisms
Annual exceedance probability (AEP)	The likelihood of occurrence of a flood of given size or larger occurring in any one year. AEP is expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of five per cent, it means that there is a five per cent risk (ie a risk of one in 20) of a peak flood discharge of 500 m^3/s or larger occurring in any one year
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZG	Australian and New Zealand Guidelines
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
Aquatic ecology	Flora and fauna that live in or on water for all or a substantial part of their lifespan (generally restricted to fresh/inland waters)
Bedrock	Rock of a substantial thickness and extent underlying a relatively soft and variable surface
Biota	All organisms in a given area (including flora and fauna), considered as a unit
BTEX	Benzene, toluene, ethylbenzene and xylenes. Naturally occurring compounds in crude oil
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location
CEMP	Construction Environmental Management Plan
Chlorophyll *a*	A measure of the amount of algae growing in a waterway
Culvert	An enclosed channel for conveying water below a road
Cut and cover	A method of tunnel construction whereby the structure is built in an open excavation and subsequently covered
Dissolved oxygen	A measure of the amount of oxygen dissolved in water
DPI	Former NSW Department of Primary Industries (now Department of Planning, Industry and Environment (Regions, Industry, Agriculture & Resources)
Ecosystem	A community of organisms interacting with one another and the environment in which they live
Electrical conductivity	The measure of a material’s ability to accommodate the transport of an electric charge
Embankment	An earthen structure where the road (or other infrastructure) subgrade level is above the natural surface
Erosion	A natural process where wind or water remove softer material, such as soil, from harder material
Fill	The material placed in an embankment
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, local overland flooding associated with major drainage before entering a watercourse, coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami
Floodplain	Area of land which is inundated by floods up to and including the probable maximum flood event (ie flood prone land)
Geomorphology	The study of shaping the landscape by water, wind and other processes. Commonly used to describe the condition of streams as they are shaped by erosion and/or accretion of sediments

Term	Definition
GPT	Gross Pollutant Trap. A device designed to capture stormwater pollution thereby retaining gross pollutants, litter, sediment and associated oils before it has a chance to enter waterways
Groundwater	Water that is held in the rocks and soil beneath the earth's surface
Groundwater dependent ecosystem (GDE)	Refers to communities of plants, animals and other organisms whose extent and life process are dependent on groundwater, such as wetlands and vegetation on coastal sand dunes
Habitat	The place where a species, population or ecological community lives (whether permanently, periodically or occasionally). Habitats are measurable and can be described by their flora and physical components
Hydrology	The study of rainfall and surface water runoff processes
Impact	Influence or effect exerted by a project or other activity on the natural, built and community environment
Interchange	A grade separation of two or more roads with one or more interconnecting carriageways
mg/L	Milligrams per litre
mL	Millilitres
Median	The central reservation which separates carriageways from traffic travelling in the opposite direction
Metals	Occur naturally at trace levels in the environment. This category includes the elements arsenic, cadmium, copper, chromium, iron, lead, manganese, mercury, nickel, selenium and zinc
Micro Siemens per centimetre (mS/cm)	A measure of electrical conductivity. Commonly used to measure the salinity of water
Nutrients	Nutrients in aquatic environments promote the growth of algae and increase turbidity which in turn reduces light and may affect plant growth. Generally excessive nutrient inputs lead to excessive algal growth and formation of nuisance blooms. Nutrients consist of nitrogen (including total nitrogen, oxidised nitrogen and ammonia) and phosphorus (including total phosphorus and filterable reactive phosphorus (FRP))
OEH	Former NSW Office of Environment and Heritage (now Department of Planning, Industry and Environment (Environment, Energy and Science))
Oxidised nitrogen	Represents the level of free nitrogen within the water column that is readily available to plants
PAH	Polycyclic Aromatic Hydrocarbons are molecules found mainly in crude oil and coal as well as in processed fossil fuels and tar
pH	A measure of the acidity or alkalinity
Portal	The entry or exit to a tunnel
Project	Refers to the construction and operation of the Western Harbour Tunnel and Warringah Freeway Upgrade 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
Project footprint	The land required to construct and operate the project. This includes permanent operational infrastructure (including the tunnels) and land required temporarily for construction
Riparian	The part of the landscape adjoining rivers and streams that has a direct influence on the water

Term	Definition
	and aquatic ecosystems within them
Roads and Maritime	NSW Roads and Maritime Services
RTA	NSW Roads and Traffic Authority. Now NSW Roads and Maritime Services
Runoff	The part of the rainfall in a catchment which flows as surface discharge past a specified point
Scour	The erosion of material by the action of flowing water
Sediment	Material, both mineral and organic, that is being or has been moved from its site of origin by the action of wind, water or gravity and comes to rest either above or below water level
Sedimentation	Deposition of sediment usually by water
SHWQIP	Sydney Harbour Water Quality Improvement Plan
SMCMA	Sydney Metropolitan Catchment Management Authority
Spoil	Surplus excavated material
Staging	Refers to the division of the project into multiple contract packages for construction purposes or the construction or operation of the overall project in discrete sections
Stockpile	Temporarily stored materials such as soil, sand, gravel and spoil/waste
Stream order	A classification system which assigns an 'order' to waterways according to the number of additional tributaries associated with each waterway, to provide a measure of system complexity
Surface water	Water flowing or held in streams, rivers and other wetlands in the landscape
Swale	A shallow, grass-lined drainage channel
Terrestrial	Living or growing on land (ie terrestrial flora or fauna)
Threatened	As defined under the *Threatened Species Conservation Act 1995* (NSW), a species, population or ecological community that is likely to become extinct or is in immediate danger of extinction
Total Kjeldahl nitrogen	The total concentration of organic nitrogen and ammonia. An abundance of nutrients in the water leads to excess plant growth and eventually eutrophication
Total nitrogen	A measure of all the nitrogen species found in a waterway including oxidised nitrogen, ammonia and total organic nitrogen
Total phosphorus	A measure of both biologically available species (known as filterable reactive phosphorus) and the unavailable species
Toxicity	The degree of danger posed by a substance to human, animal or plant life
TPH	Total Petroleum Hydrocarbon
Tributary	A river or stream flowing into a larger river or lake
TRH	Total recoverable hydrocarbons
TSS	Total Suspended Solids
Turbidity	A measure of light penetration through a water column containing particles of matter in suspension
Urban design	The process and product of designing human settlements, and their supporting infrastructure, in urban and rural environments
Ventilation facility	Facility for the mechanical removal of air from the mainline tunnels, or mechanical introduction of air into the tunnels. May comprise one or more ventilation outlets

Term	Definition
Water Act 1912	*Water Act 1912* (NSW)
WM Act	*Water Management Act 2000* (NSW)
Waterway	Any flowing stream of water, whether natural or artificially regulated (not necessarily permanent)
Wetland	Wetlands are areas of land that are kept wet by surface water, groundwater or both, for long enough periods that the plants and animals in them are adapted to, and depend on, moist conditions for at least part of their lifecycle. They include areas that are inundated cyclically, intermittently or permanently with fresh, brackish or saline water, which is generally still or slow moving except in distributary channels such as tidal creeks which may have higher peak flows. Wetlands may be constructed for the purposes of removing pollutants from runoff
WQIP	Water Quality Improvement Plan
WSUD	Water-sensitive urban design

Executive Summary

Roads and Maritime Services (Roads and Maritime) is seeking approval under Division 5.2, Part 5 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Western Harbour Tunnel and Warringah Freeway Upgrade (the project), which would comprise two main components:

- A new crossing of Sydney Harbour involving twin motorway tunnels connecting the M4-M5 Link at Rozelle and the existing Warringah Freeway at North Sydney (the Western Harbour Tunnel)
- Upgrade and integration works along the existing Warringah Freeway, including allowance for connections to the Beaches Link and Gore Hill Freeway Connection project (the Warringah Freeway Upgrade).

This Technical working paper presents the assessment of potential impacts during construction and operation of the project on surface freshwater. Impacts associated with marine water quality are addressed separately in Technical working paper: Marine Water Quality (Cardno, 2020).

Major waterways relevant to the project

The waterways relevant to the project are located within the Sydney Harbour Catchment in the suburbs of Annandale, Rozelle, North Sydney, Neutral Bay, Cammeray and Crows Nest. The waterways and water bodies in proximity to the project include:

- Whites Creek at Annandale
- Willoughby Creek at Cammeray
- Quarry Creek at Cammeray
- Flat Rock Creek at Naremburn and Willoughby.

Existing water quality in all waterways indicates a highly urbanised catchment with elevated nutrients and heavy metals.

Construction impacts

Construction of the project would involve a variety of activities including utilities relocation, establishment of construction support sites, surface works, trenching, tunnel excavation and wastewater discharges from wastewater treatment plants. These construction activities have the potential to impact various aspects of the surface water, waterway form and geomorphic processes, including:

- Erosion of soils and sedimentation of waterways
- Accidental leaks or spills of chemicals and fuels during construction
- Exposure of contaminated soils and groundwater
- Discharge of poorly treated wastewater.

Construction of the project would involve a variety of activities with the potential to impact various aspects of the surface water, waterway form and geomorphic processes.

Geomorphology and water quality impacts could potentially arise from construction activities close to watercourses such as drainage and surface works, changes to creek flow rates and volumes caused by wastewater treatment plant discharges, changes to impervious surfaces and potential for subsidence below watercourses. These could lead to erosion, build-up of sediments, scouring and changes to channel, bed and bank conditions.

The impacts assessed are generally common on major road projects. With the application of standard mitigation measures and treatment of wastewater discharges, potential impacts on surface water quality and geomorphology are considered minor and manageable.

Operational impacts

There is a potential impact on surface water from the proposed works listed below:

- Groundwater and tunnel drainage management and treatment systems, including a permanent wastewater treatment plant at Rozelle
- Surface road upgrades at the Warringah Freeway and other local roads
- Operational ancillary infrastructure including motorway facilities located at Rozelle and Cammeray, and the motorway control centre at Waltham Street, Artarmon.

The potential impacts on water quality from these activities would include:

- Discharge of poorly treated tunnel wastewater
- Scour or mobilisation of sediments at outlet locations.
- Potential increase in scouring from increased road runoff
- Change in flow and velocity leading to stagnation of a waterway or an increase in turbidity and nutrient concentrations
- Spills/leaks of fuels or oils from vehicles.

The impacts identified and assessed would be generally common for major road projects. With the application of standard mitigation measures, potential operational impacts on surface water quality and geomorphology would be minor and manageable.

Management of impacts

Construction

The key water quality objective would be to ensure downstream waterways are protected against potential impacts from surface runoff generated during the construction phase of the project. Construction methods would be in accordance with Roads and Maritime's *Code of Practice for Water Management* (RTA, 1999) and the ANZECC Guidelines and National Water Quality Management Strategy (ANZG, 2018 and ANZECC/ARMCANZ, 2000). The ANZG (2018) and ANZECC Guidelines (ANZECC and ARMCANZ, 2000) indicate that several physical-chemical and toxicant parameters need to be controlled to maintain the required protection level for aquatic ecosystems during the construction and operational phases of the project.

Detailed erosion and sediment measures will be prepared as part of the Construction Environmental Management Plan (CEMP), to manage disturbed excavated and imported materials and prevent erosion and sediment impact throughout construction such that impacts on soils and water quality would be minimised. Temporary construction erosion and sediment control measures and wastewater treatment plants would be designed to treat wastewater generated from tunnel groundwater ingress, rainfall runoff in tunnel portals, heat and dust suppression water and washdown runoff during the construction phase.

Operation

Water quality during operation would be managed using:

- Procedural controls including water management controls and a maintenance and inspection program for operational controls
- Physical controls to treat and contain rainfall runoff and accidental spills
- Monitoring to assess and manage impacts on receiving water while the project site stabilises and to identify water quality conditions after development.

During the operation of the project, tunnels would incorporate drainage infrastructure to capture and treat wastewater generated from groundwater ingress and rainfall runoff in tunnel portals. A permanent operational wastewater treatment plant located at Rozelle is proposed to treat discharge and manage adverse impacts on the receiving environment at Rozelle Bay.

Conclusion

The activities associated with the construction and operation of the project have the potential to impact the surface water quality and geomorphology of the existing environment. With the implementation of management measures and appropriate treatment of wastewater discharge, the project would have minimal impact on the surface water quality, provided the identified risks are managed in accordance with the established protocols and standards.

With due consideration of these proposed mitigation and management measures, there would be minimal adverse cumulative surface water impacts anticipated. The residual risk to sensitive receiving environments and environmental values is expected be low provided the proposed management measures are implemented, maintained and monitored.

1. Introduction

This section provides an overview of the Western Harbour Tunnel and Warringah Freeway Upgrade (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), a plan 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 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 Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of 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 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 harbour crossings.

1.2 The project

Roads and Maritime Services (Roads and Maritime) is seeking approval under Division 5.2, Part 5 of the *Environmental Planning and Assessment Act 1979* to construct and operate the Western Harbour Tunnel and Warringah Freeway Upgrade (the project), which would comprise two main components:

- A new crossing of Sydney Harbour involving twin tolled motorway tunnels connecting the M4-M5 Link at Rozelle and the existing Warringah Freeway at North Sydney (the Western Harbour Tunnel)
- Upgrade and integration works along the existing Warringah Freeway, including infrastructure required for connections to the Beaches Link and Gore Hill Freeway Connection project (the Warringah Freeway Upgrade).

Key features of the Western Harbour Tunnel component of the project are shown in Figure 1-1 and would include:

- Twin mainline tunnels about 6.5 kilometres long and each accommodating three lanes of traffic in each direction, connecting the stub tunnels from the M4-M5 Link at Rozelle to the Warringah Freeway and to the Beaches Link mainline tunnels at Cammeray. The crossing of Sydney Harbour between Birchgrove and Waverton would involve a dual, three lane, immersed tube tunnel
- Connections to the stub tunnels at the M4-M5 Link project in Rozelle and to the mainline tunnels at Cammeray (for a future connection to the Beaches Link and Gore Hill Freeway Connection project)

- Surface connections at Rozelle, North Sydney and Cammeray, including direct connections to and from the Warringah Freeway (including integration with the Warringah Freeway Upgrade), an off ramp to Falcon Street and an on ramp from Berry Street at North Sydney
- A ventilation outlet and motorway facilities (fitout and commissioning only) at the Rozelle Interchange
- A ventilation outlet and motorway facilities at the Warringah Freeway in Cammeray
- Operational facilities including a motorway control centre at Waltham Street, within the Artarmon industrial area and tunnel support facilities at the Warringah Freeway in Cammeray
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, signage, tolling infrastructure, fire and life safety systems, lighting, emergency evacuation and emergency smoke extraction infrastructure, CCTV and other traffic management systems.

Key features of the Warringah Freeway Upgrade component of the project are shown in Figure 1-2 and would include:

- Upgrade and reconfiguration of the Warringah Freeway from immediately north of the Sydney Harbour Bridge through to Willoughby Road at Naremburn
- Upgrades to interchanges at Falcon Street in Cammeray and High Street in North Sydney
- New and upgraded pedestrian and cyclist infrastructure
- New, modified and relocated road and shared user bridges across the Warringah Freeway
- Connection of the Warringah Freeway to the portals for the Western Harbour Tunnel mainline tunnels and the Beaches Link tunnels via on and off ramps, which would consist of a combination of trough and cut and cover structures
- Upgrades to existing roads around the Warringah Freeway to integrate the project with the surrounding road network
- Upgrades and modifications to bus infrastructure, including relocation of the existing bus layover along the Warringah Freeway
- Other operational infrastructure, including surface drainage and utility infrastructure, signage, tolling, lighting, CCTV and other traffic management systems.

A detailed description of the project is provided in Chapter 5 (Project description) and construction of the project is described in Chapter 6 (Construction work) of the environmental impact statement. The project alignment at the Rozelle Interchange shown in Figure 1-1 and Figure 1-3 reflects the arrangement presented in the environmental impact statement for the M4-M5 Link, and as amended by the proposed modifications. The project would be constructed in accordance with the now finalised M4-M5 Link detailed design (refer to Section 2.1.1 of Chapter 2 (Assessment process) of the environmental impact statement for further details).

The project does not include ongoing motorway maintenance activities during operation or future use of residual land occupied or affected by project construction activities, but not required for operational infrastructure. These would be subject to separate planning and approval processes at the relevant times.

Subject to the project obtaining planning approval, construction is anticipated to commence in 2020 and is expected to take around six years to complete.

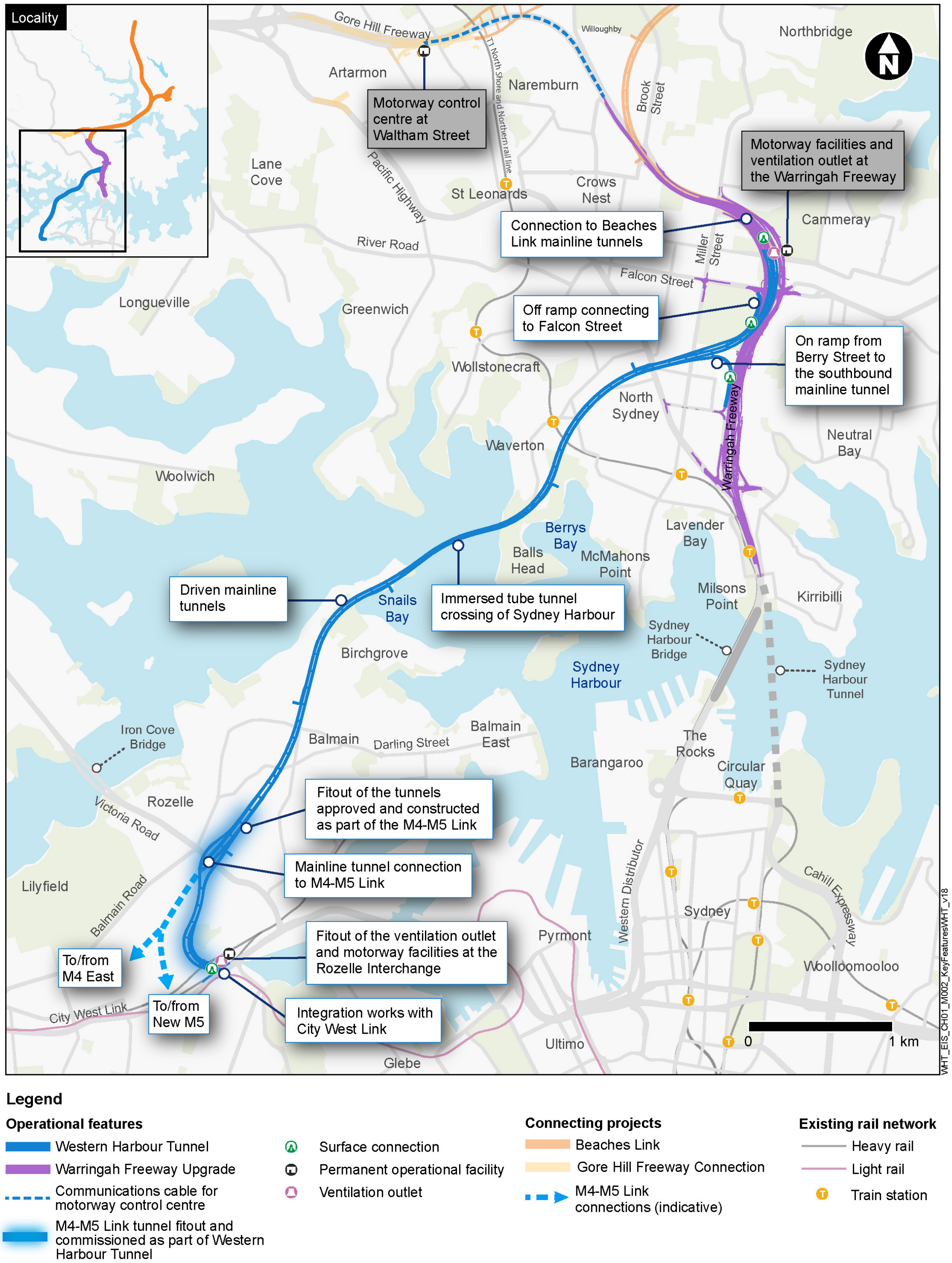


Figure 1-1 Key features of the Western Harbour Tunnel component of the project

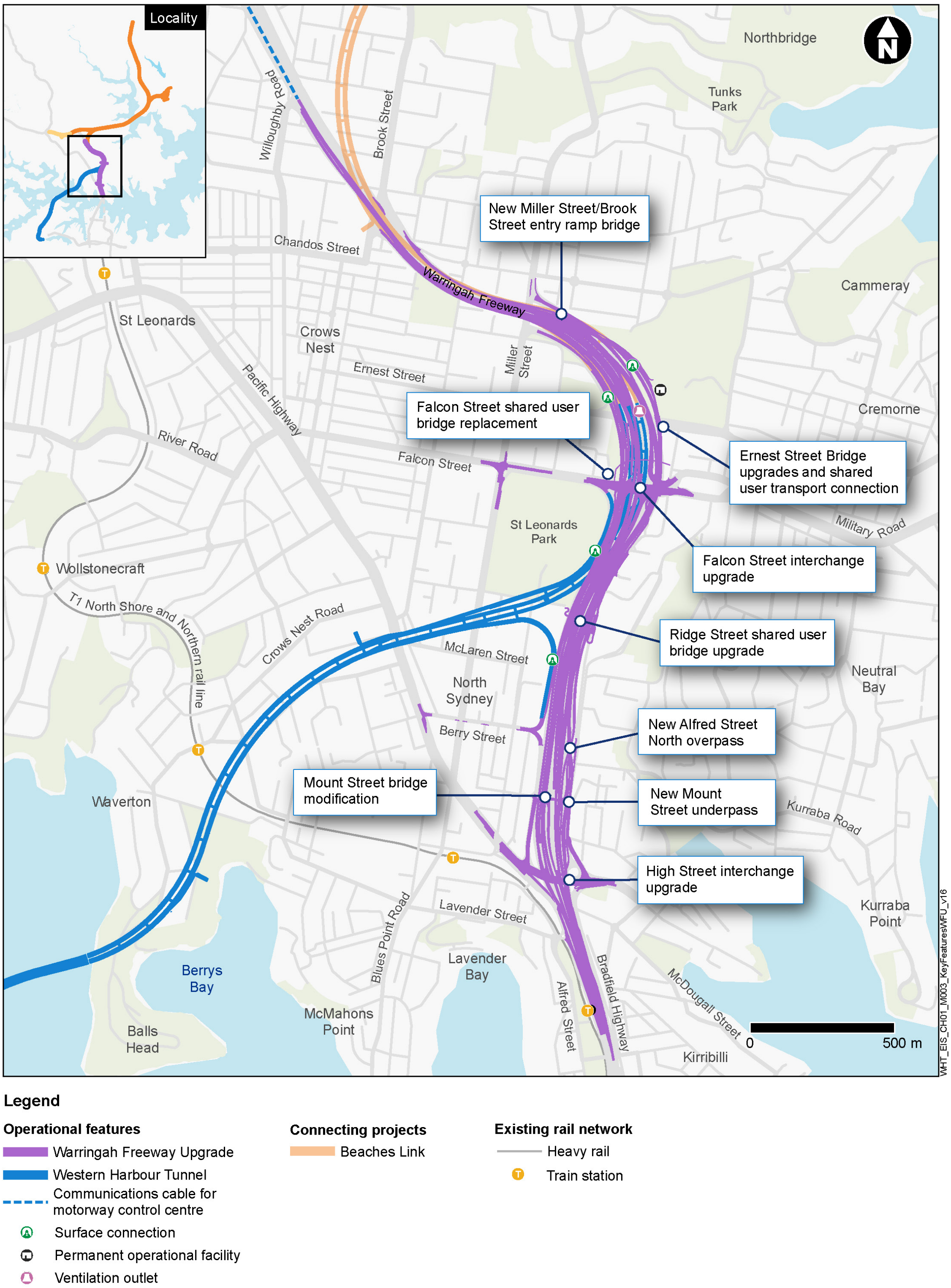


Figure 1-2 Key features of the Warringah Freeway Upgrade component of the project

1.3 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 tunnels. However, surface areas would be required to support tunnelling activities and to construct the tunnel connections, tunnel portals and operational ancillary 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) and traffic management controls, vegetation clearing, earthworks and demolition of structures, establishment of 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 within Berrys Bay and relocation of the historic vessels
- Construction of Western Harbour Tunnel, with typical activities being excavation of tunnel construction accesses, construction of driven tunnels, cut and cover and trough structures and construction of cofferdams, dredging 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 of a motorway control centre at Waltham Street in Artarmon, motorway and tunnel support facilities and ventilation outlets at the Warringah Freeway in Cammeray, construction and fitout of the project operational facilities that form part of the M4-M5 Link Rozelle East Motorway Operations Complex, a wastewater treatment plant at Rozelle and the installation of motorway tolling infrastructure
- Construction of the Warringah Freeway Upgrade, with typical activities being earthworks, bridgeworks, construction of retaining walls, stormwater drainage, pavement works and linemarking and the installation of road furniture, lighting, signage and noise barriers
- Testing of plant and equipment, and commissioning of the project, backfill of access declines, removal of 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 for Western Harbour Tunnel would include:

- Rozelle Rail Yards (WHT1)
- Victoria Road (WHT2)
- White Bay (WHT3)
- Yurulbin Point (WHT4)
- Sydney Harbour south cofferdam (WHT5)
- Sydney Harbour north cofferdam (WHT6)
- Berrys Bay (WHT7)
- Berry Street north (WHT8)
- Ridge Street north (WHT9)
- Cammeray Golf Course (WHT10)
- Waltham Street (WHT11).

