Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Appendix F (Part 2) – Further information on biodiversity matters

October 2021

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Appendix F5 – Updated biodiversity assessment

October 2021

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Updated biodiversity assessment

October 2021

Prepared for

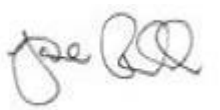
Transport for NSW

Prepared by

Arcadis

Certification under Section 6.15 of the *Biodiversity Conservation Act 2016*

As an accredited person (BAAS 17030) I certify that this report has been prepared on the basis of the requirements of (and information provided under) the Biodiversity Assessment Method as at 22 October 2021 and that this date is within 14 days of the date the report is so submitted.



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Executive summary

The *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) was prepared to support the environmental impact statement for the Beaches Link and Gore Hill Freeway Connection project (the project). The Biodiversity development assessment report was prepared in accordance with the Biodiversity Assessment Method (BAM) (2017 version) (OEH, 2017), as required by the *Biodiversity Conservation Act 2016* (BC Act) Division 2 Section 7.9 (2), and to meet the Secretary's environmental assessment requirements. The report is provided as Appendix S (Technical working paper: Biodiversity development assessment report) of the environmental impact statement and was certified by an accredited person under Section 6.15 of the BC Act.

The environmental impact statement for the project was placed on public exhibition between 9 December 2020 and 1 March 2021. Following exhibition of the environmental impact statement, Transport for NSW has prepared a submissions report to respond to issues raised by the community, interested parties and key stakeholders (including government agencies and councils). In addition to the submissions report, Transport for NSW has also prepared a preferred infrastructure report providing further assessment and information on some key issues. The environmental impact statement, submissions report and preferred infrastructure report are available on the Department of Planning, Industry and Environment website www.planningportal.nsw.gov.au/majorprojects/project/10456.

This updated biodiversity assessment has been prepared to synthesise the updated and supplementary information provided in the submissions report, with *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a). This updated biodiversity assessment has been prepared in accordance with the BAM (OEH, 2017), as required by the BC Act Division 2 Section 7.9 (2) and reflected in the Secretary's environmental assessment requirements issued by the Secretary of the Department of Planning, Industry and Environment, to satisfy the requirements of a Biodiversity development assessment report. This updated biodiversity assessment has been certified by an accredited person under Section 6.15 of the BC Act.

For impacts on biodiversity values that cannot be addressed by the BAM, ie issues related to marine and freshwater biodiversity, separate marine and freshwater ecology impact assessments have been prepared to meet the requirements of the Secretary's environmental assessment requirements, relevant Department of Primary Industries (Fisheries) guidelines and policies and *Aquatic Ecology in Environmental Impact Assessment – EIA Guideline Series* (Lincoln Smith, 2003).

The preparation of this updated biodiversity assessment has been informed by database searches, desktop review of relevant reports and spatial information, site inspections and targeted field surveys. The majority of the field surveys were carried out within the subject land between May 2016 and March 2020. Additional targeted surveys and site inspections were carried out in June and July 2021.

The land in which biodiversity values have been assessed by this updated biodiversity assessment is known as the subject land. The subject land comprises the construction (temporary) footprint and permanent (operational) footprint being considered by the environmental impact statement.

The southern parts of the subject land are located in urbanised areas and have a long history of modification and disturbance. Much of the vegetation within the subject land consists of trees and shrubs in landscaped parks and reserves, private residential gardens, road verges and native revegetation; this vegetation, which does not conform to any Plant Community Type (PCT), covers 6.80 hectares.

Native vegetation occurs in the northern parts of the subject land on either side of the Wakehurst Parkway (Killarney Heights to Frenchs Forest) and to a lesser extent, next to the Burnt Bridge Creek Deviation (Balgowlah), with smaller fragmented patches in other areas of the subject land. Six PCTs, covering 14.88 hectares, were identified in the subject land. Of these PCTs, one (PCT

1786) corresponds to a threatened ecological community (TEC): Duffys Forest Ecological Community in the Sydney Basin Bioregion. Duffys Forest Ecological Community is listed as Endangered under the BC Act and was recorded along the Wakehurst Parkway from Seaforth Oval north to Warringah Road.

The BAM credit calculator identified 43 candidate threatened flora species credit species associated with the PCTs identified in the subject land. Of these, 19 threatened flora species were considered to have a moderate to high likelihood of occurrence or were recorded in the subject land.

Two threatened flora species listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and/or BC Act were recorded within the subject land: *Callistemon linearifolius* (Netted Bottle Brush) and *Syzygium paniculatum* (Magenta Lilly Pilly). Three other threatened flora species, *Acacia terminalis* subsp. *terminalis, Epacris purpurascens var. purpurascens* and *Tetratheca glandulosa*, were recorded outside but near the subject land. *Callistemon linearifolius* and all but one individual of *Syzygium paniculatum* were recorded in landscaped areas. These planted individuals are not considered to be of conservation significance and were not assessed further under the BAM.

The credit calculator identified 37 candidate threatened fauna ecosystem credit species and 36 candidate threatened fauna species credit species. Of these, seven threatened fauna species listed under the EPBC Act and/or BC Act were recorded in the subject land or immediately adjacent during surveys carried out for the project: Powerful Owl (*Ninox strenu*a), Rosenberg's Goanna (*Varanus rosenbergi*), Eastern Pygmy-possum (*Cercartetus nanus*), Little Bent-winged Bat (*Miniopterus australis*), Large Bent-winged Bat (*Miniopterus orianae oceanensis*), Large-eared Pied Bat (*Chalinolobus dwyeri*) and Grey-headed Flying-fox (*Pteropus poliocephalus*).

A Grey-headed Flying-fox camp has been identified at a location in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the subject land. Database searches identified recordings of Eastern Pygmy-possum (*Cercartetus nanus*) and Large-eared Pied-bat (*Chalinolobus dwyeri*) on the Wakehurst Parkway east construction support site (BL13) in 2018. Red-crowned Toadlet (*Pseudophryne australis*) was assumed to be present based on recent records of the species in the northern extent of the subject land. An additional five threatened fauna species were considered to have a high likelihood of occurrence in the subject land: Glossy Black-cockatoo (*Calyptorhynchus lathami*), White-bellied Sea-Eagle (*Haliaeetus leucogaster*), Varied Sittella (*Daphoenositta chrysoptera*), Little Penguin (*Eudyptula minor*) and Eastern Coastal Free-tailed Bat (*Micronomus norfolkensis*). Two threatened fauna species, Southern Brown Bandicoot (*Isoodon obesulus obesulus*) and Southern Myotis (*Myotis macropus*), are considered likely to occur in areas next to the subject land.

Where feasible, the design of the project within the preferred corridor has been refined to avoid or minimise impacts on biodiversity. Where possible, the project design and construction methodology has been developed to avoid and minimise adverse impacts on biodiversity. This includes a number of fauna connectivity structures that would span the Wakehurst Parkway and provide for the movement of fauna species between habitat on the eastern and western side of the widened road. Some impacts however are unavoidable, and direct impacts of the project on biodiversity include:

- Removal of 13.98 hectares of native PCTs, of which 1.21 hectares is Duffys Forest Ecological Community in the Sydney Basin Bioregion, listed as Endangered under the BC Act
- Removal of 6.80 hectares of other vegetation, including 1.29 hectares of native revegetation and 5.51 hectares of non-PCT vegetation comprising native and exotic plantings
- Removal of one individual threatened plant, *Syzygium paniculatum*
- Removal of planted individuals of non-local threatened flora species
- Removal of 20.52 hectares of potential habitat for threatened fauna species, of which 6.54 hectares comprises planted non-PCT vegetation that generally occurs in parks, road verges and private residential gardens
- Mortality/injury of terrestrial fauna species would occur, with potential mortality/injury of threatened fauna species. Pre-clearing procedures would minimise this occurrence.

The indirect impacts of the project on biodiversity include:

- Edge effects on native vegetation and habitat that will be retained within or next to the subject land, particularly adjoining the Wakehurst Parkway
- Invasion and spread of weeds, pathogens and disease
- Noise and vibration impacts during construction, including on the Grey-headed Flying-fox camp located in the vegetated area between Balgowlah Road and the Burnt Bridge Creek Deviation, about 120 metres from the surface road works at Balgowlah, fauna in the vicinity of the Wakehurst Parkway during excavation activities and Little Penguin that may occur in Middle Harbour on occasion.

Prescribed biodiversity impacts in the BAM that are relevant to the project are:

- Impacts of development on the habitat of threatened species or ecological communities associated with non-native vegetation – the consequence of removing a small area of potential foraging resources for the local and bioregional persistence of threatened species is considered negligible
- Impacts of development on the habitat of threatened species or ecological communities associated with human made structures – construction of the project may directly and indirectly affect roosting habitat for threatened microbats that are known or considered likely to roost in human made structures within the subject land, including bridges and culverts
- Impacts of the development on habitat of threatened species or ecological communities associated with rocks – construction of the project would require the removal of rocky features alongside the Wakehurst Parkway resulting in the loss of potential habitat for some threatened species such as Red-crowned Toadlet, Rosenberg's Goanna and Large-eared Pied Bat
- Impacts of development on habitat connectivity, the movement of threatened species and vehicle strike– the realignment and upgrade of the Wakehurst Parkway would increase habitat fragmentation (ie would widen an existing gap in otherwise contiguous fauna habitat), which could create a further barrier to fauna movement between habitat to the east and west of the Wakehurst Parkway
- Impacts of development on water quality, water bodies and hydrological processes that sustain threatened species and TECs – construction activities may result in a potential decrease in water quality and degradation of freshwater, marine and intertidal habitats, which could adversely impact foraging habitat for threatened species that may use the habitats, such as Red-crowned Toadlet, Little Penguin and White-bellied Sea-Eagle.

Biodiversity management measures that would be implemented in accordance with Transport for NSW's *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011) would include:

- Implementing biodiversity awareness training during construction
- Minimising vegetation and habitat removal, managing risks to flora and fauna beyond the limit of clearing and avoiding clearing during threatened species breeding seasons where feasible and reasonable
- Managing weed and pest species and pathogens
- Minimising shading and artificial light impacts
- Minimising noise impacts to the Grey-headed Flying-fox camp, and monitoring the camp during the breeding season
- Employing a spotter to watch/hear for Little Penguins during marine construction activities, with a stop-work procedure to be implemented in the event of the species being detected close to works
- Completing pre-clearing surveys of built structures to be demolished, including bridges and culverts that have potential for microbat roosts
- Completing pre-clearance surveys of native vegetation, including inspecting hollows and dead timber for Eastern Pygmy-possum

- Development of active-specific management controls to manage impacts from high noise and vibration generating activities (eg controlled blasting and rock hammering) on Large-eared Pied Bat along the Wakehurst Parkway
- Management of noise and vibration-intensive works along the Wakehurst Parkway to reduce potential impacts to fauna
- Fauna connectivity measures and fauna fencing taking into account best available knowledge to facilitate fauna crossings at Wakehurst Parkway and prevent roadkill. Monitoring to be carried out during pre-construction, construction and post-construction phases of the project to determine the effectiveness of the fauna connectivity measures and fauna fencing.

As the project would require the removal of native vegetation and potential fauna habitat from the subject land, Transport for NSW are required to offset these impacts on biodiversity. The offsets required for the project were calculated using the BAM Calculator. A total of 383 ecosystem credits and 1081 species credits are required to offset the direct impacts of the project. An additional 45 ecosystem credits may be required to offset indirect impacts; these would be in addition to BAM credit obligations and are at the discretion of the Minister for Planning and Public Spaces.

The project would potentially impact about 15 metres of Burnt Bridge Creek which for the purposes of considering offsets under the *Policy and guidelines for fish habitat conservation and management* (NSW DPI, 2013), has been conservatively assigned as Type 2 Key Fish Habitat. Assuming an average bed width of about four metres in the affected area, this would equate to about 60 square metres of Type 2 Key Fish Habitat. According to the *Policy and guidelines for fish habitat conservation and management* (NSW DPI, 2013) this would equate to an offset requirement of about $6900. Final offset calculations will be carried out following further design development and in consideration of further detailed site investigations carried out since the exhibition of the environmental impact statement.

Glossary of terms and abbreviations

Terms

Term	Meaning
Accredited person	A person accredited under the *Biodiversity Conservation Act 2016* (NSW) (BC Act) to prepare a Biodiversity development assessment report in accordance with the BAM (Office of Environment and Heritage (OEH) 2017a). Referred to in the BAM as 'assessor' (OEH, 2017a).
Areas of geological significance	Geological features such as karst, caves, crevices, cliffs.
Assessment area	The area of land in the 1500 metre buffer zone surrounding the outside edge of the boundary of the subject land or 500 metre along each side of the centre line of a linear shaped development, to be determined in accordance with Subsection 4.3.2 of the BAM.
Assessor	The person accredited under the BC Act referred to in Subsection 2.1.2 of the BAM and who has been engaged by the proponent.
Avoid	Measures taken by a proponent such as careful site selection or actions taken through the design, planning, construction and operational phases of the development to completely avoid impacts on biodiversity values, or certain areas of biodiversity. Refer to the BAM for operational guidance.
Biodiversity Assessment Method (BAM)	The assessment manual that outlines how an accredited person assesses impacts on biodiversity at development sites. 2017 version used in for this report.
Benchmarks	The quantitative measures that represent the 'best-attainable' condition, which acknowledges that native vegetation within the contemporary landscape has been subject to both natural and human-induced disturbance. Benchmarks are defined for specified variables for each PCT. Vegetation with relatively little evidence of modification generally has minimal timber harvesting (few stumps, coppicing, cut logs), minimal firewood collection, minimal exotic weed cover, minimal grazing and trampling by introduced or overabundant native herbivores, minimal soil disturbance, minimal canopy dieback, no evidence of recent fire or flood, is not subject to high frequency burning, and has evidence of recruitment of native species.
Biodiversity certification	Has the same meaning as in the BC Act (OEH, 2017a).
Biodiversity credit report	The report produced by the Credit Calculator that sets out the number and class of biodiversity credits required to offset the remaining adverse impacts on biodiversity values at a development site, or on land to be biodiversity certified, or that sets out the number and class of biodiversity credits that are created at a biodiversity stewardship site (OEH, 2017a).
Biodiversity offsets	Management actions that are carried out to achieve a gain in biodiversity values on areas of land in order to compensate for losses to biodiversity values from the impacts of development (OEH, 2017a).
Biodiversity stewardship site	Has the same meaning as in the BC Act (OEH, 2017a).
Biodiversity values	Has the same meaning as Clause 1.5(2) of the BC Act (OEH, 2017a).

Term	Meaning
BioNet Atlas	The Department of Planning, Industry and the Environment (Environment, Energy and Science (DPIE (EES)) database of flora and fauna records (formerly known as the NSW Wildlife Atlas). The Atlas contains records of plants, mammals, birds, reptiles, amphibians, some fungi, some invertebrates (such as insects and snails listed under the BC Act) and some fish (OEH, 2017a).
Credit calculator	The computer program that provides decision support to assessors and proponents by applying the BAM, in particular by using the data required to be entered and the equations in Appendix 6 and Appendix 9 of the BAM to calculate the number and class of biodiversity credits required to offset the impacts of a development or created at a biodiversity stewardship site (OEH, 2017a).
Critically Endangered Ecological Community	An ecological community specified as critically endangered in Schedule 2 of the BC Act and/or listed under Part 13, Division 1, Subdivision A of the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) (OEH, 2017a).
Cumulative impact	The impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time. Refer to the project Secretary's environmental assessment requirements for cumulative impact assessment requirements.
Development site	An area of land that is subject to a proposed development that is under the *Environmental Planning and Assessment Act 1979* (NSW). The term development site is also taken to include clearing site except where the reference is to a small area development or a major project development (OEH, 2017a).
Development footprint	The area of land that is directly affected on by a proposed development, including access roads, and areas used to store construction materials. The term development footprint is also taken to include clearing footprint except where the reference is to a small area development or a major project development (OEH, 2017a). The term 'development footprint' is analogous with the term 'subject land'.
Direct impact	Direct impacts are those that result from clearing vegetation for a development. These impacts are predictable, usually occur at or near to the subject land and can be readily identified during the planning and design phases of a development. Direct impacts may be permanent (eg construction of a railway or building) or temporary (eg only occurring over weeks or months) and may result in partial (eg ground cover, litter and functional attributes such as logs removed but all other structural components of the vegetation remain) or complete clearing (DPIE, 2019).
Ecosystem credits	A measurement of the value of threatened ecological communities, threatened species habitat for species that can be reliably predicted to occur with a PCT, and PCTs generally. Ecosystem credits measure the loss in biodiversity values at a development site and the gain in biodiversity values at a biodiversity stewardship site (OEH, 2017a).
Ecosystem credit species	Threatened species or components of species habitat that are identified in the Threatened Biodiversity Data Collection as requiring assessment for ecosystem credits.