During the construction of the Warringah Freeway Upgrade, smaller construction support sites would be required to support the construction works (as shown on Figure 1-3). These include:

- Blue Street (WFU1)
- High Street south (WFU2)
- High Street north (WFU3)
- Arthur Street east (WFU4)
- Berry Street east (WFU5)
- Ridge Street east (WFU6)
- Merlin Street (WFU7)
- Cammeray Golf Course (WFU8)
- Rosalind Street east (WFU9).

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

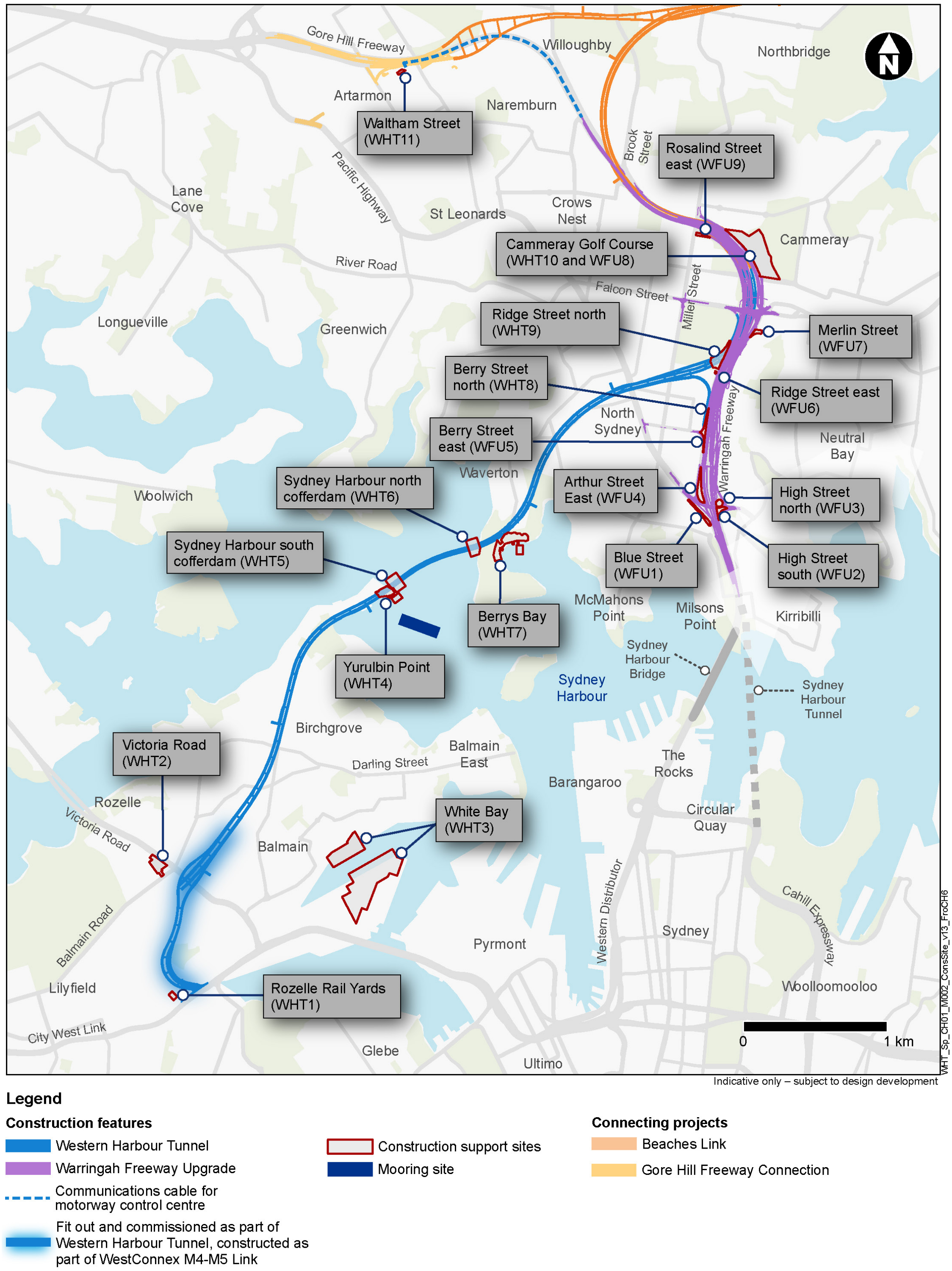


Figure 1-3 Overview of construction support sites

1.4 Project location

The project would be located within the Inner West, North Sydney and Willoughby local government areas, connecting Rozelle in the south with Naremburn in the north.

Commencing at the Rozelle Interchange, the mainline tunnels would pass under Balmain and Birchgrove, then cross Sydney Harbour between Birchgrove and Balls Head. The tunnels would then continue under Waverton and North Sydney, linking directly to the Warringah Freeway to the north of the existing Ernest Street bridge.

The motorway control centre would be located at Waltham Street, Artarmon, with a trenched communications cable connecting the motorway control centre to the Western Harbour tunnel along the Gore Hill Freeway and Warringah Freeway road reserves.

The Warringah Freeway Upgrade would be carried out on the Warringah Freeway from around Fitzroy Street at Milsons Point to around Willoughby Road at Naremburn. Upgrade works would include improvements to bridges across the Warringah Freeway, and upgrades to surrounding roads.

1.5 Purpose of the report

This report has been prepared to support the environmental impact statement for the project and to address the environmental assessment requirements of the Secretary of the Department of Planning, Industry and Environment (formerly Department of Planning and Environment) ('the Secretary's environmental assessment requirements').

This report describes the state of the existing surface freshwater environment and identifies the potential impacts that may arise from the construction and operation of the project and measures to manage the potential impacts. Specific impacts on marine water quality associated with the project are addressed separately in Technical working paper: Marine water quality (Cardno, 2020).

Recommendations for water quality monitoring during construction and operation to assess freshwater impacts are also provided. This report should be read in conjunction with Technical working paper: Marine water quality (Cardno, 2020), Technical working paper: Groundwater (Jacobs, 2020a) and Technical working paper: Contamination (Jacobs, 2020b).

1.6 Secretary's environmental assessment requirements

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

Table 1-1 Secretary's environmental assessment requirements – water (hydrology and water quality)

Secretary's environmental assessment requirements	Where addressed
9 Water – Hydrology	
1. The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes and groundwater dependent ecosystems) likely to be impacted by the project, including rivers, streams, wetlands and estuaries as described in Appendix 2 of the Framework for Biodiversity Assessment – NSW Biodiversity Offsets Policy for Major Projects (OEH, 2014).	A description of waterways and catchments is presented Section 4.1 of this report. Refer to Technical working paper: Groundwater (Jacobs, 2020a) for a description of groundwater resources and Technical working paper: Biodiversity Development Assessment Report (Arcadis, 2020) for a description on groundwater dependent ecosystems
2. The Proponent must prepare a detailed water balance for ground and surface water including the proposed intake	Section 5.1 and Section 6.1 of this report.

Secretary's environmental assessment requirements	Where addressed
and discharge locations (including mapping of these locations), volume, frequency and duration for both the construction and operational phases of the project.	
3. The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including:	Section 5.2 to Section 5.6 of this report for construction stage. Section 6.2 to Section 6.6 of this report for operational stage
a) natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity, water dependent fauna and flora and access to habitat for spawning and refuge;	Refer to Section 5.4 of this report for construction stage. Refer to Section 6.4 for operational stage. Refer to Technical working paper: Flooding (Lyall and Associates, 2020) for assessment of impact on flood behaviour including volumes, durations and velocities. Refer to Technical working paper: Marine Water Quality (Cardno, 2020) and Technical working paper: Biodiversity development assessment report (Arcadis, 2020) for assessment of impact on aquatic connectivity, water dependent fauna and flora and access to habitat for spawning and refuge
b) impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement;	Refer to Section 5.4 and Section 5.5 of this report for construction stage. Refer to Section 6.4 and Section 6.5 for operational stage. Refer to Technical working paper: Groundwater (Jacobs, 2020a) for assessment of impact on groundwater flow, groundwater users and the potential for settlement. Refer to Technical working paper: Biodiversity development assessment report (Arcadis, 2020) for assessment of impact on groundwater dependent ecosystems and species
c) changes to environmental water availability and flows, both regulated/licensed and unregulated/rules-based sources including the stormwater harvesting scheme implemented by North Sydney Council at the storage dam at Cammeray Golf Course;	Section 5.6 during construction and Section 6.6 during operation of this report. Refer to Technical working paper: Groundwater (Jacobs, 2020a) for assessment of changes on groundwater availability and flows
d) direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses;	Section 5.2 and Section 5.3 during construction stage, and Section 6.2 and Section 6.4 during operational stage. Refer to Technical working paper: Biodiversity development assessment report (Arcadis, 2020) for assessment of impact on riparian vegetation.
e) minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems; and	Refer to Section 5.1, Section 5.3 and Section 8.1 of this report for construction stage. Refer to Section 6.1, Section 6.3 and Section 8.2 of this report for operational stage.
f) measures to mitigate the impacts of the proposal and	Refer to Table 8-1 and Table 8-2.

Secretary's environmental assessment requirements	Where addressed
manage the disposal of produced and incidental water.	
4. The assessment must provide details of the final landform of the sites to be excavated or modified (eg portals), including final void management and rehabilitation measures.	Refer to Chapter 5 project description of the environmental impact statement.
5. The Proponent must identify any requirements for baseline monitoring of hydrological attributes.	Refer to Table 8-1 and Table 8-2.
6. The assessment must include details of proposed surface and groundwater monitoring.	Refer to Section 8.1 of this report for construction water quality monitoring. Refer to Section 8.2 of this report for operational water quality monitoring. Refer to Technical working paper: Groundwater (Jacobs, 2019a) for groundwater monitoring.
7. The Proponent must identify design approaches to minimise or prevent drainage of alluvium in the paleochannels.	Refer to Technical working paper: Groundwater (Jacobs, 2020a).
10 Water – quality	
1. The Proponent must:	
a) describe the background conditions for any surface or groundwater resource likely to be affected by the development;	Current surface water quality of key waterways with the potential to be affected is described in Section 4.5. Groundwater quality is described in Technical working paper: Groundwater (Jacobs, 2020a).
b) state the ambient NSW Water Quality Objectives (NSW WQO) (as endorsed by the NSW Government and environmental values for the receiving waters (including groundwater where appropriate) relevant to the project and that represent the community's uses and values for those receiving waters, including the indicators and associated trigger values or criteria for the identified environmental values in accordance with the ANZECC (2000) Guidelines for Fresh and Marine Water Quality and/or local objectives, criteria or targets endorsed by the NSW Government;	The water quality guidelines and objectives applied in the assessment of surface water quality are presented in Section 2.2 and Section 4.5. The water quality guidelines and objectives applied in the assessment of marine surface water quality are presented in Technical working paper: Marine water quality (Cardno 2020).
c) identify and estimate the quality and quantity of all pollutants that may be introduced into the water cycle by source and discharge point and describe the nature and degree of impact that any discharge(s) may have on the receiving environment, including consideration of all pollutants that pose a risk of non-trivial harm to human health and the environment;	Existing groundwater quality is described in Section 5.5 of Technical working paper: Groundwater (Jacobs, 2020a) and summarized in Section 5.2 of this report. Discharge points are presented in Figure 5-1. Discharge quantities for construction are described in Section 5.1 and in Section 6.1 for operation. Surface water quality impacts are described within Section 5.2 of this report for construction and Section 6.2 of this report for operation. For marine water quality impacts refer to Section 5 of Technical working paper: Marine water quality (Cardno 2020).

Secretary's environmental assessment requirements	Where addressed
d) identify the rainfall event that the water quality protection measures will be designed to cope with;	Operational water quality targets are designed based on pollutant load reduction (rather than a rainfall event) (refer to Section 6.2.1). Construction measures will be designed in accordance with the Blue Book and relevant guidelines (refer to Section 8.1).
e) assess the significance of any identified impacts including consideration of the relevant ambient water quality outcomes;	Refer to Section 4.5, Chapter 5, Chapter 6, and Appendix A of this report.
f) demonstrate how construction and operation of the project (including mitigating effects of proposed stormwater and wastewater management) will, to the extent that the project can influence, ensure that: i. Where the NSW WQOs for receiving waters are currently being met they will continue to be protected; and ii. Where the NSW WQOs are not currently being met, activities will work toward their achievement over time;	Section 5.2, Section 6.2, Chapter 7 and Chapter 8 of this report.
g) justify, if required, why the WQOs cannot be maintained or achieved over time;	Section 4.5 currently documents the existing water quality which does not meet the current ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines and water quality objectives. Development of Site-specific trigger values (SSTVs) are discussed in Section 4.6.
h) demonstrate that all practical measures to avoid or minimise water pollution and protect human health and the environment from harm are investigated and implemented;	Refer to Chapter 8 of this report.
i) identify sensitive receiving environments (which may include estuarine and marine waters downstream including Quarry Creek and its catchment) and develop a strategy to avoid or minimise impacts on these environments;	Refer to Section 4.2 for sensitive receiving environments. Refer to sections 5.2 and 6.2 for assessment of impact on these environments, and sections 8.1 and 8.2 for environmental management measures. Refer to Technical working paper: Marine Water Quality (Cardno, 2020) for assessment of impacts on marine water quality including environmental management measures
j) identify proposed monitoring locations, monitoring frequency and indicators of surface and groundwater quality.	A surface water quality monitoring program was implemented for this assessment and it is anticipated that the same monitoring sites and indicators would be monitored in the future (refer to Section 3.2 , Appendix A and Appendix B). This will be reviewed during the construction planning phase as prescribed in the mitigation measures outlined in Section 8.1 and Section 8.2.
2. The assessment should consider the results of any current water quality studies, as available, in the project catchment	Refer to Section 3.1 of this report. Refer to Technical working paper: Groundwater (Jacobs, 2020a) for a discussion on current groundwater quality studies.

Secretary's environmental assessment requirements	Where addressed
12 Soils	
7. 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.	Refer to Section 6.2.3 of this report. Refer to Technical working paper: Contamination (Jacobs,2020b) for a discussion on soil erosion hazard.

2. Legislative and policy context

2.1 NSW legislation

The following NSW legislation and statutory requirements are relevant to the assessment of the surface water impacts of the project during construction and operation:

- *Protection of the Environment Operations Act 1997*
- *Water Management Act 2000* and *Water Act 1912*
- Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005.

2.1.1 Protection of the Environment Operations Act 1997

The *Protection of the Environment Operations Act 1997* (POEO Act) regulates air and water pollution, noise control and waste management.

Section 120 of the POEO Act makes the pollution of waters an offence. Environment protection licences under Chapter 3 of the Act are normally required for a broad range of activities listed in Schedule 1 of the POEO Act and aim to address water pollution issues created by those activities. The project would involve the construction, widening and re-routing of roads, which are listed as road construction activities in Schedule 1 of the POEO Act. An environmental protection licence for road construction would be required for the project.

2.1.2 Water Management Act 2000 and Water Act 1912

The *Water Act 1912* (NSW) and the *Water Management Act 2000* (NSW) (WM Act) are the two key pieces of legislation for the management of water in NSW and contain provisions for the licensing of water access and use. The *Water Act 1912* (NSW) is being progressively phased out and replaced by the WM Act.

The aims of the WM Act are to provide for the sustainable and integrated management of the State's water sources for the benefit of both present and future generations. The WM Act implicitly recognises the need to allocate and provide water for the environmental health of our rivers and groundwater systems, while also providing licence holders with more secure access to water and greater opportunities to trade water through the separation of water licences from land. The WM Act enables the State's water resources to be managed under water sharing plans, which establish the rules for the sharing of a particular water source between users and the environment, and rules for the trading of water in a particular water source.

The project is located within an area covered by the Water Sharing Plan for the Greater Metropolitan Region Unregulated River Water Sources (NSW Department of Primary Industries (DPI) 2011). This plan applies to surface water sources and includes rules for protecting the environment, water extraction, managing licence holders' water accounts, and water trading within the plan area. Under Schedule 4, Part 1, clause 2 of the Water Management (General) Regulation 2018 (NSW), roads authorities are exempt from the requirement to hold a water access licence to take water for road construction and road maintenance.

The Water Sharing Plan for the Greater Metropolitan Region Groundwater Source (DPI,2011) is also relevant to the project and is further discussed in Technical working paper: Groundwater (Jacobs, 2020a).

2.1.3 Sydney Regional Environmental Plan (Sydney Harbour Catchment) 2005

The Sydney Regional Environmental Plan (Sydney Harbour Catchment 2005 (Sydney Harbour REP) covers all the waterways of the Harbour, the foreshores and entire catchment. It provides an improved and clearer planning framework and better environmental outcomes for Sydney Harbour and its tributaries. The Sydney Harbour REP aims to establish a balance between promoting a prosperous working harbour, maintaining a healthy and sustainable waterway environment and promoting recreational access to the foreshore and waterways.

The planning principles for land within the Sydney Harbour Catchment REP as relevant to this assessment are:

- Action is to be taken to achieve the targets set out in *Water Quality and River Flow Interim Environmental Objectives: Guidelines for Water Management: Sydney Harbour and Parramatta River Catchment* (published in October 1999 by the Environment Protection Authority), such action to be consistent with the guidelines set out in *Australian Water Quality Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000)
- Development is to improve the water quality of urban runoff, reduce the quantity and frequency of urban runoff, and prevent the risk of increased flooding and conserve water.

The following points from Division 2 (Matters for consideration) of the Sydney Harbour Catchment REP are also relevant to this assessment:

- Development should have a neutral or beneficial effect on the quality of water entering the waterways
- The cumulative environmental impact of the development.

2.2 Water quality guidelines and policies

The water quality assessment has been prepared in accordance with the following key relevant guidelines and policies:

- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Governments and Australian state and territory governments) (ANZG, 2018)
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (Australian and New Zealand Environment and Conservation Council (ANZECC)/Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), 2000)
- *NSW Water Quality and River Flow Objectives* (NSW Department of Environment, Climate Change and Water (DECCW), 2006)
- *Guidelines for Managing Risks in Recreational Waters* (NHMRC, 2008)
- *Sydney Harbour Water Quality Improvement Plan* (Sydney Metropolitan Catchment Management Authority (SMCMA, 2010)
- *Approved Methods for the Sampling and Analysis of Water Pollutants in NSW* (DECC, 2008)
- *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) (DECC, 2008).

2.2.1 Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment and Conservation Council (ANZECC/ARMCANZ, 2000) has published *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* to provide benchmarks for assessment of the existing water quality of waterways. The guidelines have recently been updated to incorporate new science and knowledge developed over the past 20 years (ANZG 2018). Together they form part of the National Water Quality Management Strategy and list a range of environmental values assigned to that water body.

The ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines and objectives to be applied in the assessment of surface water quality are presented in Table 2-1. These guidelines and objectives are dependent on nominated environmental values. The objective adopted for the protection of aquatic ecosystems is "*to maintain and enhance the ecological integrity of freshwater and estuarine ecosystems, including biological diversity, relative abundance and ecological processes".* Aquatic ecosystems could be defined as ecosystems that depend on flows, or periodic or sustained inundation to preserve their ecological integrity (eg rivers, creeks, wetlands and groundwater dependent ecosystems (GDEs)).

The ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines provide default trigger values for physical and chemical stressors for protection of south-east Australian slightly disturbed lowland rivers and estuarine aquatic ecosystems. Both guidelines continue to be applied for this assessment as the physical and chemical stressors for aquatic ecosystems for the relevant geographic region 'Southeast Coast' have not yet been completely updated. These default trigger values would be replaced with the interim Site Specific Trigger Values (SSTVs) discussed in Section 4.6.

Table 2-1 Guidelines for Protection of Aquatic Ecosystems (ANZG, 2018 and ANZECC/ARMCANZ, 2000)

Indicator	Freshwater	Estuarine[1]
Conductivity (µs/cm)	125-1200	No guideline
pH	6.5-8.5	7-8.5
Dissolved oxygen (% saturation)	85-110	80-110
Turbidity (NTU)	6-50	0.5-10
Total Suspended Solids (mg/L)	50	50
Ammonia (µg/L)	20	15
Oxidised nitrogen (µg/L)	40	15
Total nitrogen (µg/L)	350	300
Total Phosphorus (µg/L)	25	30
Chlorophyll-a (µg/L)	3	4
Benzene (µg/L)	950	500
Toluene (µg/L)	180	180
Ethylbenzene (µg/L)	80	80
o – xylene (µg/L)	350	No guideline
m – xylene (µg/L)	75	75
p – xylene (µg/L)	200	No guideline
m+p – xylene (µg/L)	No guideline	No guideline
Bromofluorobenzene	No guideline	No guideline
Dichloroethane	No guideline	No guideline
Manganese mg/L	1.9	No guideline
Naphthalene (µg/L)	16	50
Iron (mg/L)	0.3	No guideline
Arsenic (mg/L)	0.013	No guideline
Cadmium (mg/L)	0.0002	0.0007
Chromium (mg/L)	0.001	0.0044
Copper (mg/L)	0.0014	0.0013
Nickel (mg/L)	0.011	0.007
Lead (mg/L)	0.0034	0.0044
Zinc (mg/L)	0.008	0.015
Mercury (mg/L)	0.00006	0.0001

Note 1: ANZG (2018) recommend marine toxicant trigger values be applied to estuarine ecosystems

2.2.2 NSW Water Quality and River Flow Objectives (DECCW, 2006)

The *NSW Water Quality and River Flow Objectives* (DECCW, 2006) are the agreed environmental values and long-term goals for NSW's surface waters. They are consistent with the agreed national framework for assessing water quality set out in the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines.

The WQOs provide environmental values for NSW waters and the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines provide the technical guidance to assess the water quality needed to protect these values. The project is located within the Sydney Harbour and Parramatta River catchments. Waterways relevant to the project that have been classified as "waterways affected by urban development" include:

- Whites Creek
- Willoughby Creek
- Quarry Creek
- Flat Rock Creek.

Based on this classification, nominated environmental values include protection of aquatic ecosystems, protection of visual amenity and protection of primary and secondary contact recreation.

2.2.3 Guidelines for Managing Risks in Recreational Water (NHMRC, 2008)

The *Guidelines for Managing Risks in Recreational Water* (NHMRC, 2008) aim to protect the health of humans from threats posed by the recreational use of coastal, estuarine and fresh waters.

The guidelines provide recommended values for indicators that may pose a risk to human health. These indicators are relevant for waterways that may be used for recreation and have the possibility of being impacted by runoff during the construction and operation of the project.

2.2.4 Sydney Harbour Water Quality Improvement Plan

The *Sydney Harbour Water Quality Improvement Plan* (Greater Sydney Local Land Services, 2015) (SHWQIP) was developed by Greater Sydney Local Land Services and NSW Office of Environment and Heritage (OEH) in coordination with a range of stakeholders. The SHWQIP provides a coordinated management framework for the local councils, State government agencies and Commonwealth government agencies that have a stake in improving the future health of Sydney Harbour and its catchments. This plan applies to most of the project footprint which ultimately drains to Sydney Harbour.

The main objective of the SHWQIP "*is to identify threats to water quality in the Harbour and its tributaries and to set targets for pollutant load reductions (in terms of total nitrogen, total phosphorus, suspended sediment and pathogens) required to protect the condition and values of the Sydney Harbour, its tributaries, estuaries and waterways*".

The SHWQIP is designed to give focus and direction to water quality policy development and on-ground implementation across the Sydney Harbour catchment. While the SHWQIP does not include pollutant reduction targets for individual developments, catchment load and estuary condition targets have been developed for sub-catchments and local government areas using feasible scenario options for both the management of stormwater and improvements in sewer outflow performance. These targets are based on the following scenario including assumptions of feasible change/actions:

- Water Sensitive Urban Design (WSUD) incorporated into 70 per cent of infill developments
- WSUD retrofitted into 10 per cent of existing urban areas
- Improving sewer overflow performance to limit overflows to no more than 40 events in 10 years.

The targets are designed to provide direction to change rather than being prescriptive of the exact management actions that should be carried out to achieve these goals. It is acknowledged that different scenarios to that assumed above could also achieve the targets.

3. Assessment methodology

The methodology for the assessment of surface water quality and geomorphology is outlined in the following sections and has included:

- Desktop data and literature review of available sources
- Field assessment of geomorphology and water quality monitoring to support and enhance the findings of the desktop analysis, refine the understanding of potential issues during construction and operation
- Classification of sensitive receiving environments and identification of environmental values relevant to the project and assessment of existing geomorphic characteristics
- Assessment of the potential construction and operational impacts relating to water supply, water quality and hydrodynamics
- Identification of appropriate treatment measures to mitigate potential impacts
- Development of construction and operation water management strategies and mitigation.

3.1 Desktop review

The desktop assessment also involved a review of existing information that was available for the surface water environment upstream and downstream of the project footprint to understand the existing environment and the potential impacts of the project. The review of information included data collected from North Sydney Council, Willoughby Council and Sydney Water, and literature sources including:

- AECOM (2017), *WestConnex – M4-M5 Link: Technical working paper: Surface water and flooding*. Prepared for the Roads and Maritime Services August 2017
- GHD (2015), *Sydney Harbour Catchment Coastal Zone Management Plan Scoping Study*. Literature and Data Review – Management and Use of Sydney Harbour
- Hedge L.H., Johnston E.L., Ayong S.T., Birch G.F., Booth D.J., Creese R.G., Doblin M.A., Figueira W.F., Gribben P.E., Hutchings P.A., Mayer Pinto M., Marzinelli E.M., Pritchard T.R., Roughan M., Steinberg P.D., (2013), *Sydney Harbour: A systematic review of the science*, Sydney Institute of Marine Science, Sydney, Australia
- Lyall and Associates (2017), *Flat Rock Creek Catchment Flood Study and Overland Flow Mapping Volume 1*. Draft Report for Public Exhibition
- Sydney Water (1990), *Whites Creek Catchment Management Study*
- Sydney Water (2016), *Water Quality Monitoring Program for Willoughby City Council*. Spring 2015-Autumn 2016.

The following documents were also used to review water quality treatment measures that could be used to mitigate the impact of the operation of the project on water quality:

- Roads and Traffic Authority (1997), *Roads and Maritime Water Policy*
- Roads and Traffic Authority (1999), *Roads and Maritime Code of Practice, Water Management*.
- Roads and Traffic Authority (2003a), *Procedures for Selecting Treatment Strategies to Control Road Runoff*.

A number of guidelines and management procedures relevant to the assessment of surface water quality are presented in Section 2.2, which also describes how these guidelines and procedures have been applied to determine existing water conditions along the project to help identify the appropriate water quality management and mitigation measures for implementation during the construction and operational phases of the project.

3.2 Field assessment

Site visits were carried out to monitor water quality and visually assess the conditions of the watercourses relevant to the project. Seven monitoring locations were selected and, for most waterways, monitoring was generally carried out immediately upstream and downstream of the project alignment unless site access was prevented. Sites labelled ‘a’ were located upstream of the proposed crossing, whereas sites labelled ‘b’ were located downstream of the proposed crossing. Monitoring locations are listed in Table 3-1 and shown in Figure 3-1.

Table 3-1 Project water quality monitoring sites

Site name (Figure 3-1)	Waterway	Location
1a	Whites Creek upstream	Brennan Street, Annandale
1b	Whites Creek downstream	Railway Parade, Annandale
2b	Willoughby Creek downstream	Primrose Park, Cremorne
4b	Quarry Creek	Quarry Street, Naremburn
5a	Flat Rock Creek upstream	Grandview Street, Naremburn
5b	Flat Rock Creek downstream (upstream of Quarry Creek inflow)	Flat Rock Gully
5c	Flat Rock Creek downstream (downstream of Quarry Creek inflow)	Tunks Park, Northbridge suspension bridge

Figure 3-1 Water quality monitoring sites

The monitoring dates for each sampling event are provided in Table 3-2. Dry weather is classified as less than 15 mm of rainfall 24 hours before sampling as recorded at the Bureau of Meteorology rainfall gauge (Gauge #066011). Wet weather sampling is classified as 15 millimetres or more of rainfall recorded at the same gauge 24 hours before sampling. It was anticipated monitoring would comprise three dry weather and three wet weather events conducted between October 2017 and January 2018 however due to antecedent dry weather conditions, only one wet weather event was captured. This information has been deemed sufficient for the purposes of this assessment. However, additional monitoring would be required to update baseline conditions closer to construction.

Table 3-2 Monitoring dates and event type (dry/wet)

Date	Dry/Wet	Rainfall (preceding 24 hours)
31 October – 1 November 2017	Dry	0 mm
21 – 22 November 2017	Dry	3 mm
14 – 15 December 2017	Dry	0 mm
9 January 2018	Wet	28 mm
18 – 19 January 2018	Dry	0 mm
1 – 2 February 2018	Dry	0 mm

Water quality was monitored in-situ and with grab samples. In-situ water quality parameters, temperature, conductivity, salinity, pH and dissolved oxygen, were measured using a calibrated YSI Pro Plus multi-parameter water quality meter. Turbidity was measured using a Hach turbidimeter.

Measurements were generally collected between 15 and 30 centimetres below the surface depending on the depth of water. Sampling depth was recorded in the field. For each parameter measured in-situ, three replicate measurements were recorded about 10 metres apart from the access point to the site. Each parameter was then reported as the average of the three measurements. The individual replicates are also reported to provide an understanding of the variation between individual readings (refer to Appendix A).

Grab samples were also collected at each site and sent to the laboratory for analysis. The analytical suite for laboratory analysis included:

- Chlorophyll-*a*
- Total nitrogen
- Total phosphorus
- Total suspended solids
- Total metals (As, Cd, Cr, Cu, Pb, Ni, Zn, Hg, Mn and Fe)
- Organic compounds (BTEX and TRH).

Water quality data collected during the monitoring program to establish a benchmark for discharge quality from water treatment plants during construction planning.

3.3 Site classification

3.3.1 Sensitive receiving environments

Sensitive receiving environments were identified using aquatic habitat as an indicator, which was assessed against the NSW Department of Primary Industries (DPI) *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI, 2013) and *Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge 2003). Sensitive receiving environments are identified based on the following considerations:

- Key fish habitat (DPI 2013)

- Records of threatened species listed under the *Fisheries Management Act 1994* and *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
- Groundwater and surface water dependent vegetation and fauna communities listed under the *Biodiversity Conservation Act* (BC Act) and *Environment Protection and Biodiversity Conservation Act* (EPBC Act)
- State Environmental Planning Policy (Coastal Management) 2018 and Ramsar Wetlands
- Whether the catchment falls within a drinking water catchment
- Areas that contribute to aquaculture and commercial fishing
- Activities and decisions made upstream affect water quality downstream, particularly the cumulative impacts of nutrients and sediment.

Whites Creek, Willoughby Creek, Quarry Creek and Flat Rock Creek are the downstream receiving environments relevant to the project which ultimately drain to Sydney Harbour. The water quality within these waterways is integrally linked to the level of pollutants that are discharged from the highly urbanised catchment. Catchment runoff can result in elevated nutrient levels and subsequent algal blooms, which would be undesirable given the proximity to popular recreation areas surrounding the harbour.

3.3.2 Environmental Values

Environmental values are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit or health. They are values that require protection from the effects of pollution and waste discharges (ANZECC/ARMCANZ, 2000). The Office of Environment and Heritage nominated a number of environmental values for the Sydney Harbour and Parramatta River Catchment and relevant indicators and guideline levels which are used in protecting the environmental value (DECCW, 2006).

The relevant recognised environmental values for the purposes of this assessment, include:

- Aquatic ecosystems, which assesses the physical and chemical water quality stressors that cause degradation of aquatic ecosystems. For this assessment, this includes nutrients, dissolved oxygen, pH, metals, salinity and turbidity
- Visual amenity which assesses the aesthetic appearance of a waterway. For this assessment, this includes transparency, odour and colour
- Primary and secondary contact recreation. Primary contact recreation implies direct contact with the water via bodily immersion or submersion with a high potential for ingestion. Activities classified as primary contact recreation include swimming, diving and water skiing. Secondary contact recreation implies some direct contact with the water would be made but ingestion is unlikely in activities such as boating, fishing and wading. Bacteriological indicators are used to assess the suitability of water for recreation.

3.3.3 Water quality criteria

As identified in the Secretary’s environmental assessment requirements, the desired performance outcome for the project in relation to surface water quality is that:

“The project is designed, constructed and operated to protect the NSW Water Quality Objectives (WQOs) where they are currently being achieved, and contribute towards achievement of the WQOs over time where they are currently not being achieved, including downstream of the project to the extent of the project impact including estuarine and marine waters (if applicable)”.

The assessment included consideration of the performance of the project against the agreed water quality objectives outlined in Section 2.2. The performance against these objectives during construction and operation is presented in Section 5.2.3 and Section 6.2.5 respectively.

3.4 Approach to assessment of potential impacts

3.4.1 Water balance

A water balance was prepared for both the construction and operation of the project taking into consideration water supply sources (including groundwater, harvested rain water, treated project water and municipal supplies), project water demands during construction and operation, and surplus water requiring discharge after treatment.

Modelled groundwater inflows presented in the Technical working paper: Groundwater (Jacobs, 2020a) have been apportioned to each wastewater treatment plant. Rooftop harvested rainfall has been estimated at temporary construction support site buildings and permanent ancillary infrastructure buildings.

The potential for the re-use of treated groundwater and rainwater has been assessed with respect to the water usage estimations provided by Roads and Maritime to provide an approximate supply and demand balance.

3.4.2 Assessment of construction impacts

The assessment of the potential impacts during construction involved:

- Identification of construction activities that have the potential to mobilise sediments and other pollutants to the surface water environment, and the assessment of the potential impacts on the water quality of downstream receiving environments. This was informed by a review of erosion and sediment control requirements during construction (WSP and ARUP, 2019a)
- Assessment of the potential impacts of construction wastewater treatment plant discharges into receiving environment, on water quality. For this assessment:
  - The pollutants likely to be present at each wastewater treatment plant catchment were used to carry out this assessment (refer to Technical working paper: Groundwater (Jacobs, 2020a))
  - The ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines were used with regard to the relevant environmental objectives of aquatic ecosystems, visual amenity and primary and secondary contact recreation.
- Assessment of geomorphology impacts resulting from the construction wastewater treatment plants. This assessment was based on field work observations and the annual exceedance probability flow rates for relevant watercourses to establish whether the treated proposed discharges would alter the geomorphology of the receiving watercourse
- Assessment of the potential impact of environmental water availability, including changes due to impacts on surface creek baseflows as a result of groundwater drawdown
- Assessment of changes on the North Sydney Council stormwater harvesting scheme during construction
- Identification of appropriate treatment measures to mitigate the impact of the construction phase.

3.4.3 Assessment of operational impacts

The assessment of the potential impacts during operation involved:

- Identification of operational infrastructure or activities that have the potential to mobilise sediments and other pollutants to the surface water environment, and the assessment of the potential impacts on the water quality of downstream receiving environments
- Assessment of the potential impacts on water quality of operational wastewater treatment plant discharges into the receiving environment
- Assessment of potential geomorphological impacts on creeks due to wastewater treatment plant discharges, subsidence and changes to baseflows, as documented in Technical working paper: Groundwater (Jacobs, 2020a)
- Assessment of changes on the North Sydney Council stormwater harvesting scheme during operation

- Identification of appropriate treatment measures to mitigate the impact of the operational phase.

3.4.4 Assessment of cumulative impacts

The assessment of surface water cumulative impacts involved:

- Identification of major projects that is likely to overlap with the project
- Identification of common sensitive receivers for each project, assessment of likely cumulative impacts and identification of mitigation measures.

4. Existing environment

4.1 Waterways and catchments

The project falls within the Sydney Harbour Catchment, a drowned river valley characterised by steep-sided banks which are eroded up to 85 metres into the Hawkesbury Sandstone and overlying Ashfield Shale (NSW Department of Mineral Resources, 1983). Sea level rise flooded the valley about 17,000 years ago, forming a flood tide delta – the Sydney Harbour estuary. The configuration of the Sydney Harbour estuary catchment drainage system and the orientation of bays and shorelines are controlled by geological structures (faults and fractures) (Hedge *et al* 2013). The catchment comprises both natural and urban landscapes rich in cultural, geological and biological diversity and heritage. The catchment covers the harbour itself, Parramatta River, Lane Cove River and Middle Harbour.

The Sydney Harbour Catchment spans over 25 local government areas. It is a highly urbanised catchment (86 per cent) which results in rapid runoff during high precipitation events. The downstream catchment is tidal with tides in the Harbour being semidiurnal, reversing every six hours (GHD, 2015). The waterways traversing the project footprint are within the suburbs of Willoughby, Naremburn, Northbridge, Cammeray and Neutral Bay, which form part of the Middle Harbour sub-catchment and drain to Willoughby Creek, Quarry Creek and Flat Rock Creek. Whites Creek is one of three major drainage canals in the Inner West local government area which drains to Rozelle Bay on the southern side of Sydney Harbour.

The main bodies of water near the project are Sydney and Middle Harbours which are estuaries. The main waterways and catchments with the potential to be impacted by the project are shown on Figure 4-1 and described in the following sections.

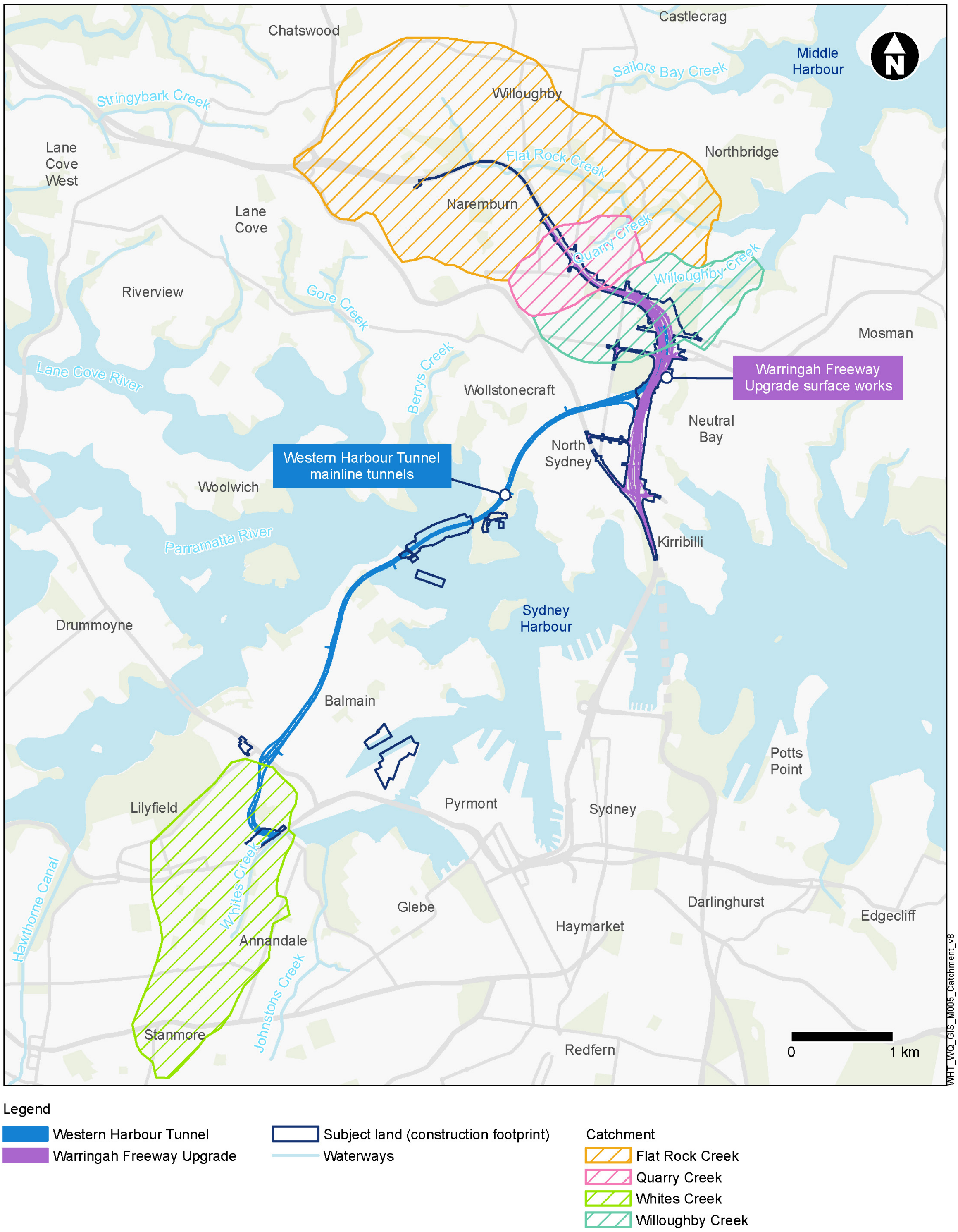


Figure 4-1 Waterways and catchments

4.1.1 Whites Creek

Whites Creek is a small creek (about two kilometres long) in the densely developed inner western suburbs of Sydney. Its headwaters are in the suburbs of Stanmore and Leichhardt, and flow in a northerly direction between Annandale and Lilyfield discharging to Rozelle Bay, Sydney Harbour. Whites Creek drains a catchment of 2.62 square kilometres comprising 55 per cent residential land, 25 per cent roads and 3.5 per cent parkland (Floyd, 2007). All native bushland has been removed and the complete length of the creek is now a stormwater drain with buried pipes in the upper reaches and open concrete channel for the lower one kilometre (Figure 4-2).

There are no GDEs recorded within 500 metres of Whites Creek (BoM 2018). Sea walls have been constructed around the shoreline of Rozelle Bay and White Bay where development occurs up to the shoreline and vessel moorings also located within the bays. Sydney Water has begun works on naturalising Whites Creek to improve its deteriorated condition. It is likely to incorporate features such as sandstone blocks and vegetated benches to provide ecological benefits to the channel. Water pollution in the creek originates from all land areas in the catchment, the major sources being leaks from the wastewater pipes and runoff from roads (Floyd, 2007).

Figure 4-2 Whites Creek concrete-lined stormwater channel. Upstream section (left photo). Downstream section (right photo)

4.1.2 Willoughby Creek

Willoughby Creek is a small modified concrete and rock channel which drains the suburbs of Neutral Bay and Cammeray directly into Willoughby Bay at Cremorne (Figure 4-3). Willoughby Bay and Long Bay are popular boating and swimming areas for local residents. The development of impervious surfaces within the catchment has increased the volume and rate of runoff, which has in turn necessitated flood mitigation measures primarily in the mid and upper catchment. Semi-natural channel morphology exists within sections where the presence of bedrock has negated the need for channel stabilisation initiatives. There are no GDEs recorded within 500 metres of Willoughby Creek (BoM, 2018).

Figure 4-3 Willoughby Creek, Primrose Park. Looking downstream (left photo) pooling under dry waterfall (right photo)

4.1.3 Quarry Creek

Quarry Creek is a small natural estuarine tributary of Flat Rock Creek, which drains Cammeray and has a history of being quarried for sandstone. The creek has steep embankments on both sides now densely vegetated by weeds and has limited accessibility (Figure 4-4). Limited site access has prevented assessment of Quarry Creek. However, it is likely to have similar geomorphic conditions to the downstream extents of Flat Rock Creek, with a steep catchment characterised by bedrock steps and rocky riffle/runs with low to moderate flow during dry weather. The Coastal Sandstone Gully Forest GDE is recorded as extending along the entirety of Quarry Creek (BoM, 2018).