Term	Meaning
Endangered Ecological Community (EEC)	An ecological community specified as endangered in Schedule 2 of the BC Act, or listed under the EPBC Act (OEH, 2017a).
Environmental management measure	Action to reduce the severity of an impact.
Habitat	An area or areas occupied, or periodically or occasionally occupied, by a species, population or ecological community, including any biotic or abiotic component (OEH, 2017a).
Habitat component	The component of habitat that is used by a threatened species for either breeding, foraging or shelter (OEH, 2017a).
Interim Biogeographically Regionalisation of Australia (IBRA) subregion	A subregion of a bioregion identified under the IBRA system (OEH, 2017a).
Indirect impact	Where a primary action is a substantial cause of a secondary event or circumstance which has an impact on a protected matter (Commonwealth of Australia, 2012).
Matter of National Environmental Significance (MNES)	A Matter of National Environmental Significance (MNES) protected by a provision of Part 3 of the EPBC Act.
Mitchell landscape	Landscapes with relatively homogeneous geomorphology, soils and broad vegetation types, mapped at a scale of 1:250,000 (OEH, 2017a).
Northern Beaches Hospital road upgrade project	Northern Beaches Hospital Connectivity and Road Network Enhancement project. The project included Stage 1 Connectivity Works being road works to enhance connectivity to the hospital, and Stage 2 Network Enhancement Works being works to improve the broader road network capacity.
Population	A group of organisms, all of the same species, occupying a particular area.
Residual impact	An impact on biodiversity values after all reasonable measures have been taken to avoid and minimise the impacts of development. Under the BAM, an offset requirement is calculated for the remaining impacts on biodiversity values (OEH, 2017a).
Species credit species	Threatened species or components of species habitat that are identified in the Threatened Biodiversity Data Collection as requiring assessment for species credits (DPIE (EES), 2020c).
Species/ ecosystem credit species	A threatened species whereby part of their habitat is assessed as a species credit (eg breeding habitat) and the remaining habitat is assessed as an ecosystem credit (eg foraging habitat).
Species credits	The class of biodiversity credits created or required for the impact on threatened species that cannot be reliably predicted to use an area of land based on habitat surrogates. Species that require species credits are listed in the Threatened Biodiversity Data Collection (DPIE (EES), 2020c).
Subject land	Land to which the BAM is applied in Stage 1 to assess the biodiversity values of the land. It includes land that may be a development site, clearing site, proposed for biodiversity certification or land that is proposed for a biodiversity stewardship agreement (OEH, 2017a). The term ‘subject land is analogous with the term ‘development footprint’.

Term	Meaning
Target species	A species that is the focus of a study or intended beneficiary of a conservation action or connectivity measure.

Abbreviations

Term	Meaning
AOBV	Areas of Outstanding Biodiversity Value
ARI	Average Recurrence Interval
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016* (NSW)
BDAR	Biodiversity development assessment report
CEEC	Critically Endangered Ecological Community
CMA	Catchment Management Authority
DAWE	Australian Government Department of Agriculture, Water and the Environment
DoEE	The former Australian Government Department of Energy and Environment, now DAWE
DPI	The former NSW Department of Primary Industries, now Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources)
DPIE	NSW Department of Planning, Industry and Environment
DPIE (EES)	NSW Department of Planning, Industry and Environment (Environment, Energy and Science) (former OEH, see below)
DPIE (RIAR)	NSW Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) (former DPI, see above)
DBH	Diameter at Breast Height
EEC	Endangered Ecological Community
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999* (Cwlth)
FM Act	*Fisheries Management Act 1994* (NSW)
IBRA	Interim Biogeographically Regionalisation of Australia
MNES	Matters of National Environmental Significance
NSW	New South Wales
OEH	The former NSW Office of Environment and Heritage, now part of the DPIE (EES)
PCT	Plant Community Type
RMS	former NSW Roads and Maritime Services
SAT	Spot Assessment Technique (Koala survey method)
SEARs	Secretary’s Environmental Assessment Requirements
SEPP	State Environmental Planning Policy
TBDC	Threatened Biodiversity Data Collection
TEC	Threatened Ecological Communities
TSC Act	*Threatened Species Conservation Act 1995* (NSW) (now repealed)
VIS	Vegetation Information System

1 Introduction

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

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* (NSW Government, 2018), that sets the 40 year vision, directions and outcomes framework for customer mobility in NSW. The Western Harbour Tunnel and Beaches Link program of works is proposed to provide additional road network capacity across Sydney Harbour and Middle Harbour and to improve transport connectivity with Sydney's Northern Beaches. The Western Harbour Tunnel and Beaches Link program of works include:

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

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

1.2 The project

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

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

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

An environmental impact statement for the project was prepared and was placed on public exhibition on 9 December 2020, with an exhibition closing date of 1 March 2021. Public exhibition of the environmental impact statement provided the community, interested parties and key stakeholders (including government agencies and councils) with an understanding of the project and the opportunity to comment on the environmental impact statement.

Following the end of exhibition, the Secretary of the Department of Planning, Industry and Environment requested Transport for NSW on 11 March 2021 respond to the issues raised in the submissions in a submissions report. In addition, Department of Planning, Industry and Environment also requested Transport for NSW on 14 May 2021 prepare a preferred infrastructure report, in addition to a submissions report, providing further assessment and information on some key issues. The environmental impact statement, submissions report and preferred infrastructure report are available on the Department of Planning, Industry and Environment website www.planningportal.nsw.gov.au/majorprojects/project/10456.

1.3 Project location

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

Commencing at the Warringah Freeway at Cammeray, the mainline tunnels would pass under Naremburn and Northbridge, then cross Middle Harbour between Northbridge and Seaforth. The mainline tunnels would then split under Seaforth into two ramp tunnels and continue north to the Wakehurst Parkway at Killarney Heights and north-east to Balgowlah, linking directly to the Burnt Bridge Creek Deviation to the south of the existing Kitchener Street bridge.

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

The project would also be located within the Newcastle local government area during construction. During further design development and construction planning in 2021, Transport for NSW identified a preferred location for a loadout facility at the Port of Newcastle for sediment from Middle Harbour that is not suitable for offshore disposal (refer to Section 5 (Treatment and loadout of dredged and excavated material not suitable for offshore disposal) of the preferred infrastructure report for further details). This area, as is applicable to the updated biodiversity assessment, is discussed further in Section 2.2.1.

1.4 Key features of the project

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

- Twin mainline tunnels about 5.6 kilometres long and each accommodating three lanes of traffic in each direction, together with entry and exit ramp tunnels to connections at the surface. The crossing of Middle Harbour between Northbridge and Seaforth would involve three lane, twin immersed tube tunnels
- Connection to the stub tunnels constructed at Cammeray as part of the Western Harbour Tunnel and Warringah Freeway Upgrade project
- Twin two lane ramp tunnels:
  - Eastbound and westbound connections between the mainline tunnel under Seaforth and the surface at the Burnt Bridge Creek Deviation, Balgowlah (about 1.2 kilometres in length)
  - Northbound and southbound connections between the mainline tunnel under Seaforth and the surface at the Wakehurst Parkway, Killarney Heights (about 2.8 kilometres in length)
  - Eastbound and westbound connections between the mainline tunnel under Northbridge and the surface at the Gore Hill Freeway and Reserve Road, Artarmon (about 2.1 kilometres in length)

- An access road connection at Balgowlah between the Burnt Bridge Creek Deviation and Sydney Road including the modification of the intersection at Maretimo Street and Sydney Road, Balgowlah
- Upgrade and integration works along the Wakehurst Parkway, at Seaforth, Killarney Heights and Frenchs Forest, through to Frenchs Forest Road East
- New open space and recreation facilities at Balgowlah
- New and upgraded pedestrian and cyclist infrastructure
- Ventilation outlets and motorway facilities at the Warringah Freeway in Cammeray, the Gore Hill Freeway in Artarmon, the Burnt Bridge Creek Deviation in Balgowlah and the Wakehurst Parkway in Killarney Heights
- Operational facilities, including a motorway control centre at the Gore Hill Freeway in Artarmon, and tunnel support facilities at the Gore Hill Freeway in Artarmon and the Wakehurst Parkway in Frenchs Forest
- Other operational infrastructure including groundwater and tunnel drainage management and treatment systems, surface drainage, signage, tolling infrastructure, fire and life safety systems, roadside furniture, lighting, emergency evacuation and emergency smoke extraction infrastructure, Closed Circuit Television (CCTV) and other traffic management systems.

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

- Upgrade and reconfiguration of the Gore Hill Freeway between the T1 North Shore & Western Line and T9 Northern Line and the Pacific Highway
- Modifications to the Reserve Road and Hampden Road bridges
- Widening of Reserve Road between the Gore Hill Freeway and Dickson Avenue
- Modification of the Dickson Avenue and Reserve Road intersection to allow for the Beaches Link off ramp
- Upgrades to existing roads around the Gore Hill Freeway to integrate the project with the surrounding road network
- Upgrade of the Dickson Avenue and Pacific Highway intersection
- New and upgraded pedestrian and cyclist infrastructure
- Other operational infrastructure, including surface drainage and utility infrastructure, signage and lighting, CCTV and other traffic management systems.

A detailed description of the project is provided in Chapter 5 (Project description) of the environmental impact statement. Section A4 of the submissions report also provides several design refinements to the project which have been made in 2021 to further minimise impacts on the environment and community.

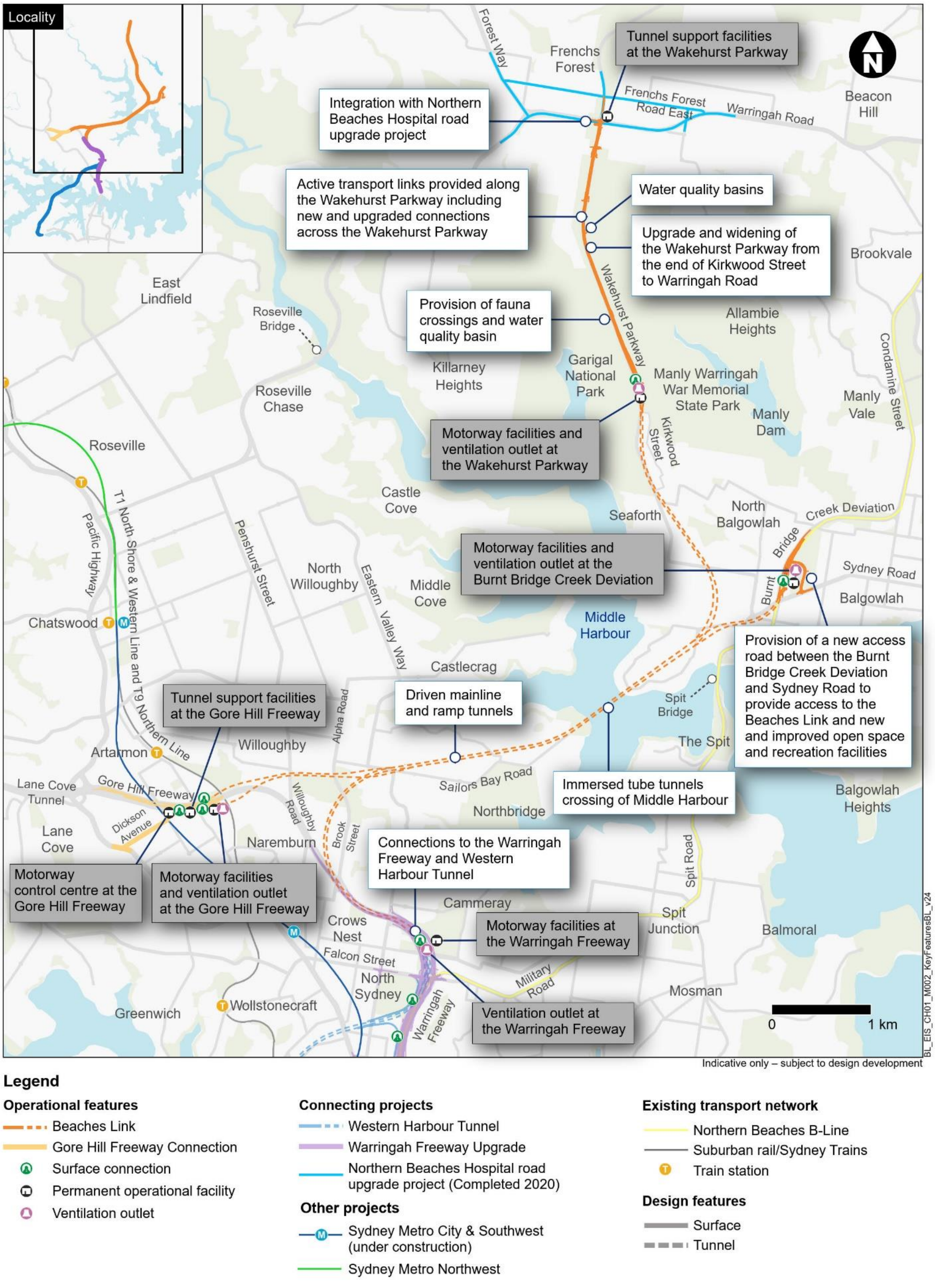


Figure 1-1 Key features of the Beaches Link component of the project

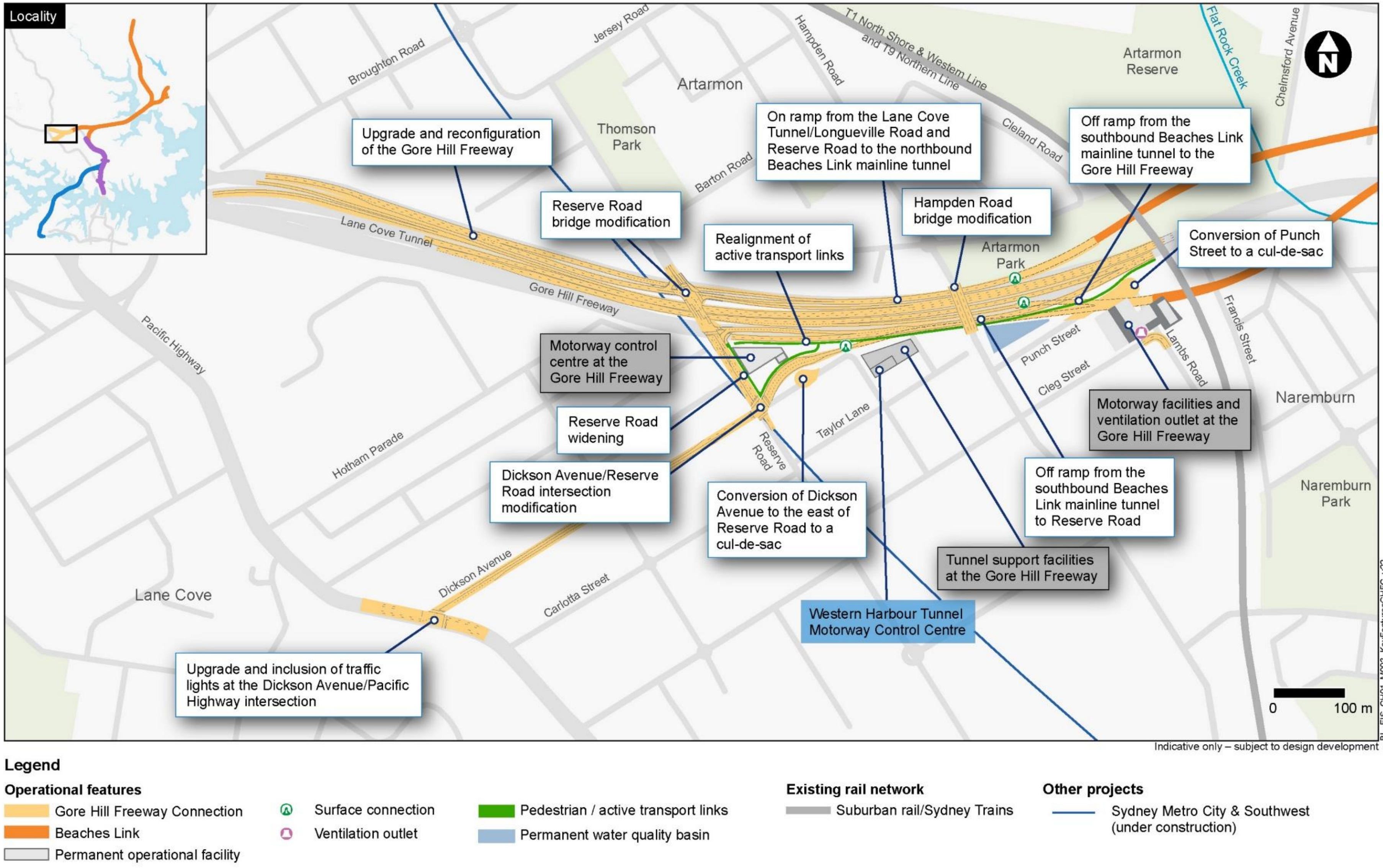


Figure 1-2 Key features of the Gore Hill Freeway component of the project

1.5 Key construction activities

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

Key construction activities would include:

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

Temporary construction support sites would be required as part of the project, and would include tunnelling and tunnel support sites, civil surface sites, cofferdams, mooring sites, wharf and berthing facilities, laydown areas, parking and workforce amenities, and a loadout facility for sediment from Middle Harbour that is not suitable for offshore disposal. Construction support sites would include:

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

- Middle Harbour north cofferdam (BL8)
- Spit West Reserve (BL9)
- Balgowlah Golf Course (BL10)
- Kitchener Street (BL11)
- Wakehurst Parkway south (BL12)
- Wakehurst Parkway east (BL13)
- Wakehurst Parkway north (BL14)
- Port of Newcastle construction support site (BL15).

Refer to Figure 1-3 for temporary construction support sites nearby the tunnelling and surface works for the project. Refer to Figure 1-4 for the location of the Port of Newcastle construction support site (BL15).

A detailed description of construction works for the project is provided in Chapter 6 (Construction work) of the environmental impact statement and should be read in conjunction with the refinements and clarifications provided in Section A4 and A5 of the submissions report. Section 5 (Treatment and loadout of dredged and excavated material not suitable for offshore disposal) of the preferred infrastructure report provides further details on the loadout facility at the Port of Newcastle for sediment from Middle Harbour that is not suitable for offshore disposal.

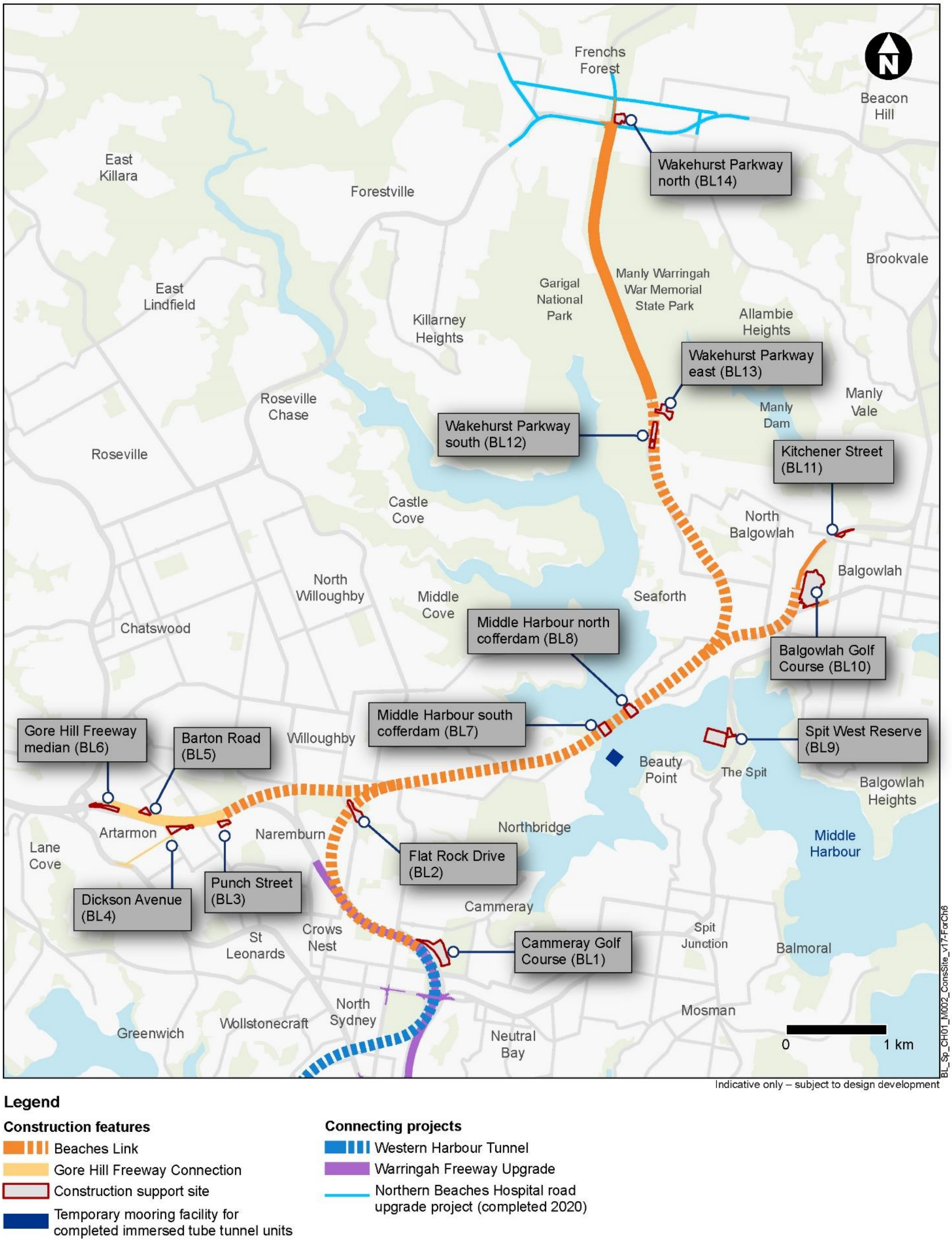


Figure 1-3 Overview of the construction support sites

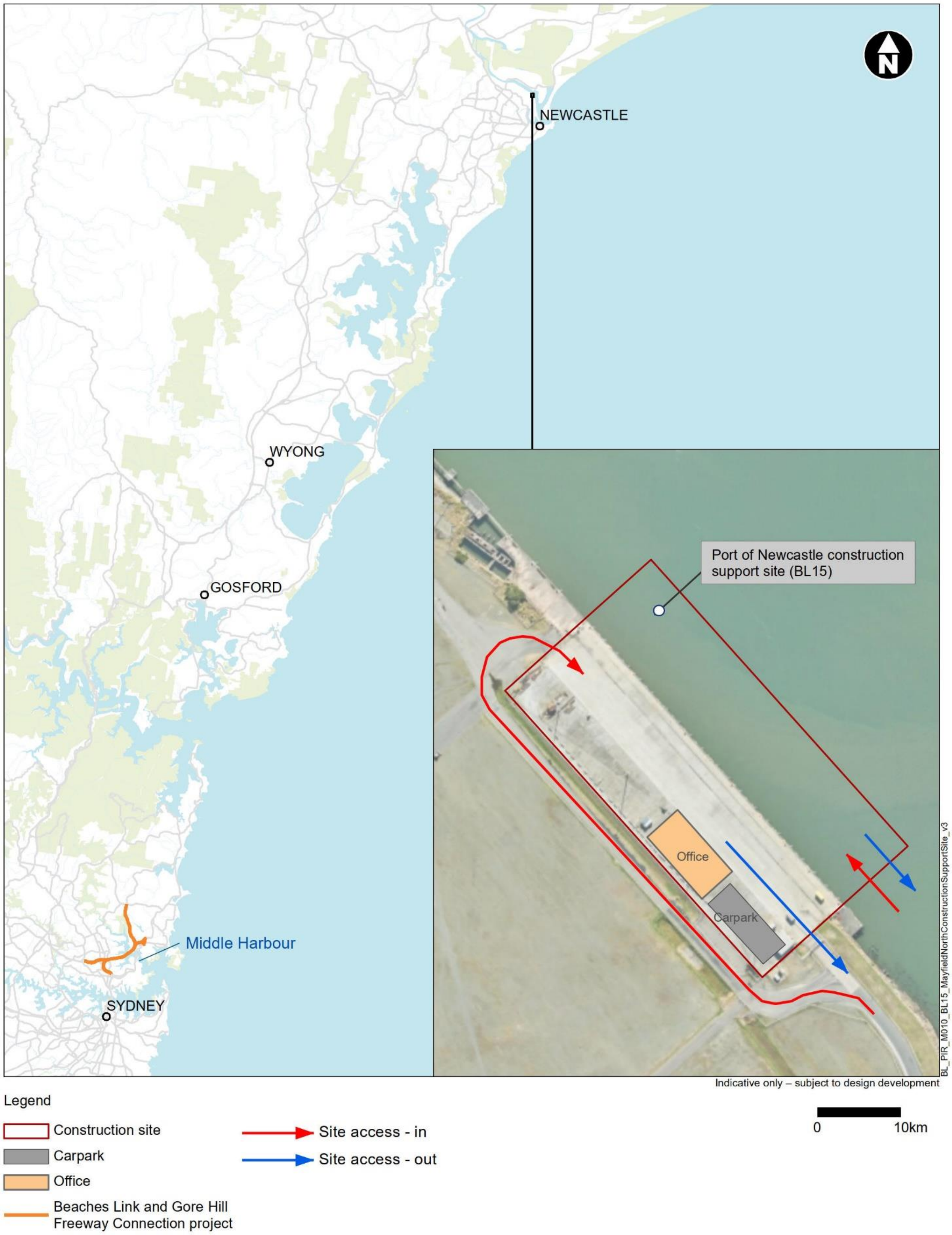


Figure 1-4 Location of Port of Newcastle construction support site (BL15)

1.6 Purpose of this updated biodiversity assessment

The *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) was prepared to support the environmental impact statement for the project. The Biodiversity development assessment report was prepared in accordance with the Biodiversity Assessment Method (BAM) (OEH, 2017), as required by the *Biodiversity Conservation Act 2016* (BC Act) Division 2 Section 7.9(2), and to meet the Secretary's environmental assessment requirements.

This updated biodiversity assessment has been prepared to support the submissions report for the project. The purpose of this updated biodiversity assessment is to:

- Identify the biodiversity values on land proposed to be developed for the project
- Determine the impacts of the project on biodiversity values
- Quantify and describe the biodiversity credits required to offset the residual impacts of the project
- Include updated and supplementary information provided in the submissions report further to the detail provided in *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a).

This updated biodiversity assessment also identifies how Transport for NSW (the proponent) proposes to avoid and minimise impacts on biodiversity, and describes any potential impacts of the project that could be characterised as serious and irreversible.

This updated biodiversity assessment has been prepared in accordance with the:

- Secretary's environmental assessment requirements, relating to biodiversity, as specified in Section 1.7
- Biodiversity Assessment Method (BAM) (2017 version), as required by BC Act Division 2 Section 7.9 (2) and reflected in the Secretary's environmental assessment requirements.

The assessment of the potential impacts to marine mammals and reptiles, fish and marine habitats as a result of the project has been addressed within *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b).

1.7 Secretary's environmental assessment requirements

The *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) provided as Appendix S in the environmental impact statement was prepared to address the Secretary's environmental assessment requirements relating to biodiversity.

This updated biodiversity assessment was also prepared in accordance with the Secretary's environmental assessment requirements relating to biodiversity. The Secretary's environmental requirements relating to biodiversity, and where these requirements are addressed in this document, are outlined in Table 1.1.

Table 1.1 Secretary's environmental assessment requirements – Biodiversity

Requirement	Where addressed
1. Biodiversity impacts related to the proposal are to be assessed in accordance with the Biodiversity Assessment Method and documented in a Biodiversity Development Assessment Report (BDAR).	This updated biodiversity assessment. Section 1.9 discusses the BAM requirements and how they have been considered.
2. The BDAR must include information in the form detailed in the *Biodiversity Conservation Act 2016* (s. 6.12), *Biodiversity Conservation Regulation 2017* (s. 6.8) and Biodiversity Assessment Method (BAM) including details of the measures proposed to address the offset obligation as follows: a. the total number and classes of biodiversity credits required to be retired for the developments/project; b. the number of classes of like-for-like biodiversity credits proposed to be retired; c. the number and classes of biodiversity credits proposed to be retired in accordance with the variation rules; d. any proposal to fund a biodiversity conservation action; and e. any proposal to make a payment to the Biodiversity Conservation Fund.	This updated biodiversity assessment. Offsets are discussed in Section 7 of this updated biodiversity assessment.
3. The BDAR must document the application of the avoid, minimise and offset framework including assessing all direct, indirect and prescribed impacts in accordance with the BAM.	Section 4 and 5 of this updated biodiversity assessment.
4. If requesting the application of the variation rules, the BDAR must contain details of the reasonable steps that have been taken to attempt to obtain the required like-for-like biodiversity credits.	Not applicable.
5. The BDAR must include all spatial data associated with the survey and assessments as per Appendix 11 of the BAM.	Attached as part of the updated biodiversity assessment submission and BAM credit calculator finalisation.
6. The BDAR must be prepared by a person accredited in accordance with the *Accreditation scheme for the Application of the Biodiversity Assessment Method Order 2017* under s. 6.10 of the *Biodiversity Conservation Act 2016*.	This updated biodiversity assessment has been prepared by Jane Rodd and Kate Carroll, both accredited persons under the *Biodiversity Conservation Act 2016* (BC Act) (Accreditation numbers BAAS17030 and BAAS17070).

Requirement	Where addressed
7. In accordance with sections 9.1 and 9.2 of the BAM the BDAR must assess all direct and indirect impacts of the proposal on native vegetation, threatened ecological communities (TECs) and threatened species habitat.	Section 5 of this updated biodiversity assessment.
8. Impacts on biodiversity values that cannot be assessed using the BAM must also be otherwise assessed. The values include: a. marine mammals; b. wandering seabirds; and c. matters of national significance listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*.	Section 5 of this updated biodiversity assessment, which provides a summary of the *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b). Annexure D and Attachment A of Annexure G of this updated biodiversity assessment, which provides an assessment of impacts on freshwater ecology.
9. Species declared as threatened under the *Biodiversity Conservation Act 2016* and recorded recently (since 1990) within approximately 1.5 kilometres of the project's development corridor should be considered as likely to be affected by the proposal.	Section 3.6 and 5 of this updated biodiversity assessment.
10. Identify and assess the impact of tidal flushing on the crossing of Middle Harbour. This assessment should also include details of any potential sediment accumulation and the impact this may have on marine populations that dwell on the harbour floor.	*Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b), and Section 4 (Assessment of potential effects of the immersed tube tunnel sill) and Appendix A of the preferred infrastructure report.

1.8 Legislative context

1.8.1 Biodiversity Conservation Act 2016

The purpose of the *Biodiversity Conservation Act 2016* (BC Act) is to maintain a healthy, productive and resilient environment for the greatest well-being of the community, now and into the future, consistent with the principles of ecologically sustainable development.

The BC Act replaced the *Threatened Species Conservation Act 1995* (TSC Act) on 25 August 2017. The BC Act incorporates broadly similar objectives to those identified the TSC Act, and additionally seeks to establish a framework for assessment and offsetting of development impacts as well as investment in biodiversity conservation, specifically:

- The NSW Biodiversity Offsets Scheme, established under Part 6 of the BC Act
- The Biodiversity Assessment Method (BAM), established under Section 6.7 of the BC Act. The purpose of the BAM is to assess certain impacts on threatened species and TECs, and their habitats, and the impact on biodiversity values, where required under the BC Act.

The NSW Biodiversity Offsets Scheme applies to State Significant Infrastructure projects, unless the Secretary of the Department of Planning, Industry and Environment and the Chief Executive of Department of Planning, Industry and Environment (Environment, Energy and Science) determine that the project is not likely to have a significant impact. Under the NSW Biodiversity Offsets Scheme, an accredited assessor must apply the BAM to the proposal.

The *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) was prepared on the basis of the BAM in force before 22 October 2020. Accordingly, this updated biodiversity assessment had also been prepared on the basis of the BAM in force before 22 October 2020.

1.8.2 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is Commonwealth legislation that provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places, defined in the EPBC Act as Matters of National Environmental Significance (MNES). MNES identified in the EPBC Act include:

- World heritage properties
- National heritage places
- Wetlands of international importance (listed under the Ramsar Convention)
- Threatened species and communities
- Migratory species protected under international agreements
- Commonwealth marine areas
- The Great Barrier Reef Marine Park
- Nuclear actions (including uranium mines).

In accordance with sections 67 and 67A of the EPBC Act, any works that have the potential to result in a significant impact on any MNES or on Commonwealth land are considered 'controlled actions' and require a referral to the Federal Minister for the Environment for approval.

1.9 Biodiversity Assessment Method Requirements

The *Biodiversity Assessment Method* (BAM) (OEH, 2017a) is the assessment manual that outlines how an accredited person assesses impacts on biodiversity at development sites. The BAM provides:

- A consistent method for the assessment of biodiversity on a proposed development or major project, or clearing site
- Guidance on how a proponent can avoid and minimise potential biodiversity impacts
- The number and class of biodiversity credits that need to be offset to achieve a standard of 'no net loss' of biodiversity.