Figure 4-4 Quarry Creek steep bedrock steps upstream and likely transition to rocky riffle/runs downstream

4.1.4 Flat Rock Creek

The Flat Rock Creek catchment has a total area of about seven square kilometres and includes the suburbs of Artarmon, Willoughby, Naremburn, Northbridge, St Leonards, Cammeray and Crows Nest. Flat Rock Creek is the main waterway in a catchment predominantly comprising low to medium-density residential (with some high density), and commercial and industrial uses. Areas of open space within the catchment include Gore Hill Oval, Talus Reserve, Naremburn Park, Artarmon Reserve, Bicentennial Reserve and Tunks Park (Lyall and Associates, 2017). There are minor named and unnamed tributaries that drain to Flat Rock Creek including two on the southern side and three on the northern side (Lyall and Associates, 2017).

The natural drainage characteristics of the Flat Rock Creek catchment have been altered by residential, commercial and industrial development. The creek is predominantly a concrete-lined (open and closed) stormwater channel draining the suburbs of Artarmon, Naremburn and Willoughby. The channel travels underground from between Grandview Drive at Naremburn and Flat Rock Drive at Willoughby and has low flows during dry weather (Figure 4-5). Flat Rock Creek at its downstream reach drains a relatively steep catchment characterised by rocky riffle/runs with low to moderate flow during dry weather (Figure 4-6).

The substrate consists primarily of bedrock and boulders and riparian vegetation both native and exotic (Sydney Water, 2016). The end point is a tidally influenced naturalised estuary at the base of Flat Rock Gully discharging into Long Bay (Figure 4-7). The downstream reaches are surrounded by native coachwood forests with popular walking tracks and give access to large sporting fields at Tunks Park, Cammeray. In its original state, this area would have contained mangrove thickets and mudflats (NSC, 2003).

Flat Rock Reserve at its upstream extent was previously a rubbish tip until 1985 when it was deposited with soil fill.

The Technical working paper: Biodiversity development assessment report (Arcadis, 2020) notes GDEs mapped as ‘moderate to high potential for terrestrial GDE’ at the lower reaches of Flat Rock Creek at Munro Park. Eco-systems mapped include Coastal Sandstone Gully Forest and Sandstone Riparian Scrub Coastal Sand Forest.

Figure 4-5 Flat Rock Creek: concrete-lined stormwater channel (left photo) and the point where the creek begins to flow underground (right photo)

Figure 4-6 Flat Rock Creek: boulder-strewn bed (left photo) and riffle/run formation (right photo)

Figure 4-7 Flat Rock Creek: lower estuarine section

4.1.5 Drainage catchments

Some surface works would be located on catchments dominated by drainage lines that drain towards Sydney Harbour, rather than watercourses.

Surface works that would be located on drainage catchments are:

- Victoria Road construction support site (WHT2). Drainage lines from this construction support site, drain towards Iron Cove
- Yurulbin Point construction support site (WHT4). Drainage lines from this construction support site, drain towards Snails Bay
- Berrys Bay construction support site (WHT7). Drainage lines from this construction support site, drain towards Berrys Bay
- Warringah Freeway Upgrade. Drainage lines from the southern end of the upgrade drain towards Neutral Bay
- Waltham Street (WHT11). Drainage lines from this construction support site, drain towards Flat Rock Creek.

4.2 Sensitive receiving environments

Whites Creek, Willoughby Creek, Quarry Creek and Flat Rock Creek are the main waterways relevant to the project. Two of these watercourses are sensitive receiving environments:

- Quarry Creek
- Flat Rock Creek.

Whites Creek was not identified as Key Fish Habitat based on DPI (2007) mapping. Site investigations confirm that the upstream reaches are not considered Key Fish Habitat based on urban characteristics including concrete-lined substrate with no fish refuge and with limited or no riparian habitat.

Willoughby Creek is a highly urbanised stormwater channel that was formerly a wastewater treatment plant on the western side of Primrose Park. It contains limited natural features such as entrenched bedrock substrate with pools and overhanging vegetation. These features would classify the creek as ‘Type 3 minimally sensitive Key Fish Habitat’. The creek is not considered a sensitive receiving environment.

Upstream, sections of Flat Rock Creek are concrete stormwater channel, however downstream, Flat Rock Creek becomes a tidally influenced estuarine habitat where Quarry Creek tributary meets Flat Rock Creek. Emergent macrophytes, bank undercutting, dense overhanging vegetation and instream woody debris were identified as potential fish refuge. One GDE (Coastal Sandstone Gully Forest) has been identified within 500 metres of the downstream receiving environment. As such, Flat Rock Creek and Quarry Creek are both characterised as ‘Type 1’ highly sensitive Key Fish habitat according to *the Policy and Guidelines for Fish Habitat* (DPI 2013).

Both Flat Rock Creek and Quarry Creek drain to Middle Harbour and Sydney Harbour which are also sensitive receiving environments are discussed in the Technical working paper: Marine Water Quality (Cardno, 2020).

4.3 Environmental values

Environmental values have been assigned to each waterway and will be used to determine existing water quality (Table 4-1). Aquatic ecosystems and visual amenity apply to all waterways within 500 metres upstream and downstream of the project footprint. Flat Rock Creek walking tracks are situated close to the creek banks and rock crossings occur through the watercourse. Long Bay, Willoughby Bay and Rozelle Bay are popular boating recreation areas where people are frequently in direct contact with the water; these are the downstream receiving waterways to Flat Rock Creek, Willoughby Creek and Whites Creek. Secondary contact recreation areas would apply at all watercourses relevant to the project. While commercial fishing has been banned in the harbour, some recreational fishing occurs along the foreshore where consumption of fish is likely. The water quality of each of the waterways with the potential to be impacted is discussed below. The results of the water quality monitoring conducted for the project at each waterway are presented in Appendix A.

Table 4-1 Assigned environmental values for freshwater waterways

Waterway	Environmental value		
	Aquatic ecosystems	Visual amenity	Secondary contact recreation
Whites Creek	✓	✓	
Willoughby Creek	✓	✓	✓
Quarry Creek	✓	✓	✓
Flat Rock Creek	✓	✓	✓

4.4 Existing water quality infrastructure for road pavement runoff

4.4.1 Rozelle

Drainage from the existing road surface network at Rozelle discharges to existing council drainage systems and ultimately to Whites Creek and Rozelle Bay. Roads and Maritime (2017) notes the former Rozelle Rail Yards site is an area that has little known formal drainage other than:

- The Easton Park drain and associated drains in the north of the site
- An open channel running west to east along the base of the rock-wall to the south of Lilyfield Road, between Denison Street and Cecily Street. The channel discharges into a culvert underneath 92 – 94 Lilyfield Road. It is likely that this drain discharges into the Easton Park drain
- A small number of pits and pipes found throughout the site
- An existing stormwater drain from Rozelle Rail Yards into Rozelle Bay near the mouth of Whites Creek.

Surface drainage infrastructure in this area will be modified as part of the M4-M5 Link. This includes the provision of an upsized culvert drainage system under Rozelle Rail Yards that will drain into Rozelle Bay via an upgraded outlet (Roads and Maritime, 2017).

4.4.2 Warringah Freeway

Drainage from the existing Warringah Freeway road surface and next to road networks in North Sydney currently discharges to existing council drainage systems and ultimately to Sydney Harbour or Middle Harbour. The existing stormwater drainage systems collect runoff from substantial upstream urban areas within North Sydney and Willoughby Councils and discharge to the Harbours.

The existing Warringah Freeway does not currently have any specific spill risk management devices.

4.4.3 Waltham Street, Artarmon

Drainage from the site to be occupied by the Waltham Street (WHT11) construction support site discharges into the local stormwater system then travels into Flat Rock Creek which ultimately discharges into Middle Harbour.

4.5 Existing surface water quality

Surface water quality of waterways relevant to the project has been heavily impacted by urban development. The water quality is influenced by both point and diffuse sources of pollution including stormwater, wastewater overflows and leachate from contaminated reclaimed land. The waterways have also undergone a substantial change from natural channels to artificial, hard (concrete-lined) channels. This, together with an increase in impervious areas, would have resulted in increased runoff of greater velocities and the transport of sediments and contaminants to the downstream receiving environment.

The water quality of each of the waterways relevant to the project with the potential to be impacted is discussed below. The results of water quality monitoring completed for this assessment for each waterway are presented in Appendix A.

4.5.1 Whites Creek

Whites Creek is a stormwater drainage system owned by Sydney Water. The water quality of the creek has historically been sampled by Sydney Water on an ad hoc basis in the vicinity of Wisdom Street in Annandale. The data is limited to analytes relevant to wastewater and include faecal coliforms and ammonia which are typically higher in wastewater than ambient water quality or stormwater. Data collected between 2006 and 2017 can be interpreted as showing that wastewater does influence the water quality of Whites Creek on occasion with median faecal coliforms of 8100 cfu/100mL and ammonia concentrations of 0.15 mg/L, which is 10 times the recommended limit for protection of aquatic ecosystems.

The water quality of Whites Creek was also monitored as part of the M4-M5 Link and The Bays Precinct project. Sampling was carried out between June 2016 and May 2017 at a tidally influenced location at Whites Creek Valley Park at Annandale. During this monitoring period, elevated levels of heavy metals (chromium, copper, lead and zinc) were recorded as were elevated concentrations of nutrients including total phosphorus, total nitrogen and oxidised nitrogen. The pH of the water was at times outside the recommended guideline limit for protection of aquatic ecosystems and turbidity exceeded recommended guideline levels (AECOM, 2017).

As part of this assessment, the water quality of Whites Creek has been measured upstream and downstream of the alignment over a three-month period to gain an appreciation of ambient water quality (refer to Table A-1 and Table A-2 in Appendix A). At these locations, Whites Creek is a tidally influenced, concrete-lined stormwater channel. The water quality was generally poor with elevated concentrations of nutrients and heavy metals (copper, lead, zinc and iron). Dissolved oxygen levels were also low on occasion while pH and turbidity were elevated. Hydrocarbons and BTEX were also sampled for but not detected in Whites Creek on any occasion. Over the monitoring period, a single wet weather event was captured with 28 millimetres falling within 24 hours. Despite this rainfall, water quality was similar to dry weather quality and representative of a degraded urban waterway with poor water quality. Neither TPH nor BTEX were detected during the monitoring program.

In summary, the indicators which failed to meet the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines on most occasions in Whites Creek were dissolved oxygen, pH, copper, lead, zinc, iron, oxidised nitrogen, total nitrogen and total phosphorus.

4.5.2 Willoughby Creek

Willoughby Creek is not routinely monitored at present. As such, monitoring data collected as part of this project is the only data available from which to interpret current water quality conditions. Water quality monitoring of Willoughby Creek at Primrose Park, Cremorne over the past three months has shown very high levels of nutrients and elevated concentrations of zinc and copper at all times, and iron on occasion (refer to Table A-3 in Appendix A). Total phosphorus and total nitrogen concentrations were generally five to 10 times the recommended guideline limit for protection of aquatic ecosystems and oxidised nitrogen was measured at more than 50 times the recommended guideline limit. Dissolved oxygen levels were low and likely due to the low flow and isolated pools where monitoring was carried out. There were no detections of BTEX or hydrocarbons.

In summary, the indicators which frequently failed to meet the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines for protection of aquatic ecosystems were dissolved oxygen, copper, zinc, oxidised nitrogen, total nitrogen and total phosphorus.

4.5.3 Quarry Creek

Quarry Creek in North Sydney is a tributary of Flat Rock Creek which flows into Long Bay in Middle Harbour. North Sydney Council undertook testing of this creek between 2001 and 2011 for a range of water quality indicators (Table 4-2). Summary statistics provided by North Sydney Council suggests that the water quality of the creek has elevated median concentrations of copper, zinc, total nitrogen and total phosphorus. Both pH and dissolved oxygen are towards the upper recommended limits with median pH exceeding eight. Faecal coliform counts are also very high indicating microbial contamination.

Table 4-2 Quarry Creek water quality data summary (North Sydney Council)

Indicator	Quarry Creek[2]		ANZG (2018), ANZECC/ARMCANZ (2000) guidelines
	East	West	
Faecal coliforms (cfu/100mL)	**2500**	**4500**	<1000 (secondary contact)
Dissolved oxygen (% sat)	91.8	106.9	85–110
Total nitrogen (mg/L)	**2** (0.049)	**1.8** (0.009)	<0.35mg/L
Total phosphorus (mg/L)	**0.14** (0.049)	**0.17** (0.009)	<0.025mg/L
Turbidity (NTU)	11	22	<50NTU
Total zinc (mg/L)[1]	**0.052** (0.018)	**0.06** (0.01)	0.008mg/L
Total lead (mg/L)[1]	**0.0015** (0.018)	**0.001** (0.009)	0.0034mg/L
Total copper (mg/L)[1]	**0.01** (0.018)	**0.005** (0.01)	0.0014mg/L
pH (pH units)	8.02	7.5	6.5–8.5
Electrical conductivity (µS/cm)	400	212	125–2220µS/cm

Note 1: Total metal results represent the hardness adjusted value as per ANZECC/ARMCANZ (2000) which *"recommends adjusting the trigger value for hardness related metals to account for local water hardness".* This is important because the trigger values for these metals have been derived for soft waters (30mg/L $CaCO_3$) corresponding to high toxicity.

Note 2: Cells shaded in grey denote an exceedance of guidelines. Number in brackets denotes wet weather median. Where numerous sites were sampled on a creek, results are displayed from downstream to upstream in the table.

Monitoring carried out between October 2017 and February 2018 also shows that Quarry Creek has elevated nutrients, copper and zinc concentrations (refer to Table A-4 in Appendix A). Specifically, the indicators which exceeded recommended guidelines on all sampling occasions were copper, zinc, oxidised nitrogen, total nitrogen and total phosphorus. Dissolved oxygen and iron exceeded guideline limits 50 per cent of the time.

4.5.4 Flat Rock Creek

The water quality of Flat Rock Creek is monitored by North Sydney Council at two locations in the middle of the catchment and towards the downstream end (Table 4-3). The mid-catchment site is a concrete-lined channel and, according to North Sydney Council, the site is frequently found to contain rubbish. Generally, median in-situ indicators are compliant in the creek with pH, dissolved oxygen, turbidity and conductivity all within guideline limits. Metal concentrations are low with the exception of total copper and zinc, which were detected in elevated concentrations during dry weather. Nutrient concentrations are very high, particularly total nitrogen indicating eutrophic conditions. Microbiological contamination is also evident, particularly at the downstream site with high counts of faecal coliforms and enterococci.

Monitoring of Flat Rock Creek was also carried out as part of this water quality assessment at three locations, upstream of the proposed crossing (5a), and downstream of the proposed crossing at Flat Rock Gully (5b) and Northbridge Suspension Bridge (5c) (refer to Table A-5 and Table A-6 and Table A-7 in Appendix A). Flat Rock Creek site 5c is the most downstream site, located downstream of the Quarry Creek confluence. Recent monitoring corresponds with previous monitoring trends whereby the creek shows elevated nutrient levels (NO_x, TN and TP) and elevated concentrations of heavy metals copper and zinc. Iron concentrations were elevated on occasion at sites 5a and b, and at all times at site 5c. pH levels were high at the upstream site (5a) but complied downstream. Dissolved oxygen levels showed the opposite trend and were good at the upstream site but very low and below recommended limit for protection of aquatic ecosystems at the downstream site. Overall nutrient concentrations decreased downstream whereas metal concentrations increased.

Table 4-3 Flat Rock Creek water quality data summary (North Sydney Council)

Indicator	Flat Rock Creek[2]		Guideline
	Midstream	Downstream	
Faecal coliforms (cfu/100mL)	235	**1880**	<1000 (secondary contact)
Enterococci (cfu/100mL)	**150**	**340**	
Dissolved oxygen (% sat)	100.1	85.7	85–110
Total nitrogen (mg/L)	**1.320**	**3.89** (3.02)	<0.35mg/L
Total phosphorus (mg/L)	**0.042**	**0.043** (0.034)	<0.025mg/L
Turbidity (NTU)	4.6	5.9	<50NTU
Total zinc (mg/L)[1]	**0.014**	**0.03** (0.021)	0.008mg/L
Total lead (mg/L)[1]	0.001	0.001 (0.001)	0.0034mg/L
Total copper (mg/L) ^	**0.005**	**0.005** (0.004)	0.0014mg/L
pH (pH units)	7.98	7.64 (7.82)	6.5–8.5
Conductivity (µS/cm)	305	401	125–2220µS/cm

Note 1: Total metal results represent the hardness adjusted value as per ANZECC/ARMCANZ (2000) which *"recommends adjusting the trigger value for hardness related metals to account for local water hardness". This is important because the trigger values for these metals have been derived for soft waters (30mg/L $CaCO_3$) corresponding to high toxicity.*

Note 2: Cells shaded in grey denote an exceedance of guidelines. Number in brackets denotes wet weather median (no wet weather monitoring events happened at the upstream site). Where numerous sites were sampled on a creek, results are displayed from downstream to upstream in the table.

In summary, pH, copper, zinc, oxidised nitrogen and total nitrogen and phosphorus failed to comply with the recommended limits for the protection of the nominated environmental values on all sampling occasions at the upstream site. Total iron failed to comply on four of the six sampling occasions and chlorophyll-*a* failed twice. At the downstream sites, dissolved oxygen, copper, zinc, iron, oxidised nitrogen, total nitrogen and total phosphorus exceeded recommended limits on all sampling occasions and lead exceeded guidelines on 50 per cent of sampling occasions. The poorer water quality downstream may be influenced from leachate from the former landfill site.

4.6 Site-specific trigger values

The Australian and New Zealand Environment and Conservation Council (ANZECC/ARMCANZ, 2000) have default guidelines for water quality which have been collated and updated in the ANZG (2018) water quality guidelines. These guidelines provide benchmarks for assessment of the existing water quality of the river. The application of the criteria is dependent on the environmental values assigned to the waterway.

Default trigger values for toxicants, such as metals, pesticides and other organic and inorganic chemicals provided in the ANZG (2018) have been derived using advanced statistical analysis of data on the long term toxic effects on aquatic biota. They have been developed to protect designated percentages of aquatic life. As such, development of SSTV is not needed for toxicants, however values should be consisted with an appropriate percent protection level for the site.

In heavily urbanised and modified environments such as the environment surrounding the project, water quality indicators often exceed the recommended ANZECC/ARMCANZ (2000) default trigger values for physical and chemical stressors for estuarine and lowland river ecosystems. A targeted water quality monitoring program was carried out to collect water quality data at each waterway that has the potential to be impacted by the project. This information confirmed that the receiving environments for the construction and operational water treatment plant discharges from the project are highly disturbed ecosystems.

As such, the default trigger values are not a suitable comparison with ambient water quality. A more suitable approach is to determine SSTVs from a local reference data set for physical and chemical stressors. This approach would involve calculating the 80th percentile of baseline data (and the 20th percentile where water quality would fall within a specified range, eg pH, dissolved oxygen and electrical conductivity) or a less conservative target 90th percentile given the highly modified state of the receiving environment.

The resulting SSTVs would be used for designing temporary construction wastewater treatment plants and setting their discharge criteria.

4.7 Contamination

Areas of environmental interest for contamination along the alignment are discussed in detail in Technical working paper: Contamination (Jacobs, 2020b). Each of the areas was given a risk ranking from low to high, to indicate the potential for contamination. An assessment on whether the contamination is likely to be present in the groundwater is discussed in detail in Technical working paper: Groundwater (Jacobs, 2020a). Areas of environmental interest with assigned moderate to high exposure risk rankings are listed in Table 4-4 and shown in Figure 4-8. This figure also shows NSW EPA regulated/notified sites within 500 metres from the project alignment.

Table 4-4 Potential areas of environmental interest for contamination with assigned moderate to high exposure risk rankings

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W1	Rozelle Rail Yards	Above tunnel and within footprint of construction support site	Rozelle Rail Yards (WHT1) construction support site and below ground tunnels (surface and depth)	Residual contamination from historical railway usage and historical demolition of on-site structures	Surface and depth (potentially 0m to > 4m). Depth distribution associated with potential underground storage tanks	Heavy metals, hydrocarbons, pesticides, asbestos	High • Known contamination • Excavation activities for construction compound and tunnel within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).
				Potential infill of former creek line and adjoining low-lying areas	Surface and depth (potentially 0m to > 2m). Depth distribution associated with depth of infilling. Infilling materials could comprise historical furnace waste from harbourside industry	Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos	High • Known contamination • Excavation activities for construction compound and tunnel within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W2	Easton Park – Corner Denison Street and Lilyfield, Rozelle	Above tunnel	Tunnel (depth)	Potential infill of former creek line and adjoining low-lying areas	Surface and depth (potentially 0m to > 2m). (Depth distribution associated with depth of infilling. Infilling materials could comprise historical furnace waste from harbourside industry)	Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos	Moderate • Possible contamination • No excavation activities for tunnel within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).
W3	Yurulbin Park, Birchgrove	Above tunnel and within footprint of construction support site	Yurulbin Point (WHT4) construction support site (surface) and tunnel (depth)	Slag and ash fill material (historical furnace waste from harbourside industry), historical industrial land use, demolition of on-site buildings /structures.	Surface (potentially 0–1m)	Heavy metals, hydrocarbons, asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically) • Potential contamination distribution unlikely to affect tunnelling (based on depth to tunnel).

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W4	Birchgrove Peninsula and Park – Louisa Road, Birchgrove	Above tunnel and within footprint of construction support site	Yurulbin Point (WHT4) construction support site (surface) and tunnel (depth)	Slag and ash fill material (historical furnace waste from harbourside industry)	Surface (potentially 0–0.5m)	Heavy metals, hydrocarbons, asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically) • Potential contamination distribution unlikely to affect tunnelling (based on depth to tunnel).
W5	Sediments within Sydney Harbour	Above tunnel and within footprint of construction support site	Sydney Harbour south cofferdam (WHT5) and Sydney Harbour north cofferdam (WHT6) construction support sites (surface) and tunnel (depth)	Contamination associated with industrial use of Sydney Harbour and catchment inputs	Surface to recent (~150 year) depositional extent	Heavy metals, hydrocarbons (mainly PAH), pesticides, PCB, PFAS, dioxin, organotins	High • Known contamination • Dredging activities for construction support site and tunnel within site footprint • Dredging activities within potential contamination distribution range.

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W6	Wharf – Balls Head Drive, Waverton	Above tunnel and within footprint of construction support site	Berrys Bay (WHT7) construction support site (surface) and tunnel (depth)	Commercial /industrial marine land use (current and/or historical)	Surface (potentially 0–0.5m)	Heavy metals, hydrocarbons, organotins	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically) • Potential contamination distribution unlikely to affect tunnelling (based on depth to tunnel).
	Berrys Bay Marina – Balls Head Road, Waverton	Adjacent to construction support site footprint and tunnel (laterally, not vertically)	Berrys Bay (WHT7) construction support site (surface) and tunnel (depth)	Commercial/industrial marine land use (current and/or historical)	Surface (potentially 0–0.5m)	Heavy metals, hydrocarbons, organotins	Low • Possible contamination • Excavation activities within site footprint limited to tunnel decline only • Excavation activities limited to tunnel decline only which is within potential contamination distribution range for surface work • Potential contamination distribution unlikely to impact tunnelling (based on depth to tunnel).

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W7	Former bulk fuel storage – Balls Head Road, Waverton	Above tunnel and within footprint of construction support site	Berrys Bay (WHT7) construction support site (surface) and tunnel (depth)	Above-ground storage of fuels	Surface (potentially 0–0.5m)	Heavy metals, hydrocarbons, PFAS	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically – surface work only) • Potential contamination distribution unlikely to impact tunnelling (based on depth to tunnel).
W8	Waverton Park – Woolcott Road, Waverton	Above tunnel	Tunnel (depth)	Infill/reclamation next to shore line	Surface and depth (potentially 0m to > 20m). (Depth distribution associated with depth of infilling)	Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos	High • Known contamination (which could impact upon groundwater) • Tunnel below site footprint
W9	Unsealed areas next to Warringah Freeway – Alfred Street, North Sydney	Within footprint of construction support site and surface works	Blue Street (WFU1) construction support site and WFU surface work (surface)	Deposition of particulate matter	Surface (potentially 0–0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	High • Known contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).

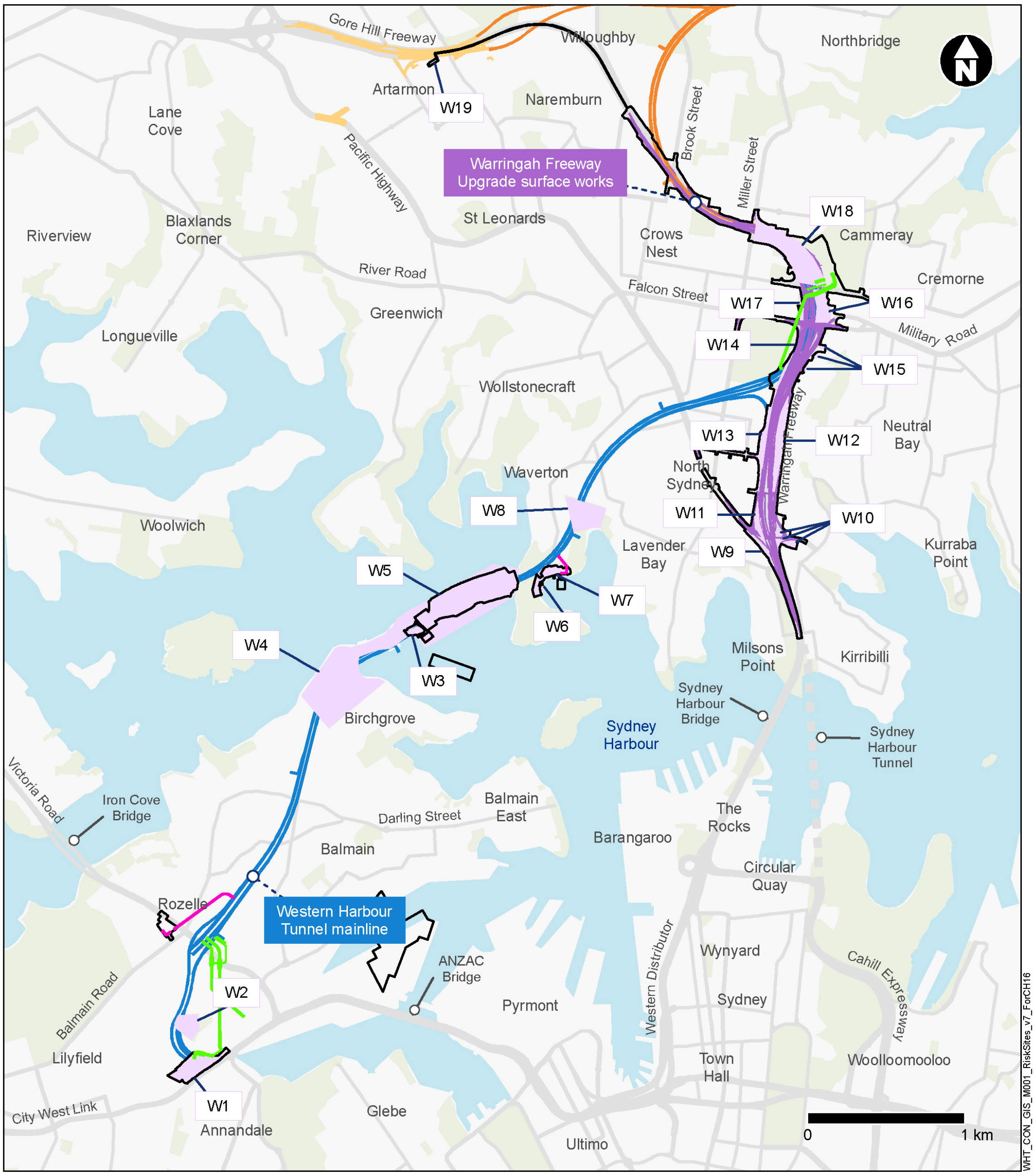
ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W10	Unsealed areas next to Warringah Freeway – High Street, North Sydney	Within footprint of construction support site and surface works	High Street north (WFU3) construction support site and WFU surface work (surface)	Deposition of particulate matter	Surface (potentially 0–0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).
W11	Unsealed areas next to Warringah Freeway – Eastern side (between Arthur Street and Warringah Freeway, North Sydney	Within footprint of construction support site and surface works	Arthur Street east (WFU4) construction support site and WFU surface work (surface)	Deposition of particulate matter	Surface (potentially 0-0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).
W12	Unsealed areas next to Warringah Freeway – Western side (between Mount Street and Ridge Street), North Sydney	Within footprint of construction support site and surface works	Ridge Street east (WFU6) construction support site and WFU surface work (surface)	Deposition of particulate matter	Surface (potentially 0-0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically – surface work only) • Potential contamination distribution unlikely to impact tunnelling (based on depth to tunnel).

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W13	Unsealed areas next to Warringah Freeway – Eastern side (between Berry Street and Ridge Street), North Sydney	Within footprint of construction support site and surface works	Berry Street east (WFU5) and Cammeray Golf Course (WFU8) construction support sites and WFU surface work (surface)	Deposition of particulate matter	Surface (potentially 0-0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically – surface work only) • Potential contamination distribution unlikely to impact tunnelling (based on depth to tunnel).
W14	St Leonards Park bordering Warringah Freeway (between Ridge Street and Falcon Street), North Sydney	Within footprint of construction support site and surface works	Ridge Street north (WHT9) construction support site and WFU surface work (surface)	Deposition of particulate matter and filling	Surface and depth (potentially 0-2m)	Heavy metals, hydrocarbons, pesticides, PCB, nutrients, cyanide, VOC, asbestos, PFAS	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically – surface work only) • Potential contamination distribution unlikely to impact tunnelling (based on depth to tunnel).

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W15	Unsealed areas next to Warringah Freeway – Western side (between Merlin Street and Warringah Freeway), Neutral Bay	Within footprint of construction support site and surface works	Merlin Street (WFU7) construction support site and WFU surface work (surface)	Deposition of particulate matter	Surface (potentially 0-0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).
W16	Unsealed areas next to Warringah Freeway – Western side (between Ernest and Falcon streets), North Sydney	Above tunnel and within footprint of surface works and pedestrian bridge construction site	WFU surface work (surface) and tunnel (depth)	Deposition of particulate matter	Surface (potentially 0-0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically – surface work only) • Potential contamination distribution unlikely to impact tunnelling (based on depth to tunnel).

ID (Figure 4-8)	Site	Location relative to alignment	Construction element and anticipated depth	Potential contamination source	Potential contamination distribution	Potential contaminants	Risk ranking
W17	Unsealed areas next to Warringah Freeway – Eastern side (between Ernest Street and Falcon Street), Cammeray	Above tunnel and within footprint of surface works and pedestrian bridge construction site	WFU surface work (surface) and tunnel (depth)	Deposition of particulate matter	Surface (potentially 0-0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	Moderate • Possible contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically – surface work only) • Potential contamination distribution unlikely to impact tunnelling (based on depth to tunnel).
W18	Unsealed areas next to Warringah Freeway – Ernest to Miller Street), Crows Nest	Within footprint of surface works	WFU surface work (surface)	Deposition of particulate matter	Surface (potentially 0-0.1m)	Heavy metals (mainly lead), hydrocarbons (mainly PAH), asbestos	High • Known contamination • Excavation activities within site footprint • Excavation activities within potential contamination distribution range (laterally and vertically).
W19	Factories /warehouses, Waltham Street at Artarmon	Within footprint of Motorway Control Centre site	Waltham Street (WHT11) site (surface)	Commercial /industrial land use (current and/or historical)	Surface and depth (potentially 0m to > 4.0m). (Depth distribution associated with potential underground storage tanks)	Heavy metals, hydrocarbons	Moderate • Possible contamination • Excavation activities within site footprint and within potential contamination distribution range (laterally and vertically – surface works only).

Source: Technical working paper: Contamination (Jacobs, 2020b).



Legend

Operational features
- Western Harbour Tunnel
- Warringah Freeway Upgrade
- Ventilation tunnel

Construction features
- Construction footprint
- Access decline

Connecting projects
- Beaches Link
- Gore Hill Freeway Connection

Contaminated sites
- Moderate to high risk contaminated site

Figure 4-8 Areas of environmental interest with assigned moderate to high exposure risk rankings

4.8 Acid sulfate soils risk

Acid sulfate soils (ASS) is 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:

- Sydney Harbour and Rozelle Bay – (A) high probability/confidence unknown
- Lilyfield to Snails Bay – (B3) low probability/low confidence
- Balls Head to Crows Nest – (C4) extremely low probability/very low confidence
- Artarmon – (B4) low probability/very low confidence.

A review of the ASS risk maps from the Leichhardt Local Environmental Plan 2013 indicated that the project is located within areas of predominantly Class 5 ASS risk with isolated areas of Class 1 (Rozelle Rail Yards) and Class 2 (Birchgrove Park) ASS risk. The North Sydney Local Environmental Plan 2013 does not contain ASS risk maps. The respective LEPs do not cover ASS risk within Sydney Harbour and associated bays.

Land next to watercourses such as Whites Creek are identified as having a high probability of being potential ASS.

The LEP details 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 1 – Any work
- Class 2 – Work below the natural ground surface or work which is likely to lower the water table
- Class 5 – Work within 500 metres of nearby Class 1, 2, 3 or 4 land that is below five metres Australian Height Datum and by which the water table is likely to be lowered below one metre Australian Height Datum on nearby Class 1, 2, 3 or 4 land.

Probability of ASS occurrence (from ASRIS) along the alignment is presented in Figure 4-9.

4.9 North Sydney Council stormwater harvesting scheme

North Sydney Council has established an extensive stormwater harvesting scheme, which includes a storage dam at Cammeray Golf Course of about 45 metres by 35 metres in size. The dam receives stormwater harvested from the surrounding catchments, that is then used to irrigate a number of community parks and the golf course itself. Harvested water is also piped through the existing stormwater system back to St Leonards Park, which is used to irrigate the public parklands and North Sydney Oval. The dam also serves as a sediment settlement pond which improves the quality of water re-entering the catchment and harbour.

The dam has become habitat for wildlife such as ducks since its construction and saves about 90 million litres of clean water each year (North Sydney Council, 2018).

Legend

Western Harbour Tunnel
Warringah Freeway Upgrade
Communications cable for motorway control centre

Acid sulfate soils probability
High probability of occurrence
Disturbed terrain

Figure 4-9 Acid sulfate soil risk classification

5. Assessment of construction impacts

Construction of the project would involve a range of activities at different locations within the project footprint. Construction of the project presents a risk of degradation of downstream water quality if management measures are not implemented, monitored and maintained throughout the construction phase. Water quality management and mitigation measures would be an integral part of construction activities.

5.1 Water use and water balance

This section provides a preliminary assessment of the water balance during construction of the project based on the groundwater inflow estimates presented in Technical working paper: Groundwater (Jacobs, 2020a). The water demand estimates in Table 5-1 and the groundwater inflows that would be available for reuse after treatment at each construction wastewater treatment plant (refer to Figure 5-1 for the location of the project's construction wastewater treatment plants).

5.1.1 Construction water use

Construction water usage estimates have been developed as part of the project design and are shown in Table 5-1. The total volume of water required during construction of the project is estimated to be around 1.3 megalitres per day which equals around 475 megalitres per annum. The water usage estimates are averages during the entire construction period (2021–2026). The actual water usage during construction is expected to show considerable variation during this period depending on the nature and extent of construction activities taking place.

Table 5-1 Construction daily water demand breakdown

Activity[1]	Tunnelling works (kL/d)	Surface works (kL/d)	Office use (kL/d)	Total (kL/d)
Warringah Freeway Upgrade[2]	0	100	9	109
Rozelle Rail Yards (WHT1)	0	30	9	39
Victoria Road (WHT2)	421	25	14	460
White Bay (WHT3)	0	60	15	75
Yurulbin Point (WHT4)	211	12	5	228
Berrys Bay (WHT7)	211	18	12	241
Cammeray Golf Course (WHT10)	144	10	5	159
Waltham Street (WHT11)	0	0	16	16
Total	**987**	**255**	**85**	**1,327**

Note 1: Water demand and use estimates for Sydney Harbour south cofferdam (WHT5) and Sydney Harbour north cofferdam (WHT6) construction support sites are included in White Bay (WHT3) construction support site.

Note 2: Warringah Freeway Upgrade estimates include all nine Warringah Freeway Upgrade construction support sites, Berry Street North construction support site (WHT8) and Ridge Street north construction support site (WHT9).

5.1.2 Tunnel construction wastewater management

Temporary construction wastewater treatment plants would be designed to treat wastewater generated from tunnelling activities (including from heat and dust suppression) or rainfall runoff collected from the tunnel portals.

Indicative construction wastewater treatment discharges and discharge points are presented in Table 5-2. The treated wastewater discharge points are shown in Figure 5-1.

Wastewater treatment plants that discharge to the marine environment are considered in Technical working paper: Marine water quality (Cardno, 2020).

Table 5-2 Construction wastewater treatment plants and discharge points

Plant location	Discharge location	Ultimate receiving waters
Rozelle Rail Yards construction support site (WHT1)	Local stormwater	Rozelle Bay, Sydney Harbour
Victoria Road construction support site (WHT2)	Local stormwater	Iron Cove, Sydney Harbour
Yurulbin Point construction support site (WHT4)	Snails Bay	Snails Bay, Sydney Harbour
Berrys Bay construction support site (WHT7)	Berrys Bay	Berrys Bay, Sydney Harbour
Cammeray Golf Course construction support site (WHT10)	Local stormwater	Willoughby Creek, Middle Harbour

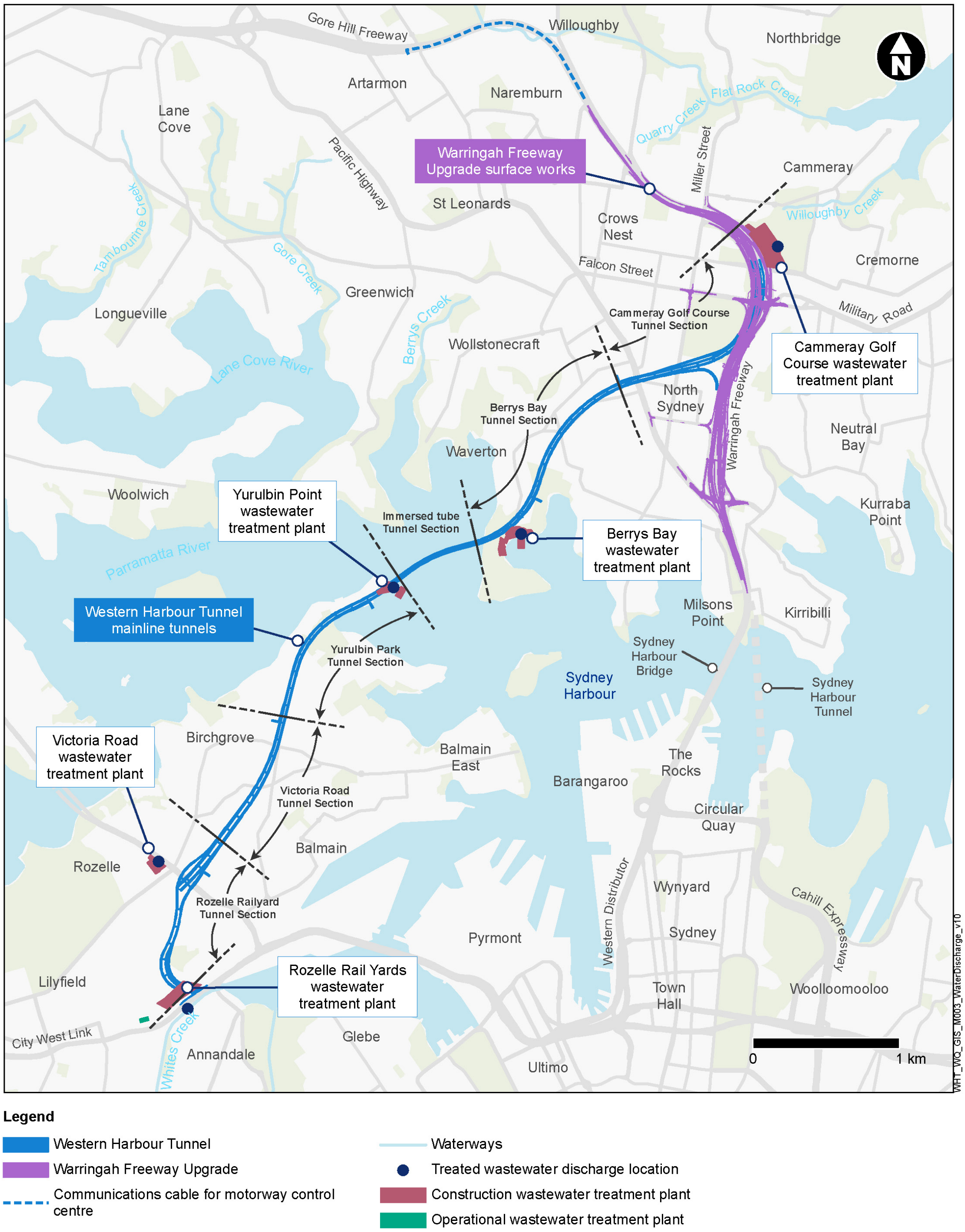


Figure 5-1 Wastewater treatment plants and discharge locations

5.1.3 Water balance

The water balance for the construction phase is shown in Table 5-3.

Non-potable water uses would include roadheader supply, dust suppression, plant wash-down and rock bolting. Some demand activities involve consumption such as in the offices. This is assumed to be discharged to the sewerage network. There would also be minor losses in the system due to evaporation. The remainder would be treated and discharged at the locations shown in Figure 5-1.

There is potential for some of the water supply for the non-potable demand during the construction to be sourced from treated groundwater inflows and treated rainwater harvested from building rooftops. The deficit for the non-potable demand and any potable demand would be sought from the Sydney Water supply network. Where possible, the use of non-potable water over potable would be preferential however this is dependent on the location and nature of the use, and quantity and quality of available water at the time. Water availability would vary due to climate and as construction progresses. It is expected that the potential for treated wastewater reuse would also show variability.

Table 5-3 Construction water balance (based on average groundwater inflows)

Activity[1]	Total water demand (kL/d)	Consumption (kL/d)	Groundwater inflows (kL/d)	Harvested rainwater (kL/d)	Treated wastewater reused (kL/d)	Sydney water supply (kL/d)	Discharged quantity (kL/d)
Warringah Freeway upgrade[2]	109	109	0	0	0	109	0
Rozelle Rail Yards (WHT1)	39	39	243	1	30	9	214
Victoria Road (WHT2)	460	39	168	1	177	283	413
White Bay (WHT3)	75	75	0	0	0	75	0
Yurulbin Point (WHT4)	228	17	94	1	92	136	214
Berrys Bay (WHT7)	241	30	144	1	107	134	249
Cammeray Golf Course (WHT10)	159	15	135	1	84	75	196
Waltham Street (WHT11)	16	16	0	0	0	16	0
Total	**1327**	**340**	**783**	**5**	**490**	**837**	**1286**

Note 1: Water demand and use estimates for Sydney Harbour south cofferdam (WHT5) and Sydney Harbour north cofferdam (WHT6) construction support sites are included in White Bay (WHT3) construction support site.

Note 2: Incorporates all nine Warringah Freeway Upgrade construction support sites plus Berry Street North (WHT8) and Ridge Street north (WHT9) construction support sites.

Note 3: Groundwater inflow estimates have been apportioned based on the tunnel drainage design to provide an indicative estimate of likely inflow volumes that would be pumped to each construction wastewater treatment plant.

5.2 Impacts on surface water quality

Potential risks to surface water quality from tunnelling and surface activities are discussed in the following section.

5.2.1 Tunnelling activities

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

- Groundwater ingress
- Rainfall runoff in tunnel portals and ventilation outlets
- Heat and dust suppression water
- Washdown runoff.

Tunnel wastewater, if discharged untreated or poorly treated, has the potential to impact ambient water quality of the receiving waterways by introducing increased nutrient loading, resulting in algal growth with increased risk to human health. There is also potential for reduction in visual amenity and impacts on aquatic species as a result of heavy metals or other toxicants.

Rozelle Rail Yards, Victoria Road, Yurulbin Point and Berrys Bay construction wastewater treatment plants would treat wastewater from tunnelling activities and discharge treated wastewater into marine environments. The impact of treated wastewater into marine environments is discussed and assessed in Technical working paper: Marine Water Quality (Cardno, 2020).

The Cammeray Golf Course construction wastewater treatment plant would treat the tunnel inflows estimated in Table 5-3 which would be discharged into Willoughby Creek via the local stormwater system. Table 5-4 summarises the expected contaminants to be captured at this wastewater treatment plant based on the existing groundwater quality as documented in Technical working paper: Groundwater (Jacobs, 2020a) and selected areas of environmental interest (as listed in Table 4-4). In summary:

- Sampling of groundwater bores in the area identified key pollutants that pose a risk to the water quality of Willoughby Creek in excess of the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines. These pollutants of concern are provided in Table 5-4 (refer to Appendix B for all indicators)
- Generally, groundwater returned elevated results for some total recoverable hydrocarbons (TRH) fractions, indicating that the groundwater is contaminated with petroleum products. The median concentrations were greater than background levels recorded in Willoughby Creek for the fractions TRH C10-C16 (F2) and TRH>C10-C40 (sum of total). These petroleum products are known to be toxic to aquatic fauna and flora and can deposit in the creek sediment. As a worst case, the potential impact to Willoughby Creek could be loss of species and threat to public health
- Water quality results from groundwater bores also reported high levels of total nitrogen and phosphorus however total nitrogen while exceeding the recommended ANZG (2018) and ANZECC/ARMCANZ (2000) limit was only a third of the concentration recorded in Willoughby Creek itself. Noting that nitrogen is already elevated in Willoughby Creek, the addition of more nitrogen rich water could result in eutrophication and algal blooms
- Reported groundwater concentrations of ammonia and total phosphorus present a similar risk to Willoughby Creek as they were recorded in concentrations that exceed recommend limits for protection of aquatic ecosystems. Metal concentrations, in particular iron and manganese, were reported to be elevated in groundwater. Filtered iron concentrations are almost three times the total background concentration recorded in Willoughby Creek and filtered manganese is more than 11 times higher in groundwater than in the creek itself. This presents a risk to water quality if appropriate treatment does not occur before discharge as the discharged water could be rapidly oxidised causing precipitation of iron and manganese oxides/hydroxides out of solution. This can aesthetically impact the creek as the

water can become reddish/brown and result in algal blooms and thick mats of iron bacteria. This could result in reduced dissolved oxygen levels and an impact on surface water aquatic ecology.