An accredited assessor must document the results of the BAM in a Biodiversity development assessment report. The Biodiversity development assessment report identifies how the proponent proposes to avoid and minimise impacts, any potential impact that could be characterised as serious and irreversible (according to specified principles) and the offset obligation required to offset the likely biodiversity impacts of the development or clearing proposal, expressed in biodiversity credits.

The requirements for a Biodiversity development assessment report (major projects) are listed in Appendix 10 of the BAM.

Table 1.2 identifies where each requirement has been addressed during preparation of this updated biodiversity assessment.

Table 1.2 Minimum information requirements from OEH (2017a)

BAM Requirement		Where addressed in this updated biodiversity assessment
Section	**Information to be included**	
Introduction	Identification of development site* footprint, including: • Operational footprint • Construction footprint indicating clearing associated with temporary construction facilities and infrastructure.	Section 1.2 Section 1.5 Section 2.2
	General description of development site*	Section 1.1
	Sources of information used in the assessment, including reports and spatial data.	Section 2.3
Landscape features	• Interim Biogeographically Regionalisation of Australia (IBRA) bioregions and subregions, NSW landscape region and area (hectares) • Native vegetation extent in the assessment area • Cleared areas • Evidence to support differences between mapped vegetation extent and aerial imagery • Rivers and streams classified according to stream order • Wetlands within, next to and downstream of the site • Connectivity features • Areas of geological significance and soil hazard features • Site context components, including: – Identification of method applied (ie linear or site-based) – Per cent native vegetation cover in the landscape (development site*).	Section 3.1
Native vegetation	Describe Plant Community Types (PCTs) within the development site*	Section 3.3
	Perform a vegetation integrity assessment of the development site*	Section 3.3
Threatened species	Identify ecosystem credit species associated with PCTs on the development site*	Section 3.6
	Identify species credit species on the development site	Section 3.6
Avoid and minimise impacts	Demonstration of efforts to avoid and minimise impact on biodiversity values	Section 4
	Assessment of direct and indirect impacts unable to be avoided at the development site*	Section 5
	For major projects: details of the adaptive management strategy proposed to monitor and respond to impacts on biodiversity values that are uncertain	Section 6
Impact summary	Identification and an assessment of the impacts which are potential serious and irreversible impacts	Section 5.3
	Identification of impacts requiring offsets	Section 7
	Identification of impacts not requiring offsets	Section 7

BAM Requirement		Where addressed in this updated biodiversity assessment
Section	**Information to be included**	
	Identification of areas not requiring further assessment	Section 7
	Ecosystem credits and species credits that measure the impact of the development on biodiversity values	Section 7
Biodiversity credit report	Credit classes for ecosystem credits and species credits at the development site*	Section 3.6

* note – the term ‘development site’ is a term used by the BAM, which for the purposes of this assessment, is analogous with the terms ‘subject land’ and ‘development footprint’

2 Methodology

2.1 Overview

The preparation of this updated biodiversity assessment has been informed by database searches, desktop review of relevant reports and spatial information, site inspections and targeted field surveys.

The scope of work for this updated biodiversity assessment is:

- Carry out a desktop review of databases, reports, aerial photographs and vegetation and habitat mapping relevant to the subject land (refer to Section 2.2.1 for a definition of the subject land)
- Describe flora and fauna species, populations, ecological communities and habitat that occur or are considered likely to occur in the subject land, including:
  - Terrestrial flora species and populations
  - Terrestrial and arboreal fauna species and populations
  - Wandering seabirds, shorebird species (ie birds that inhabit the shorelines of coasts and inland water bodies during most of their life cycles) and Little Penguin
- Determine the presence or likely occurrence of threatened species, population and ecological communities (or their habitats) as listed under the BC Act and EPBC Act
- Assess impacts of the project on native vegetation, threatened species, populations, ecological communities and their habitats, and groundwater dependent ecosystems that occur in the subject land
- Identify and describe environmental management measures using the principles of ‘avoid, minimise, mitigate’
- Outline any offsetting requirements.

The assessment of the potential impacts to marine mammals, reptiles, fish and marine habitats as a result of the project has been addressed in *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b).

2.2 Subject land for this assessment

The land in which biodiversity values have been assessed by this updated biodiversity assessment is known as the subject land. The subject land sits within a larger assessment area.

2.2.1 Definition of subject land

The term ‘subject land’ is analogous with the term ‘construction footprint’ that is used in the environmental impact statement, and with the term ‘development footprint’ that is prescribed by the BAM. The subject land is shown in Figure 2-1.

The subject land comprises the construction (temporary) footprint and design (operational) footprint being considered by the environmental impact statement. The subject land consists of land (at surface level) that would be directly impacted by construction and operation of the project, and would support activities such as vegetation clearing, earthworks, establishment of access roads, installation of utilities, construction of surface roads and tunnels, and surface operation facilities. For the purposes of this updated biodiversity assessment, it is assumed that all vegetation within the subject land would be removed, with the exception of the identified exclusion zone.

The southern part of the construction footprint used in the environmental impact statement overlaps with the Western Harbour Tunnel and Warringah Freeway Upgrade project construction footprint. The subject land does not include the area of overlap between the two construction footprints; the biodiversity impacts within the area of overlap are assessed in the *Western Harbour Tunnel and Warringah Freeway Upgrade Technical working paper: Biodiversity development assessment report* (Arcadis, 2020b).

Figure 2-1 Location of the subject land

The southern extent of the subject land is located within two kilometres of Sydney's Central Business District (CBD) and the northern extent of the subject land is located within 10 kilometres of Sydney CBD. As such, the subject land is heavily urbanised. Land uses within and adjoining the subject land include:

- Residential development within the suburbs of Crows Nest, Cammeray, Naremburn, Willoughby, Artarmon, Northbridge and Seaforth
- Commercial development, predominately in the suburb of Artarmon
- Industrial areas in Artarmon
- Public parks and open space such as Bicentennial Reserve Oval and Flat Rock Reserve (Naremburn, Willoughby and Northbridge) and Balgowlah Golf Course (Balgowlah)
- A portion of Middle Harbour between Northbridge and Seaforth, and a number of bays including Sailors Bay, Peach Tree Bay and Bantry Bay
- Large tracts of bushland contained within Garigal National Park, Manly Warringah War Memorial State Park and Flat Rock Reserve.

The recently completed Northern Beaches Hospital road upgrade project overlaps with northern extent of the subject land. For the purposes of the updated biodiversity assessment, all calculations of biodiversity impacts have been excluded from the area of overlap. The area of overlap has been heavily modified/cleared as a result of construction of the Northern Beaches Hospital road upgrade project.

In addition, the Port of Newcastle construction support site (BL15) would be included in the subject land, according to the definition under the BAM. This site is mapped in Figure 1-4. However, it has generally been excluded from this updated biodiversity assessment as it is located within an existing industrial land use and provides negligible biodiversity value (refer to Section 5 (Treatment and loadout of dredged and excavated material not suitable for offshore disposal) of the preferred infrastructure report). It is absent of PCTs and other native vegetation, and is located on and surrounded by hard stand (refer to Plate 1). Assessment of this site has been carried out by desktop. Direct, prescribed and indirect impacts to biodiversity values covered by the BAM are not anticipated. There is a small area of adjacent open water that would be used for mooring barges. This area is included on the important area shorebird mapping which is considered further in Section 3.7.5.

Legend

Port of Newcastle construction support site (BL15)

Plate 1 Aerial view of Port of Newcastle construction support site (BL15) showing adjacent hard stand areas and the south channel of the Hunter River (source: Hunter and Central Coast Development Corporation, 2012)

2.2.2 Definition of assessment area

In accordance with the BAM for assessing linear-shaped developments, a buffer of 500 metres was applied to the subject land to determine the assessment area. Consideration of the assessment area (that surrounds the subject land) is required as the assessment area may contain biodiversity values that are important for informing the likely habitat suitability of the subject land. The assessment area is shown in Figure 2-1.

In accordance with the requirements of the BAM, Figure 2-1 also shows landscape features including:

- IBRA region and subregion
- Local government areas
- Rivers and streams classified according to stream order (Strahler, 1952)
- Native vegetation cover.

2.3 Assessment guidelines and information used in this report

The assessment presented in this updated biodiversity assessment was carried out in accordance with the requirements of the BAM (OEH, 2017a). Other assessment guidelines used to inform this updated biodiversity assessment include:

- *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (Department of Primary Industries (DPI), 2012)
- *NSW Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities – Working Draft Nov 2004* (NSW Department of Environment and Conservation (DEC), 2004)

- *Policy and Guidelines for Fish Habitat Conservation and Management - Update 2013* (DPI, 2013)
- *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge, 2003)
- *Aquatic Ecology in Environmental Impact Assessment - EIA Guideline* (NSW Department of Planning, 2003)
- *Matter of National Environmental Significance Significant Impact Guidelines 1.1 Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth of Australia, 2013)
- *Threatened species survey and assessment guidelines: field survey methods for fauna (Amphibians)* (Department of Environment and Climate Change (DECC), 2009)
- *Commonwealth Survey Guidelines for Australia's Threatened Bats* (DEWHA, 2010b)
- *Referral guideline for management actions in Grey-head and Spectacled Flying-fox camps* (Commonwealth of Australia, 2015)
- *'Species credit' threatened bats and their habitats NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a)
- *Threatened migratory shorebird habitat mapping project* (DEC, 2006).

Other relevant sources of information used to inform this updated biodiversity assessment include:

- *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a)
- *Western Harbour Tunnel and Warringah Freeway Upgrade Technical working paper: Biodiversity development assessment report* (Arcadis, 2020b)
- *Northern Beaches Hospital Road Upgrade Wildlife Connectivity and Road Risk Minimisation Strategy* (Biosis, 2020)
- *Biodiversity Assessment Report: Northern Beaches Hospital Connectivity and Network Enhancements Stage 2* (SMEC, 2015)
- *HarbourLink Option Alignment Ecological Constraints* (WSP, 2016)
- *HarbourLink Terrestrial Biodiversity Survey Report* (WSP, 2018)
- *Beaches Link and Gore Hill Freeway Connection Project: Freshwater Ecology Impact Assessment* (Cardno, 2020a) (provided in Annexure D)
- *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b)
- *Soil Landscapes of the Sydney 1:100 000 Sheet* (Chapman and Murphy, 1989)
- *The Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area* (version 3.0) (OEH, 2016)
- *Vegetation Information System (VIS) Classification Database* (DPIE (EES), 2020b)
- *NSW Survey Guide for Threatened Frogs: A guide for the survey of threatened frogs and their habitats for the Biodiversity Assessment Method* (DPIE (EES), 2020f)
- Threatened Biodiversity Data Collection
- *Further information on predicted groundwater baseflow reductions and related environmental impact assessment* (Jacobs, 2021) (provided in Annexure G)
- *Supplementary Koala survey and assessment* (Arcadis, 2021) (Appendix F3 of the submissions report).

2.4 Background research

2.4.1 Literature review

A review of relevant information was carried out to provide an understanding of ecological values occurring or potentially occurring in the subject land and wider region. Reports, vegetation maps, topographic maps, aerial photography and literature reviewed included, but were not limited to, the following:

- *Soil Landscapes of the Sydney 1:100 000 Sheet* (Chapman and Murphy, 1989)
- *The Native Vegetation of the Sydney Metropolitan Catchment Management Authority Area (version 3.0)* (OEH, 2016)
- *Sydney Harbour: A systematic review of the science 2014* (Hedge et al., 2014).

Background research included review of the findings and recommendations of the preliminary ecological constraint reports carried out by WSP:

- *HarbourLink Option Alignment Ecological Constraints* (WSP, 2016)
- *HarbourLink Terrestrial Biodiversity Survey Report* (WSP, 2018).

2.5 Determination of candidate species

Candidate species for this assessment were identified using the BAM credit calculator and supplemented with database searches.

Database searches were carried out to identify State and Commonwealth records of threatened entities and Commonwealth MNES that occur or have the potential to occur near the subject land (Table 2.1). Databases were first interrogated by WSP before their site inspections and more recently by Arcadis, to ensure currency of the database search results.

Two analyses of the Bionet Atlas of NSW Wildlife database searches were conducted by Arcadis:

- Assessment of the likelihood of occurrence of all species recorded within 10 kilometres of the subject land
- Assessment of the likelihood of occurrence of species declared as threatened under the BC Act and recorded recently (since 1990) within around 1.5 kilometres of the subject land (as required by the Secretary's environmental assessment requirements).

The likelihood of each threatened flora and fauna species identified in database searches to occur in the subject land was assessed using information on the known geographic distribution and habitat requirements of each species (Annexure A).

The October 2021 results of the EPBC Protected Matters Search Tool are provided in Annexure B.

Table 2.1 Database searches carried out

Database	Search date	Area searched	Reference
Bionet Atlas of NSW Wildlife	8 and 16 June 2016 31 May 2017	An area within 10 kilometres of the subject land as defined by WSP.	Department of Planning, Industry and Environment (Environment, Energy and Science) (DPIE (EES)) http://www.bionet.nsw.gov.au/
	1 April 2019 3 April 2020 8 April 2020	An area within 10 kilometres of the subject land.	
	1 April 2019 3 April 2020 8 April 2020 5 October 2021	An area within 1.5 kilometres of the subject land (post-1990 records only).	
EPBC Protected	31 May 2017	An area within 10 kilometres of the subject land as defined by WSP.	Department of Agriculture, Water and the Environment

Database	Search date	Area searched	Reference
Matters Search Tool	20 March 2019 3 April 2020 11 October 2021	An area within 10 kilometres of the subject land.	https://www.environment.gov.au/epbc/protected-matters-search-tool
Threatened biodiversity profile search	Interrogated throughout the preparation of this report.	Searches carried out for profiles of species and ecosystems known or likely to occur in subject land.	Department of Planning, Industry and Environment (Environment, Energy and Science) (DPIE (EES)) http://www.environment.nsw.gov.au/threatenedspeciesapp/

2.6 Field surveys

Field surveys were carried out at sites within the subject land by WSP ecologists between May 2016 and November 2017, by Biosis ecologists in May 2016 and by Arcadis ecologists between December 2017 and July 2021 (Table 2.2).

Table 2.2 Field surveys conducted to inform this updated biodiversity assessment

Survey area	Surveyor	Date	Purpose of survey
Burnt Bridge Creek Deviation, Hallstrom Park, Wakehurst Parkway, Artarmon, Willoughby, Northbridge	WSP	May 2016, May 2017 and August 2017	Preliminary constraints identification and targeted fauna surveys to detect threatened fauna species that are difficult to detect in other seasons.
Wakehurst Parkway	Biosis	May 2016	To collect BioBanking data and identify vegetation communities adjoining the Wakehurst Parkway.
Burnt Bridge Creek Deviation, Hallstrom Park, Wakehurst Parkway, Artarmon, Willoughby, Northbridge	WSP	July 2016	To collect BioBanking data and assess the extent and condition of vegetation and fauna habitat, especially for threatened species and ecological communities. The vegetation inspection was used to verify vegetation condition and refine vegetation community boundaries.
Burnt Bridge Creek Deviation, Hallstrom Park, Wakehurst Parkway, Artarmon, Willoughby, Northbridge	WSP	October and November 2016 and 2017	To detect threatened flora and frog species that are difficult to detect in other seasons.
Burnt Bridge Creek Deviation, Hallstrom Park, Wakehurst Parkway, Artarmon, Willoughby, Northbridge	WSP	February 2017	To target fauna species within suitable time to detect threatened fauna species that are difficult to detect in other seasons.
Burnt Bridge Creek Deviation, Wakehurst Parkway, Artarmon, Willoughby	WSP	August to November 2017	To conduct BAM vegetation integrity plots.

Survey area	Surveyor	Date	Purpose of survey
Wakehurst Parkway	Arcadis and WSP	December 2017 and March 2018	To inspect areas of potential habitat for Red-crowned Toadlet (*Pseudophryne australis*) and assess the suitability of this habitat for the species.
Wakehurst Parkway east (BL13), Wakehurst Parkway south (BL12)	Arcadis	May 2018	Additional inspection and sampling of Duffys Forest.
Flat Rock Reserve	Arcadis	June 2018	Inspection of Flat Rock Reserve.
Clive Park, Northbridge	Arcadis	July 2018	To ground-truth and describe intertidal habitats within the subject land, based on previous mapping by Creese et al. (2009) and information presented in *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b).
Flat Rock Reserve	Arcadis	October 2018	To carry out Anabat surveys, opportunistic fauna surveys, habitat assessment and complete BAM Plots.
Wakehurst Parkway east (BL13)	Arcadis	November 2018	To carry out opportunistic fauna surveys, habitat assessment and complete BAM Plots.
Bushland north of Bantry Bay Oval	Arcadis	June 2019	Inspection of area mapped as Coastal Upland Swamp.
Wakehurst Parkway and adjacent bushland in Garigal National Park, Wakehurst Parkway east (BL13) and Manly Warringah War Memorial State Park	Arcadis	December 2019 and January 2020	Targeted surveys for Large-eared Pied Bat (*Chalinolobus dwyeri)*.
Flat Rock Reserve	Arcadis	March 2020	Additional inspection of Flat Rock Reserve.
Wakehurst Parkway and adjacent bushland	Arcadis	April 2020	Vegetation condition transects.
Wakehurst Parkway and adjacent bushland, Burnt Bridge Creek Deviation	Arcadis	June, July 2021	Targeted Koala surveys.
Balgowlah Golf Course	Arcadis	June 2021	Fauna habitat assessment of golf course dam.
Flat Rock Creek and areas of Coastal Upland Swamp west of Wakehurst Parkway	Arcadis	June 2021	Ground truthing and assessment of mapped groundwater dependent ecosystems.