Table 5-4 Summary of groundwater pollutants that if untreated or poorly treated, could exceed ANZG (2018) and ANZECC/ARMCANZ (2000) or future SSTVs

Indicator	Units	Median[1]	ANZG (2018), ANZECC/ARMCANZ (2000)
TRH C10-C16 (F2)	µg/L	50	No guideline
TRH >C10-C40 (sum of total)	µg/L	120	No guideline
Ammonia as N	µg/L	160	20
Nitrogen (Total)	mg/L	1.8	0.35
Phosphorus	mg/L	0.52	0.025
Iron (filtered)	mg/L	1.365	0.3
Manganese (filtered)	mg/L	0.1745	1.9

Note 1: Median concentration from monitoring of three groundwater bores.

The wastewater treatment plant at Cammeray Golf Course would treat wastewater generated from tunnelling activities to a standard suitable for discharge based on ANZG (2018) and future SSTVs to be developed as discussed in Section 4.6. Suspended sediments and contaminants above relevant guideline values are likely to be the key water quality indicators that could impact receiving water quality if tunnel wastewater is not adequately treated. The type, arrangement and performance of construction wastewater treatment plants would be developed and finalised during detailed construction planning. Construction wastewater treatment plants would be designed to maintain the water quality outcomes of the receiving ambient environment so that water quality objectives are achieved.

Other construction wastewater treatment plants would discharge into Rozelle Bay, Iron Cove and Sydney Harbour (Snails Bay and Berrys Bay). Refer to Technical working paper: Marine water quality (Cardno, 2020) for an assessment of water quality impacts on these marine water bodies.

5.2.2 Surface activities

Disturbance to the land surface would be required to support tunnelling and to construct surface infrastructure such as roadways, bridges, tunnel portals, motorway facilities and ancillary operations buildings. The highest risk of impacts on surface water quality during construction surface works would be associated with:

- **Earthworks**. Sedimentation can result when rain or runoff comes into contact with exposed areas and stockpiles. Sediment becomes suspended and transported to receiving waters located downstream. Once sediments enter waterways, they can directly and indirectly impact the aquatic environment. Direct impacts include reducing light penetration (limiting the growth of macrophytes), clogging fish gills, altering stream geomorphology, smothering benthic organisms and reducing visibility for fish. Indirect impacts of increased sediments occur over the longer term and include accumulation and the release of attached pollutants such as nutrients and heavy metals. Activities which would involve earthworks in the project footprint include relocation of facilities and removal of vegetation
- **Demolition works.** The removal of buildings and modification and construction of bridges and other civil engineering structures, such as tunnel portals, retaining walls, active transport infrastructure (bridges, paths etc), drainage, culverts, noise barriers, fencing, tolling gantries, lighting and signage could provide a source of pollutants including asbestos and other building materials, pollutant-laden soils, or heavy metals and chemicals. Demolition can also generate dust and airborne pollutants. These pollutants once

mobilised can be picked up by stormwater runoff and distributed downstream to receiving waterways via the drainage network

- **Disturbance of areas of environmental interest for contamination**. Disturbances of these sites (refer to Section 4.7) could result in exposure of contaminants such as hydrocarbons, metals and pesticides. This could increase acidity in waterways and mobilisation of heavy metals. Refer to Technical working paper: Contamination (Jacobs, 2020b) for further detail
- **Activation of acid sulfate soils.** Earthworks in the vicinity of Rozelle Rail Yards and groundwater drawdown from tunnelling work below Birchgrove Park could activate acid sulfate soils. There is the possibility of potential acid sulfate soils being present within sediments within Sydney Harbour. If unmanaged, this could pose a risk to the water quality of Rozelle Bay and Snails Bay. Appropriate acid sulfate soils management measures would be developed and implemented to manage this risk. Refer to Technical working paper: Contamination (Jacobs, 2020b) for further detail
- **Accidental spills.** Accidental spills or leaks could occur from refuelling, leakage of hydraulic and lubricating oil from plant and equipment, or rinse water from plant washing and concrete slurries, also have the potential to enter waterways
- **Relocation of utilities**. The relocation of utilities would involve soil disturbance by trenching and underboring and construction of new service routes. The disturbance of soil by machinery could increase soil erosion which has the potential to impact downstream water quality. Further detail on utilities relocations can be found in Chapter 6 of the environmental impact statement
- **Installation of the communication link**. The trenching and underboring for the communication connection link between the Western Harbour Tunnel at Cammeray and the motorway control centre at Waltham Street, Artarmon would involve soil disturbance. The disturbance of soil by machinery could increase soil erosion which has the potential to impact downstream water quality
- **Removal of vegetation**. The removal of vegetation could increase risk of erosion and sedimentation within the surrounding waterways. The Technical working paper: Biodiversity development assessment report (Arcadis, 2020) indicates the project construction would result in the removal of exotic and native plantings. Most vegetation that would be removed is within the Warringah Freeway road reserve and Cammeray Golf Course. Additionally, a small area of planted vegetation would be removed from Yurulbin Park at Birchgrove
- **Changes to water availability and flows**. Construction would result in treated wastewater discharges from the Rozelle Rail Yards (about 214 kilolitres per day), Victoria Road (about 413 kilolitres per day), Yurulbin Point (about 214 kilolitres per day), Berrys Bay (about 249 kilolitres per day) and Cammeray Golf Course (about 196 kilolitres per day) construction wastewater treatment plants, into Rozelle Bay, Iron Cove, Snails Bay, Berrys Bay and Willoughby Creek, respectively. The project would not extract water from creeks or the harbour.

A summary of project-specific potential impacts on surface water quality is outlined in Table 5-5. Given that the majority of construction works are not located within or in close proximity to waterways and the areas are already highly modified urban areas, the risk of impacting water quality is low. Identified construction surface water quality impacts will be managed via standard erosion and sediment control management and mitigation measures for all work sites and surface works areas (refer to Section 8.1). With the implementation of appropriate measures during construction, impacts on the ambient water quality of receiving environments would be temporary and manageable with no long-term impacts expected.

Table 5-5 Summary of construction impacts on surface water quality

Location/construction component	Potentially impacting construction activities	Potential surface water quality impact	Waterway potentially impacted
All construction support sites. • Additional sites with surface works: • Unsealed areas next to Warringah Freeway – Western side (between Merlin Street and Warringah Freeway) Neutral Bay • Unsealed areas next to Warringah Freeway – Western side (between Ernest and Falcon streets) North Sydney • Disturbance to Jeaffreson Jackson Reserve to accommodate replacement of the Falcon Street shared user bridge • Unsealed areas next to Warringah Freeway – Eastern side (between Ernest and Falcon streets) Cammeray.	• Earthworks including vegetation removal and topsoil stripping, relocation of utilities • Demolition works • Establishment of sites and installation of construction support site facilities • Excavation • Concrete works • Vehicle movements to and from sites • Onsite storage of chemicals/fuel • Accidental spills/material released during transportation of building waste from demolition sites • Activities associated with construction for permanent works • Exposure of contaminated sediments from historical railway usage, reclaimed land and previously infilled creek line associated with harbourside industry • Surface works including construction support sites, shared user bridge, tunnel excavation.	• Smothering aquatic life and affecting the ecosystems of downstream sensitive creeks and waterways through increased sedimentation • Elevated turbidity, nutrients and other contaminants and low dissolved oxygen levels from exposed soil resulting in increased sedimentation • Increased alkalinity as a result of chemicals used in treatment and curing of concrete, and concrete dust being transported to waterways via stormwater and wind • Increased acidity in waterways due to the exposure of contaminated soils such as acid sulfate • Soil and pollutants entering waterways via stormwater runoff from vehicle transfer of soils via nearby roads • Pollution from increased litter and debris being washed into waterways from storms and wind.	• Whites Creek and Rozelle Bay via stormwater from Rozelle Rail Yards (WHT1) • Iron Cove via stormwater from Victoria Road (WHT2) • Willoughby Creek and Willoughby Bay via stormwater from Cammeray Golf Course (WFU8) and (WHT10) • Neutral Bay and Quarry Creek via stormwater from Warringah Freeway surface works.

Location/construction component	Potentially impacting construction activities	Potential surface water quality impact	Waterway potentially impacted
Construction works at tunnelling launch and support sites including: • Rozelle Rail Yards construction support site (WHT1) • Victoria Road construction support site (WHT2) • Cammeray Golf Course construction support site (WHT10).	• Excavation for tunnelling launch and support • Vegetation removal and topsoil stripping • Removal of existing paved areas • Establishment of construction support sites, installation of site facilities • Relocation and protection of utilities • Backfilling and disposal of dredged material • Stockpiling and transport of materials • Discharge from wastewater treatment plants.	• Elevated turbidity, nutrients and other contaminants and low dissolved oxygen levels from exposed soil resulting in increased sedimentation • If mitigation measures are not established during construction, sediment would be more easily eroded and transported into the receiving waterways • Discharge of poorly treated wastewater from construction wastewater treatment plant into stormwater network • Discharge of high volume wastewater which could scour the creek and increase turbidity of downstream waterways.	• Rozelle Bay via stormwater from Rozelle Rail Yards (WHT1) • Iron Cove via stormwater from Victoria Road (WHT2) • Willoughby Creek via stormwater from Cammeray Golf Course (WHT10).
Construction support sites at: • Rozelle Rail Yards construction support site (WHT1) • Yurulbin Point (WHT4).	• Excavation and earthworks • Tunnelling below ground.	• Activation of acid sulfate soils.	• Rozelle Bay • Snails Bay (Sydney Harbour).
Stockpiles and cut and cover locations within 500 metres of a waterway are proposed to be located at: • Rozelle Rail Yards (within 500 metres of Whites Creek) • Warringah Freeway Connection (within 500 metres of Willoughby Creek).	• Stockpiling of spoil or construction materials (eg earthwork materials, crushed rock, mulch and vegetation) • Cut and cover excavations.	• Excavations washing into waterways leading to increased levels of turbidity and sediment loads posing risk to sensitive receiving environments • Risk to water quality of downstream watercourses during rainfall if the stockpiles are not managed appropriately • Risk of movement of sediment off steep slopes during high volume rain events.	• Whites Creek via stormwater runoff from Rozelle Rail Yards • Willoughby Creek via stormwater from Warringah Freeway Connection.

Location/construction component	Potentially impacting construction activities	Potential surface water quality impact	Waterway potentially impacted
Surface works within the construction footprint including: • Surface works outside the construction support sites (eg Warringah Freeway surface road works) • Rozelle Rail Yards (WHT1) • White Bay (WHT3) • Cammeray Golf Course (WFU8) • Cammeray Golf Course (WHT10) • Waltham Street (WHT11).	• Management and haulage of spoil during tunnelling and excavation activities • Stockpiling of spoil • Installation and construction of temporary buildings • Demolition, modification and construction of bridges and other civil engineering structures • Modifications to surface roads including linemarking and road furniture adjustments • Management and haulage of spoil during tunnelling and excavation activities • Trenching through road reserve.	• Exposure of acid sulfate soils, which could lead to increased acidity in waterways (noting the general ASS probability along the alignment as either B3 (low probability/ low confidence) for the areas between Lilyfield to Snails Bay or C4 (extremely low probability/very low confidence) for the areas between Balls Head to Crows Nest (Jacobs, 2020b)) • Exposure of contaminated soils potentially containing high levels for sulfate, ammonia and hydrocarbons which would result in reductions in water quality.	• Whites Creek • Willoughby Creek • Quarry Creek • Flat Rock Creek (via Quarry Creek).

5.2.3 Impact on NSW water quality objectives during construction

The project would treat wastewater from tunnelling activities and implement standard erosion and sediment control measures for all work sites and surface works areas (refer to Section 8.1). With the implementation of these management measures, pollutant loading to the receiving waterways is considered to be low compared to the existing pollutant loading from Whites Creek, Willoughby Creek, Quarry Creek and Flat Rock Creek catchments.

The project construction is therefore likely to have a negligible influence on whether the NSW WQOs of receiving waterways are protected (if currently met) or achieved (if currently not met).

Refer to Technical working paper: Marine Water Quality (Cardno, 2020) for a discussion on impacts on NSW water quality objectives of marine environments.

5.3 Impact on local stormwater system

As noted in Section 5.1.2, construction wastewater treatment plants located at the Rozelle Rail Yards (WHT1) construction support site, Victoria Road (WHT2) construction support site and Cammeray Golf Course (WHT10) construction support site would discharge into the local stormwater network.

Table 5-6 presents the estimated average discharge quantities as well as the approximate duration of the discharge relevant to each wastewater treatment plant. There would also potentially be a period of about six months when the wastewater treatment plants at the Cammeray Golf Course construction support site (WHT10) and Beaches Link and Gore Hill Freeway Connection project Cammeray Golf Course construction support site (BL1) would discharge concurrently into the local stormwater system. The cumulative discharge from these two wastewater treatment plants is also presented in Table 5-6.

The discharge flow rates range between 0.01 and 0.05 kilolitres per second and are unlikely to have a material impact on the capacity of local stormwater system. Changes to flow (stormwater runoff) due to surface works are anticipated to be accommodated within the existing stormwater network. This would be confirmed during detailed construction planning (refer to Section 8.1).

Table 5-6 Construction wastewater treatment plants discharging into local stormwater system

Plant location	Discharged quantity (kL/d)	Approximate duration of discharge
Rozelle Rail Yards construction support site (WHT1)	214	Three years
Victoria Road construction support site (WHT2)	413	Three years and nine months
Cammeray Golf Course construction support site (WHT10)	196	Three years and six months
Cammeray Golf Course construction support site (WHT10) and Beaches Link and Gore Hill Freeway Connection project Cammeray Golf Course construction support site (BL1) (cumulative discharge)[1]	321	Six months

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

5.4 Impacts on geomorphology

Construction of the project would involve a variety of activities with the potential to impact the waterway form and geomorphic processes. There would be no direct geomorphology impacts on watercourses from:

- Rozelle Rail Yards (WHT1) construction activities, which would occur about 40 metres from Whites Creek. The risk of geomorphology impacts on Whites Creek are expected to be negligible given no instream works are proposed and the creek has been concrete lined at this location (refer to Figure 4-2)
- Cammeray Golf Course (WHT10) construction activities and works near Willoughby Creek which include the replacement of cross-drainage structures. Willoughby Creek runs below the golf course and is assumed to be concrete lined hence the risk of geomorphology impacts from these construction activities is negligible.

However, indirect impacts on geomorphology could arise from:

- Mobilised sediment which could build up in the streams if not appropriately managed
- Impervious surfaces created by the project, leading to increases in the volume and rate of runoff, which could cause erosion within the instream channel
- Subsidence below watercourses, potentially impacting on channel bed and bank conditions. Cumulative long-term surface settlement from tunnelling works and groundwater drawdown have been assessed for the project and reported by WSP and Arup (2019b). Predicted settlement at Whites Creek, Willoughby Creek, Quarry Creek and Flat Rock Creek would be negligible and unlikely to create subsidence that would trigger changes on the creek form.

Treated water discharges from construction wastewater treatment plants also have the potential to impact creek channel bed and bank conditions. As noted in Section 5.1.2, construction wastewater treatment plants at Rozelle Rail Yards, Victoria Road, Yurulbin Park and Berrys Bay construction support sites would discharge into Sydney Harbour and would not impact any creek channel bed or bank (refer to Technical working paper: Marine water quality (Cardno, 2020)).

The Cammeray Golf Course wastewater treatment plant would discharge into the local stormwater system which would ultimately discharge into Willoughby Creek at a continuous average rate of about 0.002 kilolitres per second (that is, two litres per second) for about 3.5 years (Refer to Table 5-6).

There would be also a period of about six months when the wastewater treatment plants at the Cammeray Golf Course construction support site (WHT10) and Beaches Link and Gore Hill Freeway Connection project Cammeray Golf Course construction support site (BL1) would discharge concurrently into Willoughby Creek at a continuous average rate of about 0.004 kilolitres per second (that is, four litres per second).

Both project only and cumulative discharge flows are considered to be minor when compared to creek flows experienced for the 50 per cent Annual Exceedance Probability (12.8 kilolitres per second). Cammeray Golf Course wastewater treatment plant discharges into Willoughby Creek are not anticipated to change the creek geomorphology as the creek is a modified concrete and rock channel that handles greater flows during frequent flood events than is expected to be discharged during construction. The susceptibility of the waterway to degradation as a result of increased flows is considered to be low based on assessment of its current stability and the relatively low level of discharges anticipated compared to existing flows.

The potential impacts on geomorphology would be considered minor and manageable with the application of standard mitigation measures (refer to Section 8).

5.5 Impacts on environmental water availability and flows

Water extraction from surface waters is not proposed during construction of the project.

Surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during construction of the project. Groundwater drawdown modelling documented in the Technical working paper: Groundwater (Jacobs 2020a) found:

- Drawdown in the Rozelle area would have negligible impacts on surface flows at Whites Creek as this is a concrete-lined stormwater channel not dependent on groundwater baseflows
- Willoughby Creek is also lined along most of its length and is not predicted to have noticeable flow reductions due to groundwater drawdown
- There would be no drawdown in the vicinity of Flat Rock Creek or Quarry Creek as a result of the project.
-

5.6 Impacts in North Sydney Council stormwater harvesting scheme

The existing storage dam at Cammeray Golf Course would be removed as part of the project construction and reinstated once the Western Harbour Tunnel and Beaches Link program of works at the Warringah Freeway has been completed, due to land availability. During that period, North Sydney Council would no longer be able to harvest stormwater runoff to irrigate areas such as the Cammeray Golf Course and other open space areas that form part of the scheme.

Roads and Maritime would continue to consult with North Sydney Council to identify opportunities that provide a permanent solution earlier in program that is reasonable and feasible. During periods in which the storage dam is no longer operational, Roads and Maritime would come to an arrangement concerning the period in which the storage dam is no longer operational with North Sydney Council for the increased demand on other water sources.

6. Assessment of operational impacts

Operation of the project has the potential to alter the water balance of surface and groundwater systems, and impact on surface water quality and geomorphology. Details and an assessment of the likelihood of those impacts are provided in the following sections.

6.1 Water use and water balance

This section provides a preliminary assessment of the water balance during operation of the project. Groundwater inflow estimates presented in Technical working paper: Groundwater (Jacobs, 2020a) have been used to provide an indicative estimate of likely inflow volumes that would be pumped to Rozelle Interchange wastewater treatment plant. This facility is the only permanent facility currently planned and is expected to treat all groundwater inflows during the operational period. The location of the Rozelle water treatment plant is shown in Figure 5-1.

The project-wide operational water demand estimates have been split into two key requirements, these being washdown water and deluge testing. The data provided is shown in Table 6-1 as project-wide daily averages. These activities are expected to occur at certain times in particular locations and therefore the peak daily demand would be greater than the average.

Water supply for any non-potable demand during the operational phase can be sourced from the capture and treatment of groundwater inflows. This would be dependent on water availability when it is required and the suitability of the water quality for the intended purpose. The average groundwater inflows during the operational phase are shown in Table 6-1.

Table 6-1 Operational water balance (average groundwater inflows) for the Rozelle Interchange wastewater treatment plant

Water demand		Average groundwater inflows (kL/d)[1]	Treated groundwater re-used (kL/d)	Water make-up from other sources (kL/d)	Discharged quantity (kL/d)
Washdown (kL/d)	Deluge Testing (kL/d)				
1	5	510	6	-	504

Note 1: Averaged over 100 year project life.

6.2 Impacts on surface water quality

Potential risks to surface water quality include:

- Increased impervious surfaces and the discharge of stormwater
- Tunnel discharges of potentially contaminated groundwater
- Erosion and sedimentation from recently disturbed sites
- Impacts on water availability and flows
- Impacts on the North Sydney Council stormwater harvesting scheme.

Table 6-2 provides a summary of the potential impacts and the downstream receiving waterways at risk.

Table 6-2 Summary of potential operational impacts on surface water quality

Location/construction component	Potential operation impacts	Potential surface water quality impact	Waterway potentially impacted
Operation of the project (entire alignment) and increased road surfaces including: • An on-ramp from North Sydney via Berry Street • An off-ramp to Crows Nest via Falcon Street.	• Increases in impervious areas and to a lesser extent from future increases in traffic resulting in increased pollutants from road runoff • Increased volume of road runoff associated with the introduction of additional impervious surfaces • Spills or leaks of fuels or oils on road surfaces due to vehicle accidents or heavy vehicles transporting such materials.	Increased flow and increased area of impervious surfaces and changes to geomorphology such as changing the channel, bed profile and sedimentation process. This can: • Increase sediment loads and nutrients • Reduce light penetration through the water column, impacting aquatic flora and fauna • Stimulate the excessive growth of algae and aquatic plants leading to toxic conditions • Increase siltation of waterways and associated smothering of aquatic flora and fauna • Lead to decay of organic matter and some hydrocarbons which can decrease dissolved oxygen levels affecting fish and aquatic life • Increase levels of heavy metals (including aluminium and iron) which are toxic to aquatic biota and fish • Increase levels of litter, oils and grease.	• Willoughby Creek • Quarry Creek • Flat Rock Creek.
Groundwater and tunnel drainage management and treatment systems, including a wastewater treatment plant at Rozelle.	• Discharge of poor quality groundwater • Alteration of the water table and changes to local hydrology due to groundwater drawdown.	• Stagnation of a waterway or changes in levels of turbidity, nitrogen and phosphorus, should flows be notably lower • Groundwater around the Birchgrove, Balmain and Rozelle area of relatively poor quality with high levels of sulfate, ammonia and hydrocarbons. Heavy metal toluene was also detected at Birchgrove (Technical working paper – Groundwater (Jacobs, 2020a)). If discharged untreated could impact water quality • Elevated hydrocarbons in soils below Waverton Park migrating to groundwater during tunnelling activities and being discharged to surface water.	Groundwater drawdown is only expected in the vicinity of Whites Creek but minimal due to highly modified concrete creek bed. No other creeks expected to be impacted. Water collected by the tunnel drainage system would be treated and discharged to Rozelle Bay via the stormwater network.

Location/construction component	Potential operation impacts	Potential surface water quality impact	Waterway potentially impacted
Operational ancillary facilities including: • Motorway facilities and ventilation outlets at the Rozelle Interchange and Warringah Freeway • A motorway control centre at the Gore Hill Freeway, within the Artarmon industrial area • Motorway facilities at the Warringah Freeway in Cammeray.	Spills or leaks of fuels or oils from vehicle accidents or from operational plant and equipment.	Increased levels of heavy metals (including aluminium and iron) which are toxic to aquatic biota and fish.	This could occur at any of the receiving waterways located downstream of the alignment.