2.6.1 Vegetation surveys

Vegetation surveys were carried out across the subject land by WSP ecologists, as documented in WSP (2018), and Arcadis ecologists (as summarised in Table 2.2), to verify existing vegetation mapping and to characterise the vegetation present at each site that was surveyed.

2.6.1.1 Random meander survey

Random meander surveys are a variation of the transect type survey and were completed in accordance with the technique described by Cropper (1993), whereby the recorder walks in a random meander throughout the subject land recording dominant and key plant species (eg threatened species, weeds), boundaries between various vegetation communities and condition of vegetation. WSP (2018) conducted random meander surveys in the vegetation of the subject land in 2016 and 2017, and Arcadis conducted random meander surveys in parts of the subject land between 2017 and 2020.

The time spent in each vegetation community was generally proportional to the size of the community and its species richness. This survey technique was used to verify vegetation boundaries and stratification from the desktop analysis (WSP, 2018).

2.6.1.2 BAM vegetation integrity plots

Vegetation integrity plots were carried out by WSP (2018) and Arcadis in accordance with the BAM. These quantitative (quadrat/transect) site surveys (Table 2.3) were carried out as outlined in the methodology contained within the BAM as described below. The plot requirement per PCT, as specified in the BAM, and number of plots completed are outlined in Table 2.4. Figure 2-2 illustrates the plot layout of nested 20 metre by 50 metre, 20 metre by 20 metre and one metre by one metre sub-quadrats used for the assessment of condition attributes layout at each plot site. The locations of plots and transects are shown in Figure 2-3. Detailed plot data is provided in Annexure C of this report.

Table 2.3 Location and orientation of BAM plots

Plot name	Surveyors	Easting	Northing	Bearing
BB05	WSP	338590	6259751	212
BB06	WSP	338473	6259604	210
BB07	WSP	338339	6259484	278
BB10	WSP/Arcadis	334015	6257090	16
BB13	WSP	336352	6263196	192
BB14	WSP	336368	6257110	12
BB19	WSP	332500	6260663	62
P17	WSP	336368	6261574	11
P18	WSP	336899	6262643	131
P19	WSP	336928	6262900	230
P20	WSP	336428	6262891	190
P22	WSP	336699	6259751	320
P23	WSP	336306	6259604	164
P24	WSP	336323	6259484	180

Plot name	Surveyors	Easting	Northing	Bearing
P25	WSP	336282	6263077	181
P26	WSP	336349	6263196	12
A01	Arcadis	336893	6260940	190
A02	Arcadis	333914	6257130	150
A03	Arcadis	333891	6257220	330
A04	Arcadis	337012	6261110	287
A05	Arcadis	337037	6261040	132

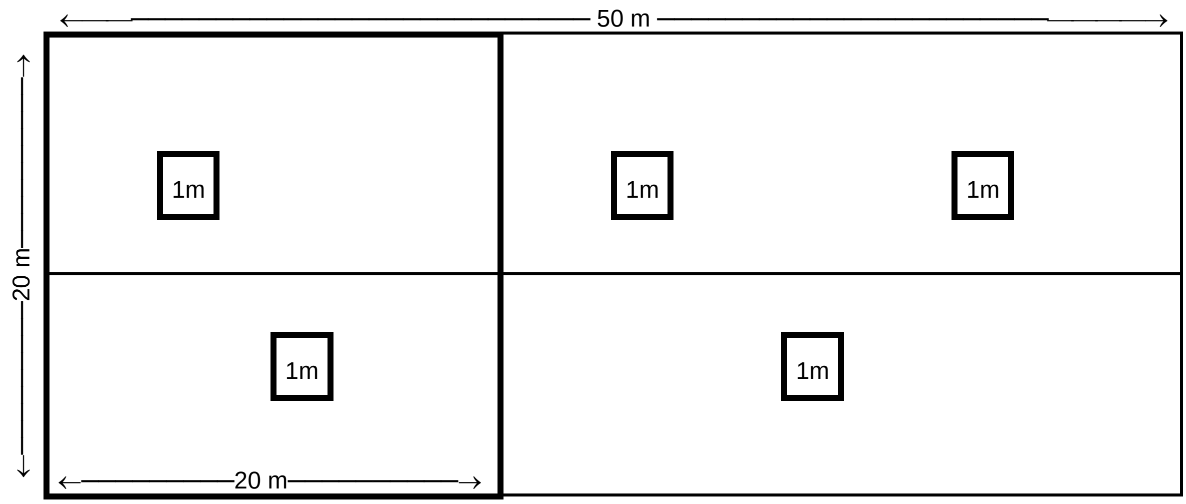


Figure 2-2 Schematic diagram illustrating the plot layout

The following site attributes were recorded at each site:

- **Location**: easting – northing, (grid type MGA 94, Zone 56)
- **Native and exotic species richness** (400 square metre quadrat): This consisted of recording all species by systematically walking through each 20 by 20 metres quadrat. The cover and abundance (percentage of area of quadrat covered) of each species was estimated. The growth form, stratum/layer and whether each species was native, exotic, or high threat weed was recorded
- **Number of trees with hollows** (1,000 square metre quadrat): This was the frequency of hollows within living and dead trees within each 50 by 20 metre quadrat. A hollow was only recorded if (a) the entrance could be seen; (b) the estimated entrance width was at least five centimetres across; (c) the hollow appeared to have depth; (d) the hollow was at least one metre above the ground; and the (e) the centre of the tree was located within the sampled quadrat
- **Number of large trees and stem size diversity** (1,000 square metre quadrat): tree stem size diversity was recorded by measuring the diameter at breast height (DBH) (ie 1.3 metre from the ground) of living trees (greater than five centimetres DBH) within each 50 metre by 20 metre quadrat. For multi-stemmed living trees, only the largest stem was included in the count. The number of large trees was determined by counting all trees with a DBH greater than the specified DBH of large trees for each vegetation formation, as noted in the VIS Classification Database (DPIE (EES), 2020b)

- **Evaluation of regeneration**: This was estimated as the presence/absence of overstorey species present at the site that was regenerating (ie saplings with a DBH less than or equal to five centimetres)
- **Total length of fallen logs** (1,000 square metre quadrat): This was the cumulative total of logs within each 50 by 20 metre quadrat with a diameter of at least 10 centimetres and a length of at least 0.5 metres
- **Litter cover**: This comprised estimating the average percentage groundcover of litter (ie leaves, seeds, twigs, branchlets and branches with a diameter less than 10 centimetres which is detached from a living plant) from within five sub-plots that measured one by one metre squared spaced evenly on either side of the 50 metre central transect.

Table 2.4 Comparison of number of plots required and completed in each vegetation zone, as per the BAM

Vegetation zone	Vegetation zone area (ha)	Plots required	Plots completed	Plots
PCT 1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion – good condition	0.20	1	1	BB13
PCT 1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion – moderate condition	0.92	1	2	BB5 BB7
PCT 1783: Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	4.22	3	4	P18 P25 P24 A05
PCT 1786: Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region – good condition	1.01	1	2	P20 BB14
PCT 1786: Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region – moderate condition	0.37	1	1	A01
PCT 1824: Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	6.18	2	4	P19 P22 P23 A04
PCT 1841: Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	1.79	1	3	BB06 BB10 BB19
PCT 1845: Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	0.39	1	2	P17 P26

Vegetation zone	Vegetation zone area (ha)	Plots required	Plots completed	Plots
Native Revegetation	1.29	0	2	A02 A03
Native Plantings	0.36	0	0	-
Urban Exotic/Native	4.64	0	0	-
Weeds and Exotics	0.23	0	0	-

2.6.1.3 Floristic Analysis

Floristic analysis of vegetation plot data was carried out to determine the vegetation community and PCT. This included comparison with:

- *The Native Vegetation of the Sydney Metropolitan Area* (Version 3.0) (OEH, 2016)
- *Vegetation Information System (VIS) Classification Database* (DPIE (EES), 2020b).

Native vegetation occurring in the subject land was identified by formation, class and type and classified in accordance with the definitions of PCTs in the V*egetation Information System (VIS) Classification Database* (DPIE (EES), 2020b). PCTs were aligned with corresponding TEC where applicable, using VIS Classification Database (DPIE (EES), 2020b).

Areas of non-PCT vegetation were also identified and mapped. Data was also collected in these areas to show the composition of non-PCT vegetation in the subject land.

2.6.1.4 Vegetation condition transects

In order to assess the extent of indirect impacts of the existing road at the Wakehurst Parkway on adjoining areas of native vegetation, ten transects were carried out to measure vegetation condition (Figure 2-3 map d and e). Each vegetation condition transect extended perpendicularly from the road edge, with native shrub cover, native ground cover and exotic cover estimated within five metre by five metre quadrats spaced at 10 metre intervals along a tape.

2.6.1.5 Ground truthing of mapped groundwater dependent ecosystems

The vegetation mapped as groundwater dependent ecosystems by BOM (2018) around Flat Rock Creek and Quarry Creek was inspected. Accessible areas of vegetation were traversed, and eight rapid assessment points were sampled (Figure 2-4). Rapid assessment points consisted of recording the dominant species in each vegetation layer within approximately 10 metres of each point, with additional notes on structure, landscape features, disturbance and health of vegetation.

The areas mapped as Coastal Upland Swamp in the Sydney Basin Bioregion TEC (Coastal Upland Swamp TEC) in Garigal National Park to the west of the Wakehurst Parkway section of the subject land were also inspected, and five rapid assessment points were conducted using the same methodology as described above.

Legend

Subject land

Vegetation survey

BAM transect

BAM plot

Figure 2-3 Vegetation survey locations (map a)

Figure 2-3 Vegetation survey locations (map b)

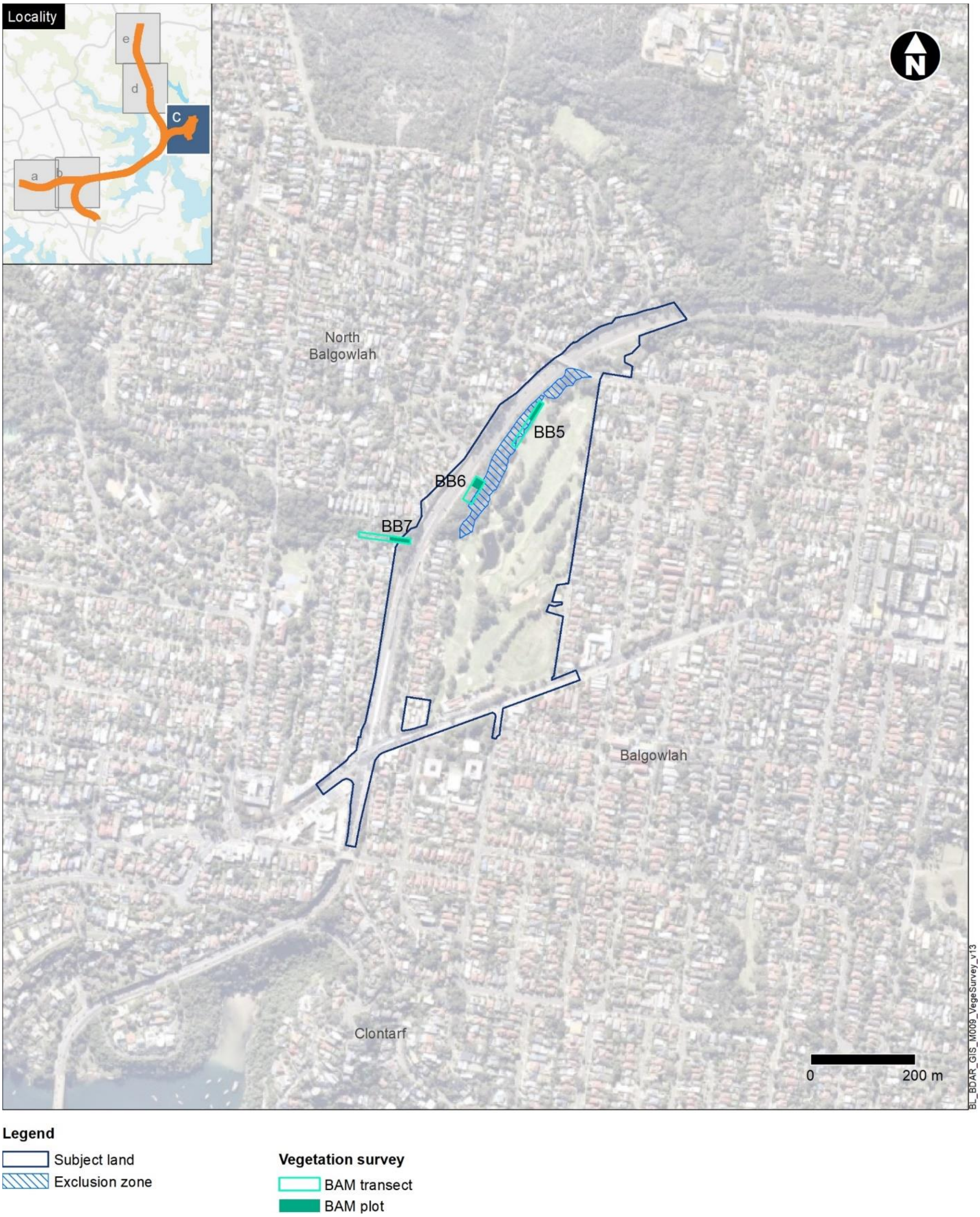


Figure 2-3 Vegetation survey locations (map c)

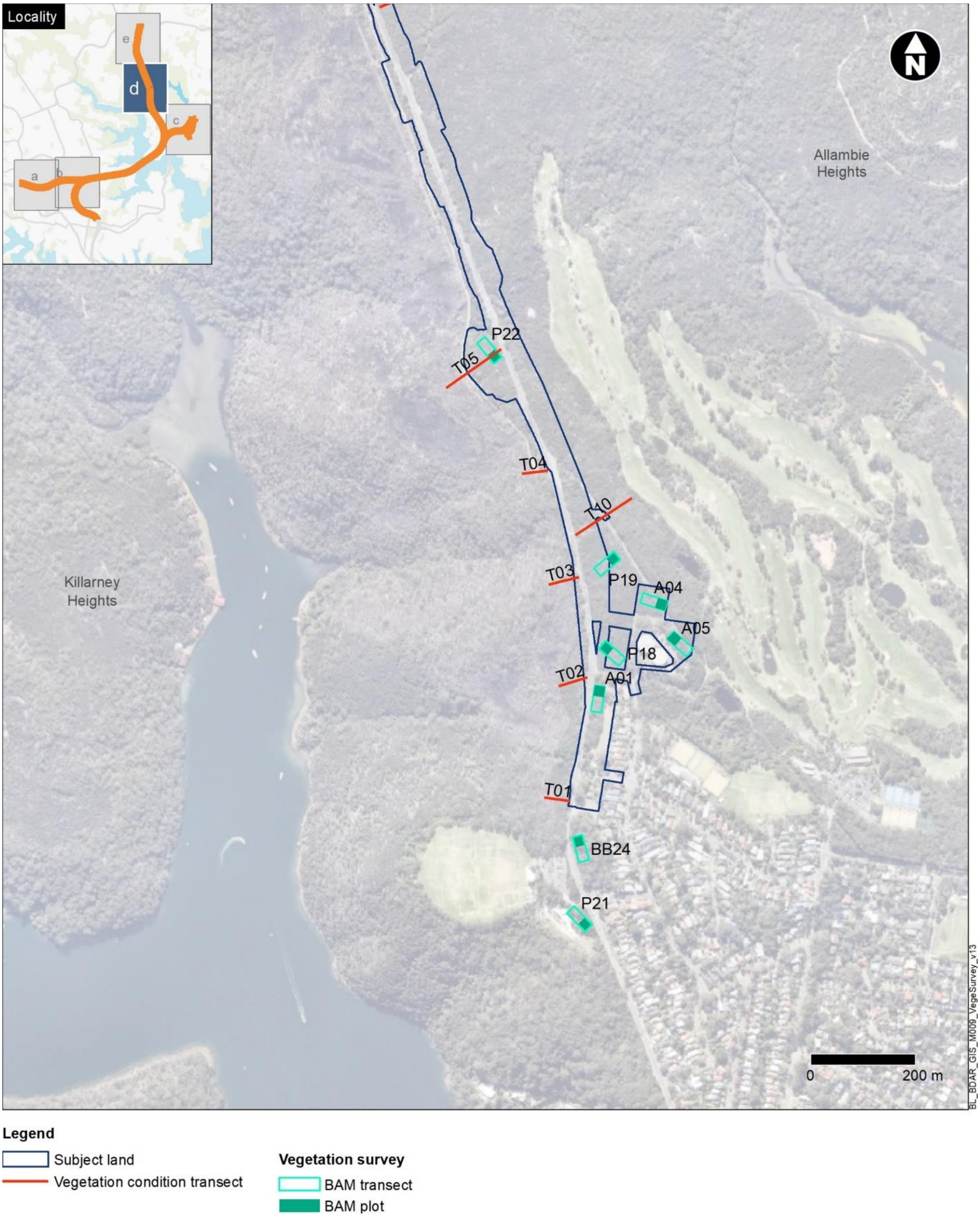


Figure 2-3 Vegetation survey locations (map d)

Legend

- Subject land
- Area not assessed by the updated biodiversity assessment
- Vegetation condition transect

Vegetation survey

- BAM transect
- BAM plot

Figure 2-3 Vegetation survey locations (map e)

Legend

Groundwater Dependent Ecosystems (mapped by BOM (2018))

- Coastal Sand Forest
- Coastal Sandstone Gully Forest
- Coastal Sandstone Plateau Heath
- Estuarine Fringe Forest
- Illawarra Gully Wet Forest
- Sandstone Riparian Scrub
- Rapid Assessment Point

Figure 2-4 Groundwater dependent ecosystems mapped by BOM (2018) and rapid assessment points around Flat Rock Creek and Quarry Creek

2.6.2 Threatened species surveys

Targeted threatened species surveys were carried out within the subject land by WSP ecologists between May 2016 and November 2017 and by Arcadis ecologists between February 2018 and July 2021. The survey techniques, optimum survey period and dates of targeted surveys for threatened flora and fauna species are summarised in Table 2.5 and Table 2.6, respectively.

2.6.2.1 Threatened flora surveys

Targeted surveys were completed for 19 threatened flora species identified as having a moderate to high likelihood of occurring in the subject land. A number of flora species that potentially occur within the subject land have seasonal survey requirements due to difficulty of detection except at specific times of the year, during their flowering period. The BAM outlines survey requirements for threatened species including requirements for seasonal surveys to maximise the likelihood of recording a species if present. The optimum survey period and dates for each threatened flora species targeted by these surveys are summarised in Table 2.5.

2.6.2.1.1 Targeted surveys for **Prostanthera** *spp.* **(WSP, 2018)**

According to the species profile for *Prostanthera junonis* (Somersby Mintbush) in the Threatened Biodiversity Data Collection (TBDC) (DPIE, 2020c), this species is confined to the Somersby Plateau. During late winter 2016, before the spring flowering period for the target *Prostanthera* species, WSP (2018) carried out consultation with DPIE (EES) in respect to *Prostanthera junonis* records from Seaforth. DPIE (EES) sighting and location notes for the three Seaforth records were provided and reviewed. DPIE (EES) indicated that the determination of each specimen type to *Prostanthera junonis* was most likely due to the uncertain taxonomic status of *Prostanthera marifolia* (Seaforth Mintbush), which at the time of the determinations, was a species presumed extinct.

Staff from the National Herbarium of New South Wales inspected the herbarium type sample from the western side of the Wakehurst Parkway, opposite Seaforth Oval at Seaforth. The type sample was determined by B.J. Conn on 4 February 2002 (NSW 497438). Herbarium staff indicated that Conn had hand written notes that stated the determination was classified as probably *Prostanthera junonis*. It is now considered that the *Prostanthera junonis* sample from Seaforth is most likely *Prostanthera marifolia.*

Regardless of the taxonomic uncertainty of the Seaforth records, reference populations of *Prostanthera junonis* (Peats Ridge Road, Somersby) were observed in full flower before the 2016 and 2017 targeted surveys (15 October 2016 and 6 October 2017).

Parallel transect surveys targeting potential habitat for both *Prostanthera junonis* and *Prostanthera marifolia* were conducted, following reference population flowering, along both the eastern and western sides of the Wakehurst Parkway. Parallel transect surveys targeting the species were conducted over two flowering seasons in 2016 and 2017.

Table 2.5 Threatened flora species survey techniques, locations and timing

Species	BC Act status*	EPBC Act status*	Survey technique	Survey location	Seasonal survey requirements#	Survey timing
Acacia bynoeana (Bynoe's Wattle)	E	V	Quadrats (30 minutes for each quadrat sampled) Random meander	Burnt Bridge Creek Deviation (PCT 1250) Wakehurst Parkway (PCT 1250)	September – March	19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 9,10, 27, 30,31 October 2017 1-2 November 2017
Acacia terminalis subsp. *terminalis* (Sunshine Wattle)	E	E	Quadrats (30 minutes for each quadrat sampled) Random meander Parallel transects	Burnt Bridge Creek Deviation (PCT 1250) Wakehurst Parkway (PCT 1250, PCT 1824)	Any season	10-12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 4 and 9 August 2017 9,10, 27, 30,31 October 2017 1-2 November 2017 12 November 2018
Callistemon linearifolius (Netted Bottle Brush)	V	-	Quadrats (30 minutes for each quadrat sampled) Random meander Parallel transects	Burnt Bridge Creek Deviation (PCT 1250, PCT 1776) Wakehurst Parkway (PCT 1250, PCT 1783, PCT 1786, PCT 1824, PCT 1845)	September – March	19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 9,10, 27, 30,31 October 2017 1-2 November 2017 12 November 2018

Species	BC Act status*	EPBC Act status*	Survey technique	Survey location	Seasonal survey requirements#	Survey timing
Epacris purpurascens var. *purpurascens*	V	-	Quadrats (30 minutes for each quadrat sampled) Random meander Parallel transects	Artarmon (PCT 1841, PCT 1776) Burnt Bridge Creek Deviation (PCT 1250, PCT 1841) Flat Rock Reserve (PCT 1841) Wakehurst Parkway (PCT 1786, PCT 1845) Northbridge (PCT 1783)	July to September	5-8, 11-12 July 2016 19-21 October 2016 24-27 October 2016 4 and 9 August 2017 24 March 2020
Eucalyptus camfieldii (Heart-leaved Stringybark)	V	V	Quadrats (30 minutes for each quadrat sampled) Random meander Parallel transects	Burnt Bridge Creek Deviation (PCT 1250) Wakehurst Parkway (PCT 1250)	Any season	10-12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 4 and 9 August 2017 9,10,27,30,31 October 2017 1-2 November 2017
Genoplesium baueri (Bauer's Midge Orchid)	E	E	Quadrats (30 minutes for each quadrat sampled) Random meander Inspection at reference site (Booralie Road, Terry Hills – 12 February 2017) did not record any specimens within known population	Wakehurst Parkway (PCT 1824)	February to March	14-15 February 2017

Species	BC Act status*	EPBC Act status*	Survey technique	Survey location	Seasonal survey requirements#	Survey timing
Grevillea caleyi (Caley's Grevillea)	CE	E	Quadrats (30 minutes for each quadrat sampled) Random meander	Wakehurst Parkway (PCT 1786, PCT 1845)	Any season	10-12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 4 and 9 August 2017 9,10, 27, 30,31 October 2017 1-2 November 2017
Haloragodendron lucasii	E	E	Quadrats (30 minutes for each quadrat sampled) Random meander	Burnt Bridge Creek Deviation (PCT 1250) Wakehurst Parkway (PCT 1250)	Any season	10-12 May 2016 5-8, 11-12 July 2016 19-21 & 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 4 and 9 August 2017 9,10, 27, 30,31 October 2017 1-2 November 2017
Hibbertia puberula	E	-	Quadrats (30 minutes for each quadrat sampled) Random meander	Burnt Bridge Creek Deviation (PCT 1250, PCT 1776) Wakehurst Parkway (PCT 1250, PCT 1783, PCT 1786)	October to December	24-27 October 2016 28-29 November 2016 9,10, 27, 30,31 October 2017 1-2 November 2017 12 November 2018

Species	BC Act status*	EPBC Act status*	Survey technique	Survey location	Seasonal survey requirements#	Survey timing
Lasiopetalum joyceae	V	V	Quadrats (30 minutes for each quadrat sampled) Random meander	Wakehurst Parkway (PCT 1824)	Any season	10-12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 4 and 9 August 2017 9,10, 27, 30,31 October 2017 1-2 November 2017 12 November 2018
Leptospermum deanei	V	V	Quadrats (30 minutes for each quadrat sampled) Random meander	Artarmon (PCT 1841) Burnt Bridge Creek Deviation (PCT 1250, (PCT 1841) Flat Rock Reserve (PCT 1841) Wakehurst Parkway (PCT 1250)	October to November	19-21 and 24-27 October 2016 28-29 November 2016 9,10, 27, 30,31 October 2017 1-2 November 2017 24 March 2020
Microtis angusii	E	E	Quadrats (30 minutes for each quadrat sampled) Random meander *Microtis angusii* was recorded in flower at reference site (Mona Vale Road, Ingleside – 19 October 2016)	Highly disturbed areas with limited or no veg Wakehurst Parkway (PCT 1786)	September to October	19-21 and 24-27 October 2016 9,10, 27, 30,31 October 2017 1-2 November 2017
Persoonia hirsuta (Hairy Geebung)	E	E	Quadrats (30 minutes for each quadrat sampled) Random meander Parallel transects	Burnt Bridge Creek Deviation (PCT 1250) Wakehurst Parkway (PCT 1250, PCT 1786, PCT 1824, PCT 1845)	December to May	10-12 May 2016 14-15 February 2017 18 May 2017 12 November 2018

<table>
<tr><th>Species</th><th>BC Act status*</th><th>EPBC Act status*</th><th>Survey technique</th><th>Survey location</th><th>Seasonal survey requirements#</th><th>Survey timing</th></tr>
<tr><td>Pimelea curviflora var. curviflora</td><td>V</td><td>V</td><td>Quadrats (30 minutes for each quadrat sampled)
Random meander
Parallel transects</td><td>Burnt Bridge Creek Deviation (PCT 1776)
Artarmon (PCT 1776)
Wakehurst Parkway (PCT 1786)</td><td>October to May</td><td>10-12 May 2016
19-21 and 24-27 October 2016
28-29 November 2016
14-15 February 2017
18 May 2017
9,10, 27, 30,31 October 2017
1-2 November 2017</td></tr>
<tr><td>Prostanthera junonis
(Somersby Mintbush)</td><td>E</td><td>E</td><td rowspan="2">Quadrats (30 minutes for each quadrat sampled)
Random meander
Parallel transects
Prostanthera junonis was recorded in flower at reference site (Somersby – 15 October 2016). This informed flowering period for Prostanthera marifolia. Reference site for Prostanthera marifolia was inspected (Seaforth Oval – 19 October 2016). However, no specimens were recorded within known population.</td><td rowspan="2">Wakehurst Parkway (PCT 1786)
Prostanthera junonis does not occur south of the Hawkesbury, species records predate description of Prostanthera marifolia. Though these have been delineated due to changes in taxonomic description surveys were carried out for both Prostanthera junonis and Prostanthera marifolia.</td><td>September to November (October to mid-December in EIA guidelines)</td><td rowspan="2">19-21 & 24-27 October 2016
9,10, 27, 30,31 October 2017
1-2 November 2017
12 November 2018</td></tr>
<tr><td>Prostanthera marifolia</td><td>CE</td><td>CE</td><td>September to October</td></tr>
<tr><td>Rhodamnia rubescens
(Scrub Turpentine)</td><td>CE</td><td>CE</td><td>Quadrats (30 minutes for each quadrat sampled)
Random meander</td><td>Wakehurst Parkway (quadrats only) (PCT 1841, PCT 1845)
Flat Rock Reserve (PCT 1841)</td><td>Any season</td><td>31 October 2017
24 March 2020</td></tr>
</table>

Species	BC Act status*	EPBC Act status*	Survey technique	Survey location	Seasonal survey requirements#	Survey timing
Syzygium paniculatum (Magenta Lilly Pilly)	E	V	Quadrats (30 minutes for each quadrat sampled) Random meander Parallel transects	Artarmon (PCT 1841) Burnt Bridge Creek Deviation (PCT 1250, PCT 1841) Flat Rock Reserve (PCT 1841)	Any season	10-12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 4 and 9 August 2017 9,10, 27, 30,31 October 2017 1-2 November 2017 19 October 2018 24 March 2020
Tetratheca glandulosa (Glandular Pink-bell)	V	-	Quadrats (30 minutes for each quadrat sampled) Random meander Parallel transects No reference site was visited for this species as it was recorded during recognised flowering period	Burnt Bridge Creek Deviation (PCT 1250) Wakehurst Parkway (PCT 1250, PCT 1786, PCT 1824, PCT 1845)	July to November	5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 4 and 9 August 2017 9,10, 27, 30,31 October 2017 1-2 November 2017 12 November 2018

* V=Vulnerable, E=Endangered, CE=Critically Endangered
# Optimal time of year for survey is based on survey months provided in Bionet

2.6.2.2 *Threatened fauna surveys*

Targeted seasonal surveys were completed for threatened fauna species identified as having a moderate to high likelihood of occurring within the subject land, which mainly included species known to occur in modified and disturbed environments. Terrestrial fauna survey locations are shown in Figure 2-5, Figure 2-6 and Figure 2-7.

Threatened fauna surveys completed within the subject land were carried out as described below and where applicable, considering the methodology detailed in the *NSW Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities* (Working Draft) (DEC, 2004), the *Survey Guidelines for Australia's Threatened Birds* (DEWHA, 2010a), *Threatened Species survey and assessment guidelines: field survey and methods for fauna-Amphibians* (DECC, 2009), *Species credit' threatened bats and their habitats: NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a) and *Survey guidelines for Australia's threatened frogs* (DEWHA, 2010c). The optimum survey period and dates surveyed for each threatened fauna species targeted by these surveys are summarised in Table 2.6.*NSW Survey Guide for Threatened Frogs: A guide for the survey of threatened frogs and their habitats for the Biodiversity Assessment Method* (DPIE (EES), 2020f) were released in September 2020. There was no requirement to adopt these guidelines for the project given the timing of release and submission of the Biodiversity development assessment report for the project (December 2020). Targeted surveys for frogs were therefore not carried out in accordance with these guidelines.

2.6.2.2.1 Diurnal bird surveys

A bird survey was completed targeting diurnal species by actively walking through a site over a period of 20 minutes. All birds were identified to the species level, either through direct observation or identification of calls. Bird surveys were completed during different times of the day, but generally occurred during morning hours or evening. Birds were also recorded opportunistically during all other surveys.

In addition, targeted surveys were conducted for threatened shorebirds within intertidal habitats that occur in the subject land and wider assessment area, specifically, at Middle Harbour (Spit West Reserve).

2.6.2.2.2 Microbat survey and roosting habitat assessment

Passive recording of echolocation calls of microchiropteran bats (microbats) was carried out at a number of sites within native vegetation in the subject land. Ultrasonic Anabat bat detection (Titley Electronics) was used to record continuously during nocturnal spotlighting transects, call playback and stag watches at potential artificial roosting culverts and bridges within the subject land.

A diurnal inspection of accessible potential roosting sites located within the subject land was carried out by WSP ecologists at the following locations:

- Concrete culvert at Balgowlah
- Concrete culvert at Artarmon
- Concrete underground walkway at Naremburn.

Inside each structure, wall cavities, ceiling cavities, crevices and any other areas considered to contain potential microbat roosting habitat (for species known to roost in human made structures) were inspected. These areas were examined for signs of past or current microbat use (evidence of guano) and their value as roosting habitat was assessed. The outside of each structure was examined for potential microbat entry and exit points.

Ecologists with spotlights were stationed at potential microbat exit points from dusk, to determine whether any microbats were leaving the potential roost sites. Handheld Anabats were used to record the echolocation calls of any microbats exiting the potential roost site.

Active Anabat surveys in conjunction with a stag watch for microbat activity also occurred at a large hollow-bearing tree at northern section of the Wakehurst Parkway (hollow greater than 20 centimetres).