6.2.1 Impervious surfaces and stormwater discharges

Surface connection at Rozelle

The Rozelle Interchange forms part of the approved M4-M5 Link and its upgraded stormwater drainage system that will discharge into Rozelle Bay. The surface connections at Rozelle for the project would integrate with the upgraded stormwater drainage system.

Surface water drainage for the project at the surface connections at Rozelle is designed so that the ingress of stormwater into the tunnels is minimised with stormwater intercepted at the portal and diverted to the local drainage network along City West Link. Stormwater that drains into the tunnels is collected and directed to the operational wastewater treatment plant (refer to Section 6.2.2).

Warringah Freeway Upgrade

Pavement drainage from the existing Warringah Freeway currently discharge to existing council drainage systems, ultimately discharging to Sydney Harbour or Middle Harbour.

New and upgraded infrastructure would be provided to convey runoff from the upgraded section of the Warringah Freeway and maintain drainage performance that is generally consistent with the existing arrangements. This would include improvements to drainage infrastructure to provide additional drainage capacity to pits and pipes under the Warringah Freeway.

A change in catchment area assessment has been carried out to examine the potential impact of increased road surface area resulting from road works. Table 6-3 summarises the changes in catchment area. Areas shown are to a point downstream of Warringah Freeway Upgrade.

Table 6-3 Changes to catchment areas at Warringah Freeway (WSP and ARUP, 2019c).

Location	Existing catchment area (Ha)	Design catchment area (Ha)	% Increase in total catchment area (Ha)
WF-CH0800	38.2	37.85	-0.92
WF-CH1070	4.51	4.24	-5.99
WF-CH1200	18.34	18.76	2.29
WF-CH1350	6.09	6.05	0.66
WF-CH2370	97.88	99.09	1.25
WF-CH8400	53.16	53.33	0.32

The results show only minor localised changes in road catchment area (between minus six and 2.3 per cent). It is unlikely that the pollutant loading from the road surface would change from the existing case due to these marginal changes. For this reason, no formal water quality treatment infrastructure is proposed except for the motorway facilities at the existing Cammeray golf course, which would have an in-line water quality device to treat runoff before discharge to the existing local stormwater network.

The reasoning for no additional water quality mitigation for the relatively small changes in rainfall is outlined below:

- The existing drainage networks are complex, servicing large upstream urban catchments including the existing Warringah Freeway pavement drainage. It is not considered feasible to manage water quality for the project in isolation
- The catchment change assessment has demonstrated very little change in the pavement catchment areas and the potential pollutant loading is not expected to be changed because of the project
- The provision of inline water quality devices within the project carriageway is the only means by which the road pavement and external catchments can be separated. However due to the complexity of the

lane arrangements and median this would result in a significant number of standalone devices. The water quality devices would pose significant risks to the road operations for maintenance activities
- The Roads and Maritime Services road pavement is an existing area and usage is already managed as part of the Sydney Harbour Catchment Management Authority stormwater quality management strategy. Treatment of discharges currently occurs with end-of-line solutions.

Should further design development identify the need for water quality controls, water quality design targets are listed in Table 6-4. These targets are as described in *Draft Managing Urban Stormwater – Council Handbook* (EPA, 2007). Where the design targets cannot be met due to site constraints, the project would provide water quality treatment to meet or improve existing conditions to ensure that there is no impact on surface water quality as a result of the project. The following aspects need to be considered when assessing site constraints:

- Practical spatial constraints, existing structures and utilities
- Maintenance access and safety considerations
- Environmental sensitivity and clearing impacts
- Performance gained against targets.

Table 6-4 Operational water quality design targets

Pollutant	Minimum reduction of the annual average load
Total suspended solids (TSS)	85%
Total phosphorus (TP)	65%
Total nitrogen (TN)	45%

6.2.2 Tunnel drainage and discharges

A drainage and sump system would be installed within the mainline tunnels to collect:

- Groundwater inflow to the tunnels
- Stormwater entering the tunnels
- Deluge water in the event of an incident or during routine testing of emergency systems
- Washdown water
- Spills and leaks.

Water intercepted by the tunnel drainage systems would be collected at a sump and pumped to the project wastewater treatment plant at Rozelle (Figure 5-1). The Rozelle operational wastewater treatment plant would be designed to treat key indicators of concern to a level that is consistent with the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines and the NHMRC (2008) recreational water quality guidelines.

Groundwater bores in the area generally exhibit elevated concentrations of metals, nutrients (total nitrogen, total phosphorus and ammonia) and are likely to contain traces of petroleum products as suggested by detection of total recoverable hydrocarbons (refer Table 5-4 and Appendix B). This groundwater is generally of poorer quality with respect to these indicators than the receiving waterways and therefore, the wastewater treatment plant at Rozelle would focus on these water quality indicators for treatment.

Following treatment, wastewater would then be discharged into Rozelle Bay via the stormwater drainage stormwater system that would be installed as part of the M4-M5 Link. There would be no discharges or impact to the water quality of Whites Creek due to the project.

The water quality of Rozelle Bay and potential impacts of these discharges is discussed in Technical Working Paper – Marine Water Quality (Cardno, 2020).

6.2.3 Erosion and sedimentation

Rehabilitated recently disturbed sites would remain susceptible to scour and erosion from stormwater runoff until the soils and vegetation are completely established. As such there is potential for sediment transport and sedimentation to occur at downstream waters, particularly after storm events. Suitable stabilisation and management techniques would be implemented during periods of vegetation establishment to minimise the potential for erosion within areas for rehabilitation at temporary construction support sites near Whites Creek and Willoughby Creek. Provided appropriate controls are implemented, short-term impacts during the establishment period would be expected to be manageable with negligible impacts on receiving water quality.

6.2.4 Spills

Though unlikely, the risk of accidental spillage of hazardous materials would always be present. Without satisfactory means of containment, the spillage of contaminants could pass rapidly into the project drainage system.

Accidental spills at the Rozelle Interchange would be managed as part of the project operational emergency response procedures.

Accidental spills along the Warringah Freeway would be managed via existing emergency response procedures which include emergency crews, vehicles and the placement of spill kits and stop board to temporarily prevent discharge from the drainage network. Additionally, the existing end-of-line devices located adjacent to the harbour would provide an additional opportunity for interception and management of accidental spills.

6.2.5 Impacts in NSW water quality objectives during operation

During operation, the project would treat tunnel inflows and road tunnel runoff at the Rozelle wastewater treatment plant. The plant would be designed to treat key indicators of concern to a level that is consistent with the ANZG (2018) and ANZECC/ARMCANZ (2000) water quality guidelines and the NHMRC (2008) recreational water quality guidelines.

Runoff from the surface connection at Rozelle that is not collected by the tunnel drainage system would use the M4-M5 Link proposed water quality treatment devices. Runoff from the surface connection at Rozelle is unlikely to decrease the water quality of Whites Creek.

Runoff from the Warringah Freeway Upgrade would not change exports of annual pollutant loads with no decrease of the water quality of Willoughby Creek or Quarry Creek.

The overall impacts on ambient water quality are likely to be negligible. The project is considered to have a negligible influence on goals to achieve the NSW WQOs for waterways and catchments.

Refer to Technical working paper: Marine Water Quality (Cardno, 2020) for a discussion on impacts on NSW water quality objectives of marine environments.

6.3 Impact on local stormwater system

Treated water from the Rozelle Interchange wastewater treatment plant would discharge into the local stormwater system at a flow rate of about 0.006 kilolitres per second (that is, six litres per second). This discharge rate is unlikely to have a material impact on the local stormwater system.

6.4 Impacts on geomorphology

Given the discharge of project stormwater would be via the stormwater network, the potential impact on the geomorphology of watercourses is considered negligible. Similarly, Rozelle Rail Yards wastewater treatment plant discharges would be received into Rozelle Bay with negligible impacts on Whites Creek geomorphology.

Cumulative long-term surface settlement from tunnelling works and groundwater drawdown have been assessed for the project and reported by WSP and Arup (2019b). Cumulative long-term surface settlement is expected to be nil or very minor at creeks intersected or in proximity to the tunnel including Whites Creek, Willoughby Creek, Quarry Creek and Flat Rock Creek. The risk of rock cracking from such surface settlement is negligible because the ground movement would be insufficient to cause any noticeable change in permeability of the rock cover.

6.5 Impacts on environmental water availability and flows

Water extraction from waterways is not proposed for the operational stage of the project.

Surface environmental water availability and flows have the potential to be reduced due to groundwater drawdown during construction of the project. The Technical working paper: Groundwater (Jacobs 2020a) predicts that:

- The project would not have an impact on the baseflows of Flat Rock Creek or Quarry Creek due to groundwater drawdown
- Drawdown is predicted to be negligible beneath Willoughby Creek. In addition, investigations have shown that the upper reaches of Willoughby Creek are lined and therefore would not be impacted by groundwater drawdown.

Treated wastewater from the Rozelle operational wastewater treatment plant would be discharged into Rozelle Bay via the local stormwater system at a rate of six litres per second. Whites Creek water availability and flows would not be changed by the project.

Additionally, the Technical working paper: Groundwater (Jacobs 2020a) reports that groundwater drawdown is expected to be negligible during operation and unlikely to impact creek flows.

The risk of creek flow losses from bed cracking is negligible. The long-term surface settlement from tunnelling works and groundwater drawdown predicted by WSP and Arup (2019b) reports no long-term settlement at Whites Creek and Willoughby Creek and minor localised settlement at Quarry Creek and Flat Rock Creek (up to two and 10 millimetres, respectively).

6.6 Impacts on North Sydney Council stormwater harvesting scheme

A new dam would be provided at the operational stage of the project within the north-western end of the golf course. The new dam would have a stormwater harvesting yield comparable to the existing one. The operational stage of the project would not impact the operation and volume of water harvested for the North Sydney Council stormwater harvesting scheme.

7. Assessment of cumulative impacts

This chapter provides an overview of the potential water quality cumulative impacts associated with the project.

The projects considered in the cumulative impact assessment for surface water and hydrology are presented in Table 7-1. The major projects considered relevant for potential cumulative surface water and hydrology impacts are those where there is an immediate interface during construction and/or operation with the project. Other projects occurring in the broader locality (eg projects in North Sydney or Artarmon within urban areas) would likely cause a negligible increase in surface flows or runoff. Combined with the distance to downstream waterways and standard management controls, the cumulative impact is expected to be negligible.

There are also a number of strategic projects in proximity to the project, such as The Bays Precinct Urban Transformation Plan and St Leonards Park Landscape Masterplan. The potential cumulative impacts that may occur have not been considered in detail given the uncertainty of the status and timing of the associated projects and construction methodologies.

The potential cumulative impact of the project and the other major projects as identified in Table 7-1 are presented in Table 7-2. Provided controls are implemented, maintained and monitored, the cumulative impacts of the projects on downstream receivers and sensitive receiving environments would be minimal.

Table 7-1 Projects considered in the cumulative impact assessment

Project name	Brief project description	Relevant locations
Approved projects and projects under construction		
M4-M5 Link 2018–2023	The M4-M5 Link project is being delivered in two stages: • M4-M5 Link tunnels – construction of the mainline tunnels between the New M4 at Haberfield and the New M5 at St Peters. This will also include stub tunnels for the Rozelle Interchange • M4-M5 Link Rozelle Interchange – construction of a mostly underground interchange at the Rozelle Rail Yards providing surface connectivity between the New M5 and M4 corridors to Victoria Road, The Crescent, City West Link, Anzac Bridge and the future Western Harbour Tunnel.	Western Harbour Tunnel
Sydney Metro City & Southwest 2017–2024	The Chatswood to Sydenham component of Sydney Metro City & Southwest involves the construction and operation of a 15.5 km metro line from Chatswood, under Sydney Harbour and through Sydney's CBD out to Sydenham. Components of the project relevant to this assessment include: • Crows Nest Station • Victoria Cross Station • Blues Point temporary construction site • Barangaroo Station • White Bay truck marshalling yard.	Western Harbour Tunnel Warringah Freeway Upgrade

Project name	Brief project description	Relevant locations
Proposed projects		
Beaches Link and Gore Hill Freeway Connection 2022–2027	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 as well as upgrade and integration works to connect to the Gore Hill Freeway.	Western Harbour Tunnel Warringah Freeway Upgrade
Sydney Metro West No timeframe information (construction overlap assumed)	The Sydney Metro West will service the key precincts of Greater Parramatta, Sydney Olympic Park, The Bays Precinct and the Sydney CBD. The project is proposed to include: • A new Metro Station in The Bays precinct • A new metro station under an existing suburban station on the T1 Northern Line east of Sydney Olympic Park • At least one Sydney Metro West station under the Sydney CBD, delivering an easy interchange between suburban rail, new light rail and the new metro stations currently under construction	Western Harbour Tunnel
Glebe Island port and concrete batching plant (Hanson Construction Materials Pty Ltd) 2019–2020	This proposal is for the construction and operation of a new aggregate handling and concrete batching facility, with the capacity to produce up to one million cubic metres of concrete per annum.	Western Harbour Tunnel
Glebe Island multi-user facility Proposed No timeframe information (construction overlap assumed)	The proposal is for the construction and operation of a ship off-loading, storage and dispatch facility for bulk construction materials such as sand, aggregates and other dry bulk construction materials. The proposal site is located within land owned by the Port Authority on the eastern side of Glebe Island.	Western Harbour Tunnel

Table 7-2 Summary of potential cumulative impacts

Common receivers	Common downstream sensitive receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
M4-M5 Link						
Whites Creek	Sydney Harbour	Increased water quality pollutants, sediment loads and litter into waterways	Erosion and sediment control measures in accordance with the Blue Book Staging of works Stockpile management Water quality monitoring	Increased water quality pollutants and litter into waterways Impacts on drainage infrastructure Flood impacts due to redirection of overland flows	Drainage upgrades Flood mitigation measures Stormwater quality treatment plant Water quality monitoring	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be minimal
Sydney Metro City & Southwest						
Flat Rock Creek	Middle Harbour Lane Cove River/Sydney Harbour	Increased water quality pollutants, sediment loads and litter into waterways	Erosion and sediment control measures in accordance with the Blue Book Staging of works Stockpile management Water quality monitoring	Increased water quality pollutants and litter into waterways Impacts on drainage infrastructure Flood impacts due to redirection of overland flows	Drainage upgrades Flood mitigation measures Water quality monitoring	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be minimal
Glebe Island concrete batching plant (Hanson Construction Materials Pty Ltd), and Glebe Island multi-user facility						
N/A	Parramatta River/Sydney Harbour	Increased water quality pollutants, sediment loads and litter into stormwater drains and Parramatta River	Staging of works, stockpile management	Increased water quality pollutants, sediment loads and litter into stormwater drains	Staging of works, stockpile management Water quality monitoring	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be minimal

Common receivers	Common downstream sensitive receivers	Potential impacts on common receivers during construction of the project	Construction mitigation measures	Potential impacts on common receivers during operation of the project	Operational mitigation measures	Construction and operation residual impacts
Beaches Link and Gore Hill Freeway Connection						
Quarry Creek Flat Rock Creek Willoughby Creek	Middle Harbour	Increased water quality pollutants, sediment loads and litter into waterways Cumulative treated wastewater discharges into Willoughby Creek. However, cumulative treated wastewater discharges would have negligible impact on the creek geomorphology, water availability and flow Cumulative groundwater drawdown, leading to impacts on base flow of Quarry Creek and Flat Rock Creek	Erosion and sediment control measures in accordance with the Blue Book Staging of works stockpile management Water quality monitoring Construction of wastewater treatment plant	Increased water quality pollutants and litter into waterways Impacts on drainage infrastructure Flood impacts due to redirection of overland flows Cumulative groundwater drawdown, leading to impacts on baseflow of Quarry Creek and Flat Rock Creek	Drainage upgrades Flood mitigation measures Stormwater quality treatment plant Water quality monitoring	Provided controls are implemented, maintained and monitored, the cumulative impacts of the project on downstream receivers and sensitive receiving environments would be minimal Impacts on the base flow of Quarry Creek and Flat Rock Creek would occur as a consequence of groundwater drawdown that occurs due to Beaches Link and Gore Hill Freeway Connection. Contributions by the project to the cumulative groundwater drawdown and baseflow impacts is negligible

8. Monitoring and management measures

Water quality management and mitigation measures would be an integral part during construction activities and when operational. This section provides an overview of these measures.

The key water quality objective is to ensure downstream waterways are protected against potential impacts from surface runoff generated during the construction and operation phase of the project. This is consistent with the Roads and Maritime Code of Practice for Water Management and the ANZG (2018) and ANZECC/ARMCANZ (2000) Guidelines.

Monitoring and management measures are proposed with the objective of minimising any short-term impacts that may be encountered on downstream waterways and sensitive receiving environments. The implementation of these measures will ensure that our water quality objective of the protection of aquatic ecosystems is met and that any changes in water quality result in a neutral or beneficial effect.

8.1 Management of construction phase impacts

The impacts of construction as discussed in Chapter 5 and would generally be mitigated using the procedural, sequencing, physical and monitoring controls as discussed in this section and provided in Table 8-1.

Standard controls and procedures would be implemented during construction activities to manage potential impacts on water quality in creeks and drainage lines within or downstream from the project construction footprint. Water quality during construction would be managed using:

- Procedural controls
- Site management controls
- Physical controls
- Monitoring.

Water quality would be managed within the area bounded by the project, including, but not limited to:

- Construction support sites
- Access and haulage tracks
- Earthworks stockpile and storage areas
- Vegetation stockpile areas
- Wash-down facilities.

Presently, no temporary sediment basins are proposed during construction because:

- Standard erosion and sediment controls would be in place at the Rozelle Rail Yards (WHT1) to complement those already proposed by the M4-M5 Link project
- Soils loss calculations carried out by WSP and Arup (2019a) in accordance with the Blue Book for construction work along the Warringah Freeway (including surface road upgrades, tunnel portals and cut and cover structures) indicated there is no requirement to install sediment basins because the area to be disturbed would not generate soil losses greater than 150 cubic metres annually. This is an acceptable practice as indicated in the Blue Book, provided alternative erosion and sediment controls are adopted in the construction catchment. Depending on final staging arrangements at the Cammeray Golf Course construction support sites (WHT10/WFU8), a basin may be required.

Final environmental controls and monitoring requirements would be determined during construction planning and in accordance with:

- *Managing Urban Stormwater: Soils and Construction*, Volume 1, 4th Edition (known as the Blue Book Volume 1)

- *Managing Urban Stormwater: Main Road Construction*, Volume 2D, NSW DECC (known as the Blue Book Volume 2)
- *Road Design Guideline*, Section 8 Erosion and Sediment (Roads and Traffic Authority, 2003b)
- *Guideline for Construction Water Quality Monitoring* (Roads and Traffic Authority, 2003c)
- *Erosion and Sediment Management Procedure* (Roads and Traffic Authority, 2009)
- Code of Practice for Water Management – Road Development and Management
- QA Specification G38 – Soil and Water Management, Edition 2/Revision 2 (Roads and Maritime Services, 2015).
- Technical Guideline –Temporary stormwater drainage for road construction (Roads and Maritime Services 2011).
- Technical Direction Geotechnology – Geotechnical design and construction requirements for sediment basins (Roads and Maritime, GTC 2016/001)

With due consideration of these mitigation and management measures, there would be minimal adverse surface water impacts. The residual risk to sensitive receiving environments and environmental values identified in Section 4.2 and Section 4.3 is expected be low, provided the proposed mitigation and management measures are implemented, maintained and monitored.

Table 8-1 Summary of environmental management measures for construction

Impact	Environmental management measure	Location
Erosion and sedimentation	Erosion and sediment measures will be implemented at all work sites and surface road upgrades in accordance with the principles and requirements in *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom, 2004), *Managing Urban Stormwater: Volume 2D Main Road Construction* (NSW Department of Environment, Climate Change and Water, 2008) and relevant guidelines, procedures and specifications of Roads and Maritime Services. A soil conservation specialist will be engaged by both Roads and Maritime and the Contractor for the duration of construction of the project to provide advice regarding erosion and sediment control including review of Erosion and Sediment Control Plans (ESCPs).	WHT/WFU
Spills and leakages	Emergency spill procedures will be developed to avoid and manage accidental spillages of fuels, chemicals or fluids during construction.	WHT/WFU
Wastewater discharge	Construction wastewater treatment plants will be designed to treat wastewater generated from tunnel groundwater ingress, rainfall runoff in tunnel portals, heat and dust suppression water and washdown runoff generated during construction. Site-specific trigger values will be developed during construction planning to set the wastewater treatment plant discharge criteria ensuring wastewater will be treated to a level that is representative of background concentrations of a suitable reference site or the ANZG (2018) guidelines.	WHT
Freshwater quality monitoring	A freshwater quality monitoring program for the construction of the project will be developed and implemented, with consideration of the freshwater monitoring being carried out for the M4-M5 Link and Beaches Link and Gore Hill Freeway Connection projects. The program will be developed in consultation with the Environment Protection Authority, Department of Planning, Industry and Environment (Regions, Agriculture and Resources), Department of Planning, Industry and Environment	WHT/WFU

Impact	Environmental management measure	Location
	(Water), and relevant councils. Sampling locations and monitoring methodology will be in accordance with the *Guideline for Construction Water Quality Monitoring* (RTA 2003). Each monitoring/discharge point will have a specific concentration of pollutant that cannot be exceeded at the discharge point. Should any of the site-specific trigger values be exceeded, a management response will be triggered. This response will be documented within the construction freshwater quality monitoring program.	
Local stormwater system capacity	Further design development will confirm the local stormwater system capacity to receive construction wastewater treatment plant inflows. In the event that there is a stormwater infrastructure capacity issue with existing infrastructure, mitigation measures such as storage detention to control water outflow during wet weather events will be implemented within the construction support site.	WHT
Watercourse geomorphology	Construction drainage and discharge outlet infrastructure will direct flows downstream to minimise alterations and erosion of watercourse bed and banks. Energy dissipation and erosion scour protection will be implemented as appropriate. Construction work activities within or next to the watercourses and drainage lines will be minimised as much as feasibly possible to minimise disturbance of sediments in or near the waterway.	WHT/WFU
North Sydney Council stormwater harvesting scheme	Reasonable and feasible opportunities to provide an interim or permanent solution for the relocation of the existing storage dam at Cammeray Golf Course earlier in program will be identified in consultation with North Sydney Council during detailed construction planning. During periods when the storage dam is no longer operational, Roads and Maritime will come to an arrangement with North Sydney Council concerning the period in which the storage dam is no longer operational for the increased demand on other water sources.	WFU

WHT = Western Harbour Tunnel, WFU = Warringah Freeway Upgrade.

8.2 Management of operational phase impacts

Mitigation and management measures for the operational phase of the project are presented in Table 8-2.

Table 8-2 Summary of environmental management measures for operation

Impact	Environmental management measure	Location
Wastewater discharge	The permanent wastewater treatment plant at Rozelle will be designed to treat wastewater generated from tunnel groundwater ingress and rainfall runoff in tunnel portals. The level of treatment provided will consider the characteristics of the receiving environment (Rozelle Bay). Discharge from WWTP during the operation of the project will be required to meet specific discharge criteria as per ANZG (2018) 95% species protection levels; ANZG (2018) 99% protection levels for contaminants that bioaccumulate and the NHMRC (2008) recreational guidelines water quality criteria for iron. These criteria will be defined during the construction planning phase to assist in determining wastewater treatment plant discharge criteria and	WHT

Impact	Environmental management measure	Location
	ensure neutral or beneficial impacts to water quality of Rozelle Bay. Should any of the criteria be exceeded, a management response will be triggered. The management response will be documented within the Water Quality Monitoring Program.	
Operational water quality monitoring	Operational phase monitoring will be carried out in line with the Roads and Maritime *Guideline for Construction Phase Water Quality Monitoring* (RTA 2003) to: a) Assess and manage impacts on the receiving waters as the sites stabilise b) Assist in deciding when the site has stabilised c) Identify water quality conditions after development d) Identify appropriate measures to improve water quality performance. As a minimum, monthly monitoring will be carried out for the first year of operation. Should any of the discharge criteria be exceeded, a management response will be triggered. The management response will be documented within the operational water quality monitoring program.	WHT/WFU
Local stormwater system capacity	The capacity for the local stormwater system to receive operational wastewater treatment plant inflows will be confirmed during further design development. In the event that there is a stormwater infrastructure capacity issue with existing infrastructure, mitigation measures such as storage detention to control water outflow during wet weather events will be implemented at the Rozelle Rail Yards.	WHT

WHT = Western Harbour Tunnel, WFU = Warringah Freeway Upgrade.

With due consideration of these proposed management measures to be implemented as part of the project operation, there would be minimal adverse cumulative surface water impacts anticipated. The residual risk to sensitive receiving environments and environmental values are identified in Section 4.3.

9. References

ANZECC/ARMCANZ (2000), *National Water Quality Management Strategy Australian and New Zealand Guidelines for Fresh and Marine Water Quality.* Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

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Appendix A. Water quality monitoring results

Table A-1 Site 1a – Whites Creek Upstream (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ(2000) estuarine guidelines)

Parameter	Units	Guideline criteria^	Whites Creek upstream monitoring – estuarine					
		ANZG (2018), ANZECC/ARMCANZ (2000)	31 Oct 2017 (dry)	21 Nov 2017 (dry)	14 Dec 2017 (dry)	9 Jan 2018 (wet)	18 Jan 2018 (dry)	2 Feb 2018 (dry)
Dissolved oxygen	% sat	80–110	35.6	97.6	131.5	99.5	90.2	39.3
Electrical conductivity	µS/cm	n/a	4534	4370	3590	1660	495	38650
pH	pH units	7–8.5	7.51	9.16	9.02	7.91	9.37	7.51
Turbidity	NTU	0.5–10	2.9	6.8	15	17.9	5	9.4
Total suspended solids	mg/L	NG	6	22	<5	18	9	25
Arsenic	mg/L	NG	<0.001	<0.001	<0.001	0.003	Not analysed	Not analysed
Cadmium	mg/L	0.0007	0.0001	0.0002	<0.0001	0.0002	Not analysed	Not analysed
Chromium	mg/L	0.0044	<0.001	<0.001	<0.001	0.001	Not analysed	Not analysed
Copper	mg/L	0.0013	0.007	0.019	0.015	0.02	Not analysed	Not analysed
Lead	mg/L	0.0044	0.001	0.014	0.014	0.005	Not analysed	Not analysed
Manganese	mg/L	NG	0.025	0.038	0.02	0.026	Not analysed	Not analysed
Nickel	mg/L	0.007	0.002	0.002	0.002	0.001	Not analysed	Not analysed
Zinc	mg/L	0.015	0.09	0.276	0.127	0.154	Not analysed	Not analysed
Iron	mg/L	0.3	0.25	0.78	0.86	0.32	Not analysed	Not analysed
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	Not analysed	Not analysed
Oxidised nitrogen	mg/L	0.015	0.31	1.12	0.81	1.43	<0.01	0.18
Total Kjeldahl nitrogen	mg/L	NG	<0.5	1.1	2.6	0.8	0.5	0.9
Total nitrogen	mg/L	0.3	<0.5	2.2	3.4	2.2	0.5	1.1
Total phosphorus	mg/L	0.03	<0.05	0.14	0.33	0.11	0.04	0.12
Chlorophyll-*a*	mg/L	4	1	22	5	<1	2	3

^ ANZG (2018) recommend marine toxicant trigger values be applied to estuarine ecosystems

Table A-2 Site 1b – Whites Creek downstream (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ (2000) estuarine guidelines)

Parameter	Units	Guideline criteria^	Whites Creek downstream monitoring – estuarine					
		ANZG (2018), ANZECC/ARMCANZ (2000)	31 Oct 2017 (dry)	21 Nov 2017 (dry)	14 Dec 2017 (dry)	9 Jan 2018 (wet)	18 Jan 2018 (dry)	2 Feb 2018 (dry)
Dissolved oxygen	% sat	80–110	57.3	40.1	104.6	91.3	15.5	30.1
Electrical conductivity	µS/cm	n/a	2928	44507	10234	8150	51733	47180
pH	pH units	7–8.5	7.43	7.62	7.82	6.88	7.26	7.22
Turbidity	NTU	0.5–10	2.6	6.9	5.3	16.3	7.2	27.1
Total suspended solids	mg/L	NG	8	15	8	19	14	14
Arsenic	mg/L	NG	<0.010	0.001	<0.001	0.002	Not analysed	Not analysed
Cadmium	mg/L	0.0007	<0.0010	<0.0001	<0.0001	<0.0001	Not analysed	Not analysed
Chromium	mg/L	0.001	<0.010	<0.001	<0.001	0.001	Not analysed	Not analysed
Copper	mg/L	0.0013	<0.010	0.021	0.009	0.016	Not analysed	Not analysed
Lead	mg/L	0.0044	<0.010	0.012	0.002	0.009	Not analysed	Not analysed
Manganese	mg/L	NG	<0.010	0.023	0.009	0.019	Not analysed	Not analysed
Nickel	mg/L	0.007	<0.010	<0.001	<0.001	0.002	Not analysed	Not analysed
Zinc	mg/L	0.015	<0.052	0.146	0.043	0.132	Not analysed	Not analysed
Iron	mg/L	0.3	<0.50	0.52	0.35	0.31	Not analysed	Not analysed
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	Not analysed	Not analysed
Oxidised nitrogen	mg/L	0.015	0.12	3.58	0.58	1.54	0.07	0.29
Total Kjeldahl nitrogen	mg/L	NG	<0.5	0.6	1.4	0.8	<0.5	0.6
Total nitrogen	mg/L	0.3	<0.5	4.2	2	2.3	<0.5	0.9
Total phosphorus	mg/L	0.03	<0.05	0.12	0.19	0.13	<0.5	0.18
Chlorophyll-*a*	mg/L	4	1	4	1	<1	1	2

^ ANZG (2018) recommend marine toxicant trigger values be applied to estuarine ecosystems

Table A-3 Site 2b – Willoughby Creek Downstream (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ (2000) lowland river guidelines)

Parameter	Units	Guideline criteria	Willoughby Creek downstream monitoring – lowland river					
		ANZG (2018), ANZECC/ARMCANZ (2000)	31 Oct 2017 (dry)	21 Nov 2017 (dry)	14 Dec 2017 (dry)	9 Jan 2018 (wet)	18 Jan 2018 (dry)	1 Feb 2018 (dry)
Dissolved oxygen	% sat	85–110	73	62.6	84.7	103.6	75	84.4
Electrical conductivity	µS/cm	125–2220	399	248	443	198	277	282
pH	pH units	6.5–8	7.71	8.14	7.59	7.63	8.35	8.67
Turbidity	NTU	6-50	2.2	3.5	6.43	14.8	12	13.83
Total suspended solids	mg/L	NG	6	8	<5	12	10	6
Arsenic	mg/L	0.013	0.001	0.001	<0.001	0.001	Not analysed	Not analysed
Cadmium	mg/L	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	Not analysed	Not analysed
Chromium	mg/L	0.001	<0.001	<0.001	<0.001	0.003	Not analysed	Not analysed
Copper	mg/L	0.0014	0.006	0.013	0.014	0.016	Not analysed	Not analysed
Lead	mg/L	0.0034	<0.001	0.002	0.003	0.006	Not analysed	Not analysed
Manganese	mg/L	1.9	0.004	0.008	0.019	0.011	Not analysed	Not analysed
Nickel	mg/L	0.011	0.002	<0.001	0.017	<0.001	Not analysed	Not analysed
Zinc	mg/L	0.008	0.031	0.049	0.148	0.075	Not analysed	Not analysed
Iron	mg/L	0.3	0.21	0.24	0.8	0.36	Not analysed	Not analysed
Mercury	mg/L	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	Not analysed	Not analysed
Oxidised nitrogen	mg/L	0.04	2.76	1.18	3.18	5.04	0.87	1
Total Kjeldahl nitrogen	mg/L	NG	0.5	0.4	1	1.5	0.5	0.4
Total nitrogen	mg/L	0.35	3.3	1.6	4.2	6.5	1.4	1.4
Total phosphorus	mg/L	0.025	0.13	0.14	0.27	0.14	0.1	0.11
Chlorophyll-*a*	mg/L	3	<1	1	<1	<1	<1	1

Table A-4 Site 4b – Quarry Creek (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ (2000) lowland river guidelines)

Parameter	Units	Guideline criteria	Quarry Creek monitoring – lowland river					
		ANZG (2018), ANZECC/ARMCANZ (2000)	31 Oct 2017 (dry)	21 Nov 2017 (dry)	14 Dec 2017 (dry)	9 Jan 2018 (wet)	18 Jan 2018 (dry)	1 Feb 2018 (dry)
Dissolved oxygen	% sat	85–110	NOT SAMPLED	74.6	82.4	NOT SAMPLED	86	92.7
Electrical conductivity	µS/cm	125–2220		399	338		312	232
pH	pH units	6.5–8		8.55	7.6		7.91	8.03
Turbidity	NTU	6–50		79.9	9.5		3.5	3.9
Total suspended solids	mg/L	NG		113	11		8	10
Arsenic	mg/L	0.013		0.001	<0.001		<0.001	<0.001
Cadmium	mg/L	0.0002		<0.0001	<0.0001		<0.0001	<0.0001
Chromium	mg/L	0.001		0.006	<0.001		<0.001	0.001
Copper	mg/L	0.0014		0.026	0.003		0.004	0.014
Lead	mg/L	0.0034		0.002	<0.001		<0.001	0.006
Manganese	mg/L	1.9		0.085	0.009		0.003	0.025
Nickel	mg/L	0.011		0.004	<0.001		<0.001	0.002
Zinc	mg/L	0.008		0.041	0.03		0.062	0.104
Iron	mg/L	0.3		1.94	0.16		0.11	0.78
Mercury	mg/L	0.00006		<0.0001	<0.0001		<0.0001	<0.0001
Oxidised nitrogen	mg/L	0.04		0.81	0.97		0.97	0.98
Total Kjeldahl nitrogen	mg/L	NG		1	0.9		0.5	0.4
Total nitrogen	mg/L	0.35		1.8	1.9		1.5	1.4
Total phosphorus	mg/L	0.025		0.21	0.14		0.16	0.06
Chlorophyll-*a*	mg/L	3		<1	<1		<1	<1

Table A-5 Site 5a – Flat Rock Creek upstream (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ lowland river guidelines)

Parameter	Units	Guideline criteria	Flat Rock Creek upstream monitoring – lowland river					
		ANZG (2018), ANZECC/ARMCANZ (2000)	31 Oct 2017 (dry)	21 Nov 2017 (dry)	14 Dec 2017 (dry)	9 Jan 2018 (wet)	18 Jan 2018 (dry)	1 Feb 2018 (dry)
Dissolved Oxygen	% sat	85–110	53.85	93.2	85.2	99.47	91	98.4
Electrical Conductivity	µS/cm	125–2220	509	333	397	163	342	314
pH	pH units	6.5–8	9.03	9.37	8.28	7.31	8.5	8.22
Turbidity	NTU	6-50	3.72	2.71	5.06	18.97	4.53	7.34
Total Suspended	mg/L	NG	10	11	<5	16	14	7
Arsenic	mg/L	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	0.001	0.008	<0.001	0.001	<0.001	0.001
Copper	mg/L	0.0014	0.006	0.007	0.004	0.01	0.002	0.004
Lead	mg/L	0.0034	0.002	<0.001	<0.001	0.002	0.001	<0.001
Manganese	mg/L	1.9	0.02	0.012	0.02	0.035	0.013	0.049
Nickel	mg/L	0.011	0.002	<0.001	0.003	<0.001	0.001	0.002
Zinc	mg/L	0.008	0.036	0.01	0.074	0.08	0.034	0.02
Iron	mg/L	0.3	0.53	0.25	0.36	0.78	0.18	0.75
Mercury	mg/L	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Oxidised nitrogen	mg/L	0.04	2.04	5.62	9.75	3.03	1.05	1.39
Total Kjeldahl nitrogen	mg/L	NG	4.2	1.8	2.6	1	0.6	1.6
Total nitrogen	mg/L	0.35	6.2	7.4	12.4	4	1.6	3
Total phosphorus	mg/L	0.025	0.05	0.04	0.07	0.07	0.03	0.06
Chlorophyll-*a*	mg/L	3	<1	<1	11	4	2	<1

Table A-6 Site 5b – Flat Rock Creek downstream 1 (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ (2000) lowland river guidelines)

Parameter	Units	Guideline criteria	Flat Rock Creek downstream 1 monitoring – lowland river					
		ANZG (2018), ANZECC/ARMCANZ (2000)	31 Oct 2017 (dry)	21 Nov 2017 (dry)	14 Dec 2017 (dry)	9 Jan 2018 (wet)	18 Jan 2018 (dry)	1 Feb 2018 (dry)
Dissolved oxygen	% sat	85–110	92.9	77.3	65.5	67.1	85.3	24.3
Electrical conductivity	µS/cm	125–2220	412	348	436	573	456	27850
pH	pH units	6.5–8	8	7.79	7.21	7.33	7.82	7.01
Turbidity	NTU	6-50	7.3	8.3	11.7	27.4	4	3.91
Total suspended solids	mg/L	NG	11	8	<5	18	8	<5
Arsenic	mg/L	0.013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cadmium	mg/L	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	<0.001	0.003	<0.001	0.001	<0.001	<0.001
Copper	mg/L	0.0014	0.008	0.004	0.008	0.015	0.004	0.008
Lead	mg/L	0.0034	<0.001	<0.001	<0.001	0.005	<0.001	0.002
Manganese	mg/L	1.9	0.008	0.013	0.016	0.039	0.007	0.049
Nickel	mg/L	0.011	0.002	0.002	0.001	0.001	<0.001	0.002
Zinc	mg/L	0.008	0.024	0.022	0.064	0.102	0.023	0.149
Iron	mg/L	0.3	0.77	0.64	1.11	0.67	0.54	0.49
Mercury	mg/L	0.00006	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Oxidised nitrogen	mg/L	0.04	2.85	2.32	4.69	2.32	2.8	3.68
Total Kjeldahl nitrogen	mg/L	NG	1.3	1.1	1.1	1.8	1	<0.2
Total nitrogen	mg/L	0.35	4.2	3.4	5.8	4.1	3.8	3.7
Total phosphorus	mg/L	0.025	0.04	0.04	0.04	0.18	0.08	<0.02
Chlorophyll-*a*	mg/L	3	<1	<1	<1	2	1	5

Table A-7 Site 5c – Flat Rock Creek downstream 2 (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ (2000) estuarine guidelines)

Parameter	Units	Guideline criteria^	Flat Rock Creek downstream 2 monitoring – estuarine					
		ANZG (2018), ANZECC/ARMCANZ (2000)	31 Oct 2017 (dry)	21 Nov 2017 (dry)	14 Dec 2017 (dry)	9 Jan 2018 (wet)	18 Jan 2018 (dry)	1 Feb 2018 (dry)
Dissolved oxygen	% sat	80–110	19.3	21.5	24.5	74.7	36.7	28.2
Electrical conductivity	uS/cm	n/a	3211	324	7533	383	27977	41330
pH	pH units	7–8.5	7.15	7.61	7.17	7.46	7.16	7.16
Turbidity	NTU	0.5–10	5.6	16.9	7	30.7	9.1	4.3
Total suspended solids	mg/L	NG	8	11	<5	20	16	<5
Arsenic	mg/L	NG	<0.001	<0.001	<0.001	<0.001	0.001	0.001
Cadmium	mg/L	0.0007	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	mg/L	0.001	<0.001	<0.001	0.001	0.002	<0.001	<0.001
Copper	mg/L	0.0013	0.005	0.017	0.006	0.02	0.005	0.006
Lead	mg/L	0.0044	<0.001	0.005	0.004	0.006	0.002	0.001
Manganese	mg/L	NG	0.045	0.052	0.016	0.032	0.044	0.062
Nickel	mg/L	0.007	0.002	0.001	<0.001	0.002	0.001	0.001
Zinc	mg/L	0.015	0.028	0.067	0.054	0.12	0.044	0.097
Iron	mg/L	0.3	0.76	0.9	0.76	0.59	0.52	0.39
Mercury	mg/L	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Oxidised nitrogen	mg/L	0.015	2.9	0.27	2.73	2.12	1.35	1.68
Total Kjeldahl nitrogen	mg/L	NG	0.7	0.7	0.8	2	1.4	<0.5
Total nitrogen	mg/L	0.3	3.6	1	3.5	4.1	2.8	1.7
Total phosphorus	mg/L	0.03	0.04	0.16	0.05	0.23	0.54	<0.05
Chlorophyll-*a*	mg/L	4	<1	<1	1	<1	1	6

^ ANZG (2018) recommend marine toxicant trigger values be applied to estuarine ecosystems

Appendix B. Groundwater quality monitoring results

Groundwater quality monitoring results

The following table presents the results of boreholes located in the Cammeray Golf Course construction wastewater treatment plant catchment, which would discharge into Willoughby Creek via the local stormwater system.

Table B-1 Median groundwater results (Cells shaded in grey denote an exceedance of the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines

Chem Group	Indicator	Units	Median	ANZG (2018), ANZECC/ARMCANZ (2000)
Lead	Lead (Filtered)	mg/L	0.0005	0.0034
Major Anions	Alkalinity (Hydroxide) as $CaCO_3$	mg/L	0.5	No guideline
	Alkalinity (total) as $CaCO_3$	mg/L	85	No guideline
	Anions Total	mEq/L	3.6	No guideline
	Chloride	mg/L	49	No guideline
Major Cations	Calcium (Filtered)	mg/L	24	No guideline
	Cations Total	mEq/L	3.69	No guideline
	Magnesium (Filtered)	mg/L	5	No guideline
	Potassium (Filtered)	mg/L	4	No guideline
	Sodium (Filtered)	mg/L	30	No guideline
PAHs	Acenaphthene	µg/L	0.5	No guideline
	Acenaphthylene	µg/L	0.5	No guideline
	Anthracene	µg/L	0.5	0.01
	Benz(a)anthracene	µg/L	0.5	No guideline
	Benzo(a)pyrene	µg/L	0.25	0.1
	Be+O30+B22	µg/L	0.5	No guideline
	Benzo(k)fluoranthene	µg/L	0.5	No guideline
	Benzo[b+j]fluoranthene	mg/L	0.0005	No guideline
	Chrysene	µg/L	0.5	No guideline
	Dibenz(a,h)anthracene	µg/L	0.5	No guideline
	Fluoranthene	µg/L	0.5	1
	Fluorene	µg/L	0.5	No guideline
	Indeno(1,2,3-c,d)pyrene	µg/L	0.5	No guideline
	Naphthalene	µg/L	0.5	16
	Polycyclic aromatic hydrocarbons	µg/L	0.25	No guideline
	Phenanthrene	µg/L	0.5	0.6
	Pyrene	µg/L	0.5	No guideline
TRH	TRH C10-C16 (F2)	µg/L	50	No guideline
	TRH >C16-C34	µg/L	50	No guideline
	TRH >C34-C40	µg/L	50	No guideline
	TRH >C10-C16 less Naphthalene (F2)	mg/L	0.05	No guideline
	TRH >C10-C40 (Sum of total)	µg/L	120	No guideline

Chem Group	Indicator	Units	Median	ANZG (2018), ANZECC/ARMCANZ (2000)
	TRH C6-C10 less BTEX (F1)	mg/L	0.01	No guideline
	TRH C6-C10 (F1)	µg/L	10	No guideline
BTEX	Benzene	mg/L	0.0005	950
	Ethylbenzene	mg/L	0.001	80
	Toluene	mg/L	0.001	180
	Total BTEX	µg/L	0.5	No guideline
	Xylene (m & p)	µg/L	1	No guideline
	Xylene (o)	µg/L	1	350
	Xylene Total	µg/L	1	No guideline
Inorganics	Ammonia as N	µg/L	160	20
	Alkalinity (Bicarbonate as $CaCO_3$)	mg/L	48	No guideline
	Carbonate Alkalinity as $CaCO_3$	mg/L	2.5	No guideline
	Fluoride	mg/L	0.05	No guideline
	Ionic Balance	%	3.975	No guideline
	Total Kjeldahl nitrogen	mg/L	4.85	No guideline
	Nitrates, expressed as N	mg/L	0.02	No guideline
	Nitrite (as N)	mg/L	0.005	No guideline
	Nitrogen (Total Oxidised)	mg/L	0.013	0.04
	Nitrogen (Total)	mg/L	1.8	0.35
	Phosphorus (Total)	mg/L	0.52	0.025
	Reactive Phosphorus as P	mg/L	0.005	0.02
	TDS	mg/L	242	No guideline
Metals	Arsenic (Filtered)	mg/L	0.0005	0.013
	Barium (Filtered)	mg/L	0.044	No guideline
	Boron (Filtered)	mg/L	0.085	0.37
	Cadmium (Filtered)	mg/L	0.00005	0.0002
	Chromium (III+VI) (Filtered)	mg/L	0.0005	0.001
	Cobalt (Filtered)	mg/L	0.0005	0.0014
	Copper* (Filtered)	mg/L	0.002	0.0014
	Iron (Filtered)	mg/L	1.365	0.3
	Manganese (Filtered)	mg/L	0.1745	1.9
	Mercury (except as provided in item 13) (Filtered)	mg/L	0.00005	0.00006
	Nickel* (Filtered)	mg/L	0.001	0.011
	Zinc* (Filtered)	mg/L	0.008	0.008
TPH	C10–C36 (Sum of total)	µg/L	142.5	No guideline
	Fuel (C6–C9 fractions)	mg/L	0.01	No guideline
	TPH C10–C14	µg/L	25	No guideline
	TPH C15–C28	µg/L	50	No guideline
	TPH C29–C36	µg/L	25	No guideline

RMS 19.1441
ISBN 978-1-922338-08-2