Large-eared Pied Bat (*Chalinolobus dwyeri*) targeted surveys

Targeted surveys for the Large-eared Pied Bat (*Chalinolobus dwyeri*) (Vulnerable – EPBC Act, BC Act) were carried out by Arcadis ecologists in the Large-eared Pied Bat survey area identified in Figure 2-6 at the Wakehurst Parkway in December 2019 and January 2020. An initial desktop assessment was carried out to identify rocky features (eg caves, scarps, cliffs, etc) within 100 metres of the subject land that could provide breeding habitat in accordance with *'Species credit' threatened bats and their habitats: NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a). High resolution aerial imagery and topographic maps were used to identify the rocky features to target for surveys (Figure 2-6). Diurnal inspections of the rocky features identified by desktop and all land within 100 metres of these areas were searched by foot to identify potential breeding habitat (Figure 2-6). Any suitable features were searched for microbats or evidence of their presence (eg guano) with a hand torch. Suitable habitat and roost search locations are shown in Figure 2-6.

Passive and active recordings of echolocation calls of microbats were carried out at six roost sites and five transects, respectively, within suitable roosting and/or foraging habitat.

Data analysis

Microbat call analyses were completed by Nathan Cooper of WSP, Carl Corden and Jessica Rooke of Arcadis, with the presentation of data considering the guidelines of the Australasian Bat Society outlined in *Bat Calls of New South Wales: region-based guide to the echolocation calls of microchiropteran bats* (Pennay et al., 2004) was used as a reference collection for microbat call identification.

All microbat calls were identified with a high degree of confidence as they were typical call frequencies and shapes for each species identified and within the known distribution and habitat types for these species.

2.6.2.2.3 Harp trapping

Harp trapping was conducted to determine the presence or absence of breeding Large-eared Pied Bats within 100 metres of the subject land at the Wakehurst Parkway. Harp trapping was conducted for Large-eared Pied Bat to meet the survey requirements of *'Species credit' threatened bats and their habitats: NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a).Trapping was conducted at five locations over a total of eight nights within the survey area shown in Figure 2-6. Harp traps were erected in potential flyways and at likely exit locations of potential roost sites (Figure 2-6). Trapping occurred from sunset to sunrise on each trap night, with checks being conducted by two ecologists around 10pm and 5.30am.

2.6.2.2.4 Spotlighting

Spotlighting was used to target threatened nocturnal mammals, birds, reptiles and amphibians. Spotlighting was completed after dusk. Surveys were completed on foot using high-powered headlamps and hand torches. Any animals observed were identified to the species level.

Additionally, spotlight surveys targeting Koalas were carried out within the subject land plus a 100 metre buffer in areas of potential Koala habitat (Figure 2-7). Surveys were carried out using handheld spotlights in conjunction with a Hikmicro Lynx Pro LH19 Thermal Monocular, used to assist in detecting the presence of Koalas by scanning vegetation. This survey method is effective at detecting arboreal mammals from heat, often more effective at detection than spotlighting (Vinson et al, 2020; Allison and Destefano, 2006; McGregor et al, 2021).

2.6.2.2.5 Stag watches

Stag watches were carried out at dusk at the two locations where hollow-bearing trees were identified within the subject land. The aim of stag watches was to identify if threatened owls were using any hollow-bearing trees within the subject land for breeding purposes.

2.6.2.2.6 Call playback

Call playback was used to survey for nocturnal birds and frogs. Call playback was completed after dusk within a number of sites in the subject land; frog call-back surveys were only carried out in areas of potential habitat, mainly at creeks and ephemeral drainage lines.

For each survey, an initial listening period of 10 to 15 minutes was carried out, followed by a spotlight search for 10 minutes to detect any animals in the immediate vicinity. The calls of the target species were then played intermittently for five minutes followed by a 10 minute listening period. After the calls were played, another 10 minutes of spotlighting was carried out nearby to check for animals attracted by the calls, but not vocalising. Calls were broadcast using a portable media player and megaphone.

2.6.2.2.7 Hair tubes

A total of 40 small (50 millimetres) and 40 medium (90 millimetres) hair tubes were used to detect the presence of small and medium-sized terrestrial mammals; hair samples become attached to double-sided tape that is attached to the inside of the tube near the bait. Each hair tube was baited with a suitable food source containing honey, and each trap and immediate vicinity was sprayed with an attractant of honey/vanilla essence mixed with water. Hair tubes were set in the field for a two week period on two occasions.

2.6.2.2.8 Terrestrial trapping

Transects of 25 Elliot traps and four cage traps were set in the field for four consecutive nights to target small to medium sized terrestrial mammals. Each trap was baited with a suitable food source for each of the targeted species. Traps were checked at dawn each morning and captured animals were identified to species level before being released. All live trapping followed guidelines and policies for wildlife research in accordance with animal ethics protocols.

2.6.2.2.9 Remote camera

Remote motion sensing infra-red cameras were positioned in the subject land, primarily to target terrestrial mammals. Remote camera traps were set with a suitable food source containing raw chicken necks and sardines (for Spotted-tailed Quoll (*Dasyurus maculatus*)) and rolled oats and peanuts with honey and vanilla essence (for Eastern Pygmy-possum (*Cercartetus nanus*) and Southern Brown Bandicoot (*Isoodon obesulus obesulus*)) in the appropriate microhabitat. Cameras were also used to target other animals occurring within survey locations including introduced species.

Six remote cameras were used to target Spotted-tailed Quoll for four consecutive nights in April. Four remote cameras used to target Eastern Pygmy-possum in appropriate microhabitats in the subject land for four consecutive nights in April 2017. Fourteen remote cameras were used to target Southern Brown Bandicoot in March to May 2017.

Unbaited cameras were used to target Koalas, positioned to face Koala feed trees species at ground level. Eight remote cameras were used to target Koalas over 16 consecutive nights from June to July 2021.

2.6.2.2.10 Nest boxes

Nest boxes were temporarily installed in trees within the subject land to survey small to medium-sized arboreal mammals. Twelve nest boxes were installed in native vegetation communities near the Wakehurst Parkway, in the northern extent of the subject land, for a period of 12 weeks. Nest boxes were installed on 23 March 2017 and were checked for fauna presence on 31 March 2017. Nest boxes were inspected on 17 and 18 August 2017 to identify the presence of any arboreal fauna species.

2.6.2.2.11 Herpetofauna searches

Searches for herpetofauna (frogs and reptiles) were carried out during the day and at night. Herpetofauna surveys were completed by one or two persons over a 30-minute period in areas of suitable habitat. Searches involved:

- Looking for active specimens and eye shine
- Turning over suitable ground shelter such as fallen timber, sheets of iron and exposed rocks, raking debris (all ground shelter was returned to its original position)
- Peeling decorticating bark
- Aural recognition of frog calls.

2.6.2.2.12 Spot Assessment Technique (SAT) Koala survey method

The Spot Assessment Technique (SAT) Koala survey method prescribed by Steve Phillips and John Callaghan (2011) was employed to identify the presence and activity of Koalas. Surveys involved searching for scat within the subject land plus a 100 metre buffer. They focused on areas of potential Koala habitat where feed tree species were present. Some areas of PCT vegetation were absent of tree cover and/or feed trees and were therefore not surveyed. Three SAT surveys were carried out by WSP in 2016 and 2017 (Figure 2-5) and twelve SAT surveys were conducted by Arcadis in June and July 2021 (Figure 2-7). Any scat samples from Arcadis surveys that were potential koala specimens were sent to Scatsabout (a scat identification specialist) for analysis.

2.6.2.2.13 Opportunistic sightings

At all survey locations, all fauna species and evidence of fauna presence observed was recorded by WSP and Arcadis ecologists. An inventory of fauna species recorded in the subject land by WSP and Arcadis was compiled (Annexure C). Opportunistic fauna surveys involved:

- Direct visual observations of animal activity
- Aural recognition of bird and frog calls
- Indirect evidence of fauna (such as scats, nests, burrows, hollows, tracks, scratches and diggings).

An inventory of fauna species recorded by WSP during field investigations is in *HarbourLink Terrestrial Biodiversity Survey Report* (WSP, 2018) (unpublished).

Table 2.6 Threatened fauna species survey techniques, locations and timing

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Giant Burrowing Frog (*Heleioporus australiacus*)	V	V	Nocturnal call playback	5 person hours	Wakehurst Parkway Artarmon Flat Rock Reserve Burnt Bridge Creek Deviation	September to May	10, 12 May 2016 23, 24, 28 and 31 March 2017 3 and 4 May 2017
			Night habitat search of damp and watery sites (30 minutes per site)	5 person hours			
			Night spotlight watercourse search	5 person hours			
Green and Golden Bell Frog (*Litoria aurea*)	E	V	Nocturnal call playback	5 person hours	Artarmon Flat Rock Reserve	November to March	17 and 18 August 2016 23, 24, 28 and 31 March 2017
			Night spotlight watercourse search	5 person hours			
Red-crowned Toadlet (*Pseudophryne australis*)	V	-	Nocturnal call playback	5 person hours	Wakehurst Parkway Artarmon Flat Rock Reserve Burnt Bridge Creek Deviation	All year	5-8, 11-12 July 2016 17 and 18 August 2016 23, 24, 28 and 31 March 2017
			Night habitat search of damp and watery sites (30 minutes per site)	5 person hours			
			Night spotlight watercourse search	5 person hours			

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Regent Honeyeater (*Anthochaera phrygia*)	CE	CE	Standard 20-minute search of a 2 hectare area	8.7 person hours	Wakehurst Parkway Flat Rock Reserve Burnt Bridge Creek Deviation	N/A	10 and 12 May 2016 5-8, 11-12 July 2016 23, 24, 28, 31 March 2017 19 April to 4 May 2017 18 May 2017
Glossy Black-Cockatoo (*Calyptorhynchus lathami*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 person hours	Wakehurst Parkway Flat Rock Reserve Burnt Bridge Creek Deviation	March to August	10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 23, 24, 28, 31 March 2017 19 April to 4 May 2017 17, 18 August 2017
Varied Sittella (*Daphoenositta chrysoptera*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 person hours	Wakehurst Parkway Flat Rock Reserve Burnt Bridge Creek Deviation	N/A	10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017. 23, 24, 28, 31 March 2017 19 April to 4 May 2017 17, 18 August 2017

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Little Lorikeet (*Glossopsitta pusilla*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 person hours	Wakehurst Parkway Artarmon Flat Rock Reserve Burnt Bridge Creek Deviation	N/A	10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017. 23, 24, 28, 31 March 2017 19 April to 4 May 2017 17, 18 August 2017
Sooty Oystercatcher (*Haematopus fuliginosus*)	V	-	Standard 20-minute search of a 2 hectare area	5 person hours	Northbridge (Hallstrom Park) Middle Harbour	All year	Targeted shorebird survey: 23–24 March 2017
Pied Oystercatcher (*Haematopus longirostris*)	E	-	Standard 20-minute search of a 2 hectare area	5 person hours	Northbridge (Hallstrom Park) Middle Harbour	All year	Targeted shorebird survey: 23–24 March 2017
White-bellied Sea-Eagle (*Haliaeetus leucogaster*)	V	-	Standard 20-minute search of a 2 hectare area	5 person hours	Northbridge (Hallstrom Park) Middle Harbour	July to December	Targeted shorebird survey: 23–24 March 2017

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Swift Parrot (*Lathamus discolor*)	E	CE	Standard 20-minute search of a 2 hectare area	8.7 person hours	Wakehurst Parkway Artarmon Flat Rock Reserve Burnt Bridge Creek Deviation	N/A	10 and 12 May 2016 5-8, 11-12 July 2016 23, 24, 28, 31 March 2017 19 April to 4 May 2017 18 May 2017
Square-tailed Kite (*Lophoictinia isura*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 person hours	Wakehurst Parkway	September to January (breeding)	10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 23, 24, 28, 31 March 2017 19 April to 4 May 2017 17, 18 August 2017
Little Eagle (*Hieraaetus morphnoides*)	V	-	Standard 20-minute search of a 2 hectare area	2.7 person hours	Wakehurst Parkway	August to October (breeding)	19-21 and 24-27 October 2016 17, 18 August 2017
Barking Owl (*Ninox connivens*)	V	-	Nocturnal call playback	12 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	May to December (breeding)	10 and 12 May 2016 23, 24, 28 and 31 March 2017 3, 4 May 2017
			Spotlight transects	18 person hours			
			Stag watches and spotlight transects	4 person hours	Wakehurst Parkway		Winter survey: 17, 18 August 2017

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements[#]	Survey timing
Powerful Owl (*Ninox strenua*)	V	-	Nocturnal call playback	12 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	May to August (breeding)	Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 and 31 March 2017 3, 4 May 2017 Winter survey: 17, 18 August 2017
			Spotlight transects	18 person hours			
			Stag watches and spotlight transects	4 person hours	Wakehurst Parkway		
Eastern Osprey (*Pandion cristatus (syn. P. haliaetus)*)	V	-	Standard 20-minute search of a 2 hectare area	5 total person hours across all sites	Northbridge (Hallstrom Park) Middle Harbour	April to November (breeding)	Targeted shorebird survey: 23 – 24 March 2017 Threatened fauna surveys: 19 April to 4 May 2017 Winter bird survey: 17, 18 August 2017
Scarlet Robin (*Petroica boodang*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	N/A	10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 23, 24 and 28 March 2017 19 April to 4 May 2017 17, 18 August 2017

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Flame Robin (*Petroica phoenicea*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	N/A	10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 23, 24 and 28 March 2017 19 April to 4 May 2017 17, 18 August 2017
Eastern Ground Parrot (*Pezoporus wallicus* subsp. *wallicus*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 total person hours	Wakehurst Parkway	All year	10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 23, 24, 28, 31 March 2017 19 April to 4 May 2017 17, 18 August 2017

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Superb Fruit-Dove (*Ptilinopus superbus*)	V	-	Standard 20-minute search of a 2 hectare area	7.3 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	N/A	5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 23, 24, 28, 31 March 2017 Threatened fauna surveys: 19 April to 4 May 2017 Winter bird survey: 17, 18 August 2017
Masked Owl (*Tyto novaehollandiae*)	V	-	Nocturnal call playback	12 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	May to August (Breeding)	Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 and 31 March 2017 3, 4 May 2017
			Spotlight transects	18 person hours			
			Stag watches and transect surveys	4 person hours	Wakehurst Parkway		Winter survey: 17, 18 August 2017
Sooty Owl (*Tyto tenebricosa*)	V	-	Nocturnal call playback	12 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	April to August (Breeding)	Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 and 31 March 2017 3, 4 May 2017
			Spotlight transects	18 person hours			
			Stag watches and spotlight transects	4 person hours	Wakehurst Parkway		Winter survey: 17, 18 August 2017

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Eastern Pygmy-possum (*Cercartetus nanus*)	V	-	Hair Tubes	560 trap nights (14 nights with 40 hair tubes (50 millimetres))	Wakehurst Parkway Flat Rock Reserve Burnt Bridge Creek Deviation	January to March and October to December	Targeted surveys: 19 April to 2 May 2017 (13 nights) Nest boxes established 23 March 2017 (12 weeks) and checked for presence on 31 March 2017, and again on 17 and 18 August 2017 Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 and 31 March 2017 3, 4 May 2017
			Nest boxes	12 weeks (12 nest boxes installed on 23 March 2017)			
			Camera traps	16 trap nights (4 nights and 4 cameras)			
			Spotlight transects	18 person hours			
New Holland Mouse *(Pseudomys novaehollandiae)*	-	V	Elliot traps	400 trap nights (4 nights with 100 Elliot traps)	Wakehurst Parkway	N/A	Targeted surveys: 19 April to 2 May 2017 (13 nights)
			Hair Tubes	1120 trap nights (28 nights with 40 hair tubes (90 millimetres))			
Spotted-Tailed Quoll (*Dasyurus maculatus maculatus*)	V	E	Camera traps	24 trap nights (4 nights with 6 cameras)	Wakehurst Parkway	N/A	Targeted surveys: 19 April to 2 May 2017 (13 nights)
			Wire cage traps	48 trap nights (4 nights with 12 cages)			

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Southern Brown Bandicoot (*Isoodon obesulus obesulus*)	E	E	Hair Tubes	1120 trap nights (28 nights with 40 hair tubes (90 millimetres))	Wakehurst Parkway Flat Rock Reserve	All year	Targeted surveys: 19 April to 2 May 2017 (13 nights)
			Camera traps	420 trap nights (30 nights with 14 cameras)			
			Wire cage traps	48 trap nights (4 nights with 12 cages)			
Koala (*Phascolarctos cinereus*)	V	V	Scat searches (Spot Assessment Technique (SAT))	15 Spot Assessments using the SAT	Wakehurst Parkway and Burnt Bridge Creek deviation	All year	In conjunction with Threatened Flora surveys: 10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017
			Habitat assessment	7 habitat assessments			
			Spotlight transects	21 person hours			

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
			Camera traps	128 trap nights (16 nights with 8 cameras)			Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 and 31 March 2017 3, 4 May 2017 15, 22 June and 1 July 2021 Threatened fauna surveys: 19 April to 4 May 2017 17, 18 August 2017 SAT surveys and camera traps (Arcadis): 17, 22 June and 1 July 2021
Grey-headed Flying-fox (*Pteropus poliocephalus*)	V	V	Spotlight transects	18 person hours	Wakehurst Parkway Flat Rock Reserve Artarmon	October to December (breeding)	In conjunction with Threatened Flora surveys: 10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 and 31 March 2017 3, 4 May 2017 Threatened fauna surveys: 19 April to 4 May 2017 17, 18 August 2017
			Opportunistic sightings	210 person hours (42 days)			

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements[#]	Survey timing
Large-eared Pied Bat (*Chalinolobus dwyeri*)	V	V	Anabat (acoustic detection)	16 recording nights	Wakehurst Parkway Artarmon Burnt Bridge Creek Deviation Flat Rock Reserve	November to January	Targeted surveys (Anabat nights): 12 May 2016 23 March 2017 24 March 2017 28 March 2017 3 May 2017 4 May 2017 19 October 2018 17 December 2020 13-16 January 2020 (3 nights) 20-24 January 2020 (4 nights) 28-29 January 2020 (1 night)
			Roost search	30 person hours	Wakehurst Parkway	November to January	Targeted surveys: 17 December 2020 7 January 2020
			Harp trapping	16 trap nights (6 nights with 2 traps, 1 night with 3 traps, 1 night with 1 trap)		November to January	Targeted surveys (trap nights): 13-16 January 2020 (3 nights) 20-24 January 2020 (4 nights) 28-29 January 2020 (1 night)

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Little Bent-winged Bat (*Miniopterus australis*)	V	-	Anabat (acoustic detection)	6 recording nights	Wakehurst Parkway Artarmon Burnt Bridge Creek Deviation Flat Rock Reserve	December to February (Breeding)	Targeted surveys (Anabat nights): 12 May 2016 23 March 2017 24 March 2017 28 March 2017 3 May 2017 4 May 2017 19 October 201
			Stag watches (culverts)	9 person hours			
Large Bent-winged Bat (*Miniopterus orianae oceanensis*)	V	-	Anabat (acoustic detection)	6 recording nights	Wakehurst Parkway Artarmon Burnt Bridge Creek Deviation Flat Rock Reserve	December to February (Breeding)	Targeted surveys (Anabat nights): 12 May 2016 23 March 2017 24 March 2017 28 March 2017 3 May 2017 4 May 2017 19 October 2018
			Stag watches (culverts)	9 person hours			

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements[#]	Survey timing
Eastern Coastal Free-tailed Bat (*Micronomus norfolkensis*)	V	-	Anabat (acoustic detection)	6 recording nights	Wakehurst Parkway Artarmon Burnt Bridge Creek Deviation Flat Rock Reserve	N/A	Targeted surveys (Anabat nights): 12 May 2016 23 March 2017 24 March 2017 28 March 2017 3 May 2017 4 May 2017 19 October 2018
Southern Myotis (*Myotis macropus*)	V	-	Anabat (acoustic detection)	6 recording nights	Wakehurst Parkway Artarmon Burnt Bridge Creek Deviation Flat Rock Reserve	October to March	Targeted surveys (Anabat nights): 12 May 2016 23 March 2017 24 March 2017 28 March 2017 3 May 2017 4 May 2017 19 October 2018
			Stag watches (culverts)	9 person hours			

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements[#]	Survey timing
Greater Broad-nosed Bat (*Scoteanax rueppellii*)	V	-	Anabat (acoustic detection)	6 recording nights	Wakehurst Parkway Artarmon Burnt Bridge Creek Deviation Flat Rock Reserve	N/A	Targeted surveys (Anabat nights): 12 May 2016 23 March 2017 24 March 2017 28 March 2017 3 May 2017 4 May 2017 19 October 2018
Broad-headed Snake (*Hoplocephalus bungaroides*)	E	V	Spotlight transects	18 person hours	Wakehurst Parkway Flat Rock Reserve Burnt Bridge Creek Deviation	August and September (breeding)	In conjunction with Threatened Flora surveys: 10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 & 31 March 2017 3, 4 May 2017 Threatened fauna surveys: 19 April to 4 May 2017 17, 18 August 2017
			Opportunistic sightings	210 person hours (42 days)			

Species	BC Act status*	EPBC Act status*	Survey technique	Survey effort	Survey location	Seasonal survey requirements#	Survey timing
Rosenberg's Goanna (*Varanus rosenbergi*)	V	-	Diurnal hand searches and visual searches (30 minute search)	2 person hours	Wakehurst Parkway	N/A	In conjunction with threatened flora surveys: 10 and 12 May 2016 5-8, 11-12 July 2016 19-21 and 24-27 October 2016 28-29 November 2016 14-15 February 2017 18 May 2017 Targeted spotlighting surveys: 10 and 12 May 2016 23, 24, 28 & 31 March 2017 3, 4 May 2017 Threatened fauna surveys: 19 April to 4 May 2017 17, 18 August 2017
			Opportunistic sightings	210 person hours (42 days)			

* V=Vulnerable, E=Endangered, CE=Critically Endangered
# Optimal time of year for survey is based on survey months provided in TBDC

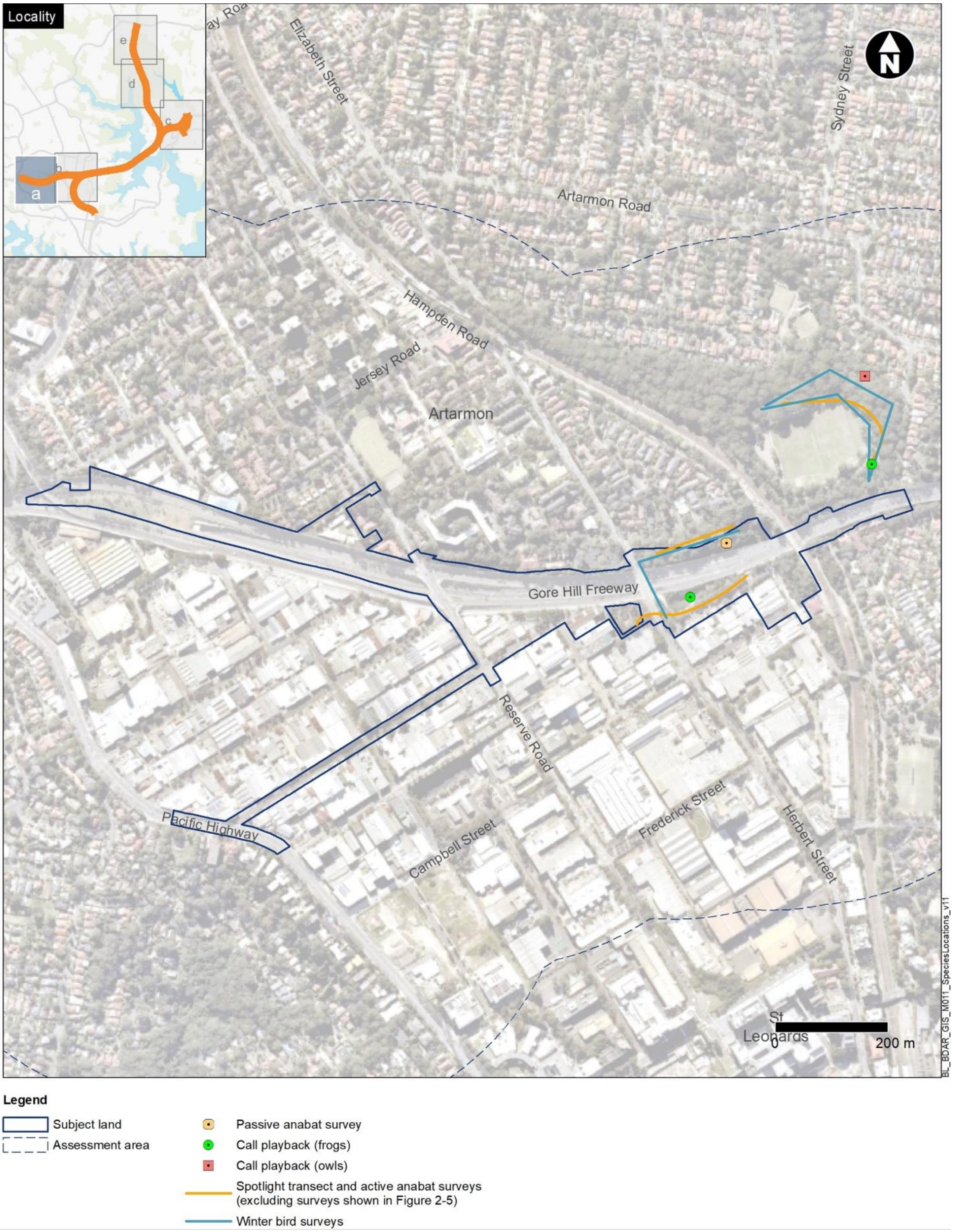


Figure 2-5 Threatened species survey locations (map a)

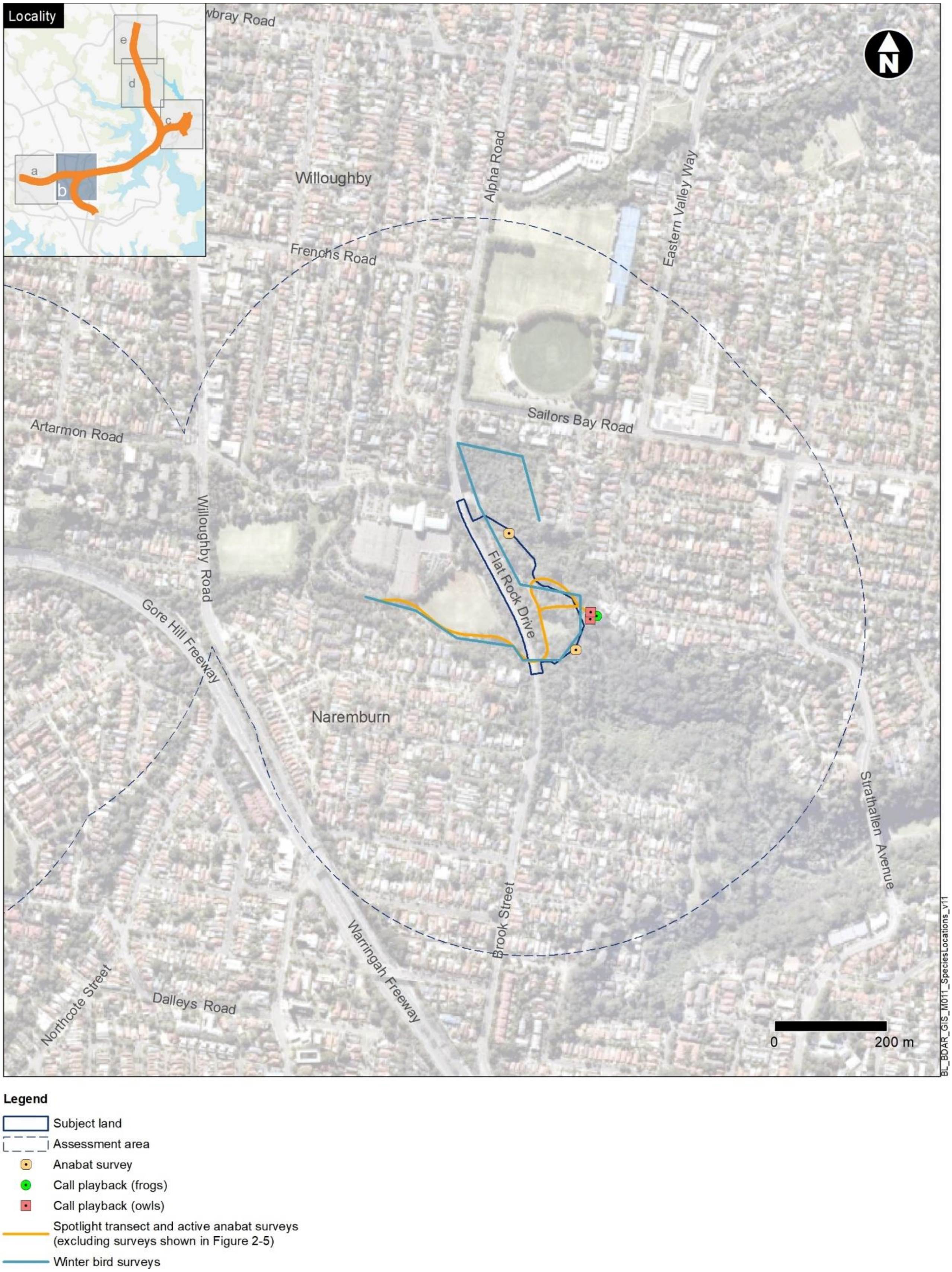


Figure 2-5 Threatened species survey locations (map b)

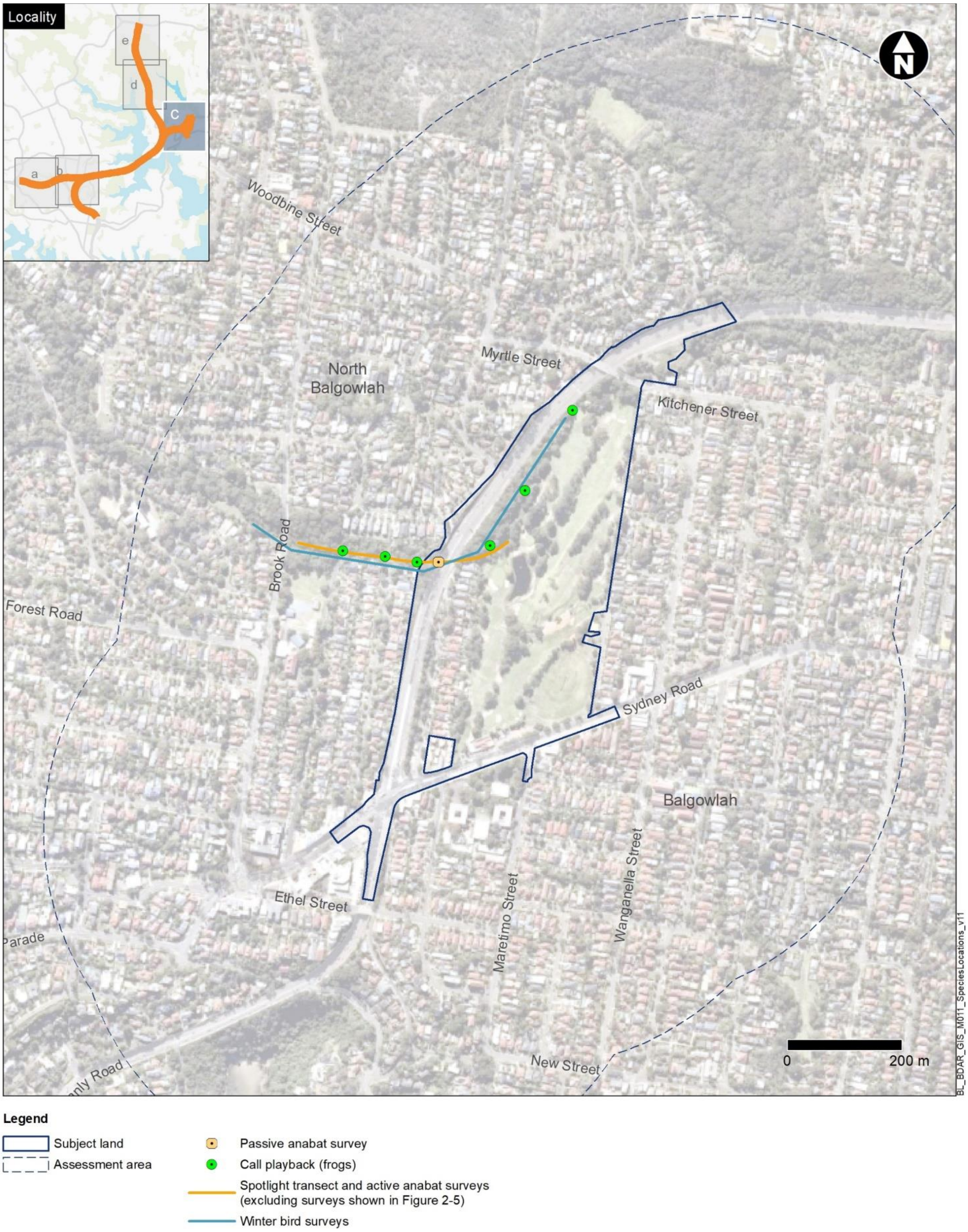


Figure 2-5 Threatened species survey locations (map c)

Legend

- Subject land
- Assessment area
- Call playback (frogs)
- Call playback (owls)
- Herpetofauna search
- Wire cage traps
- Nest boxes
- Koala scat searches (SAT)
- Camera traps
- Trap and Hair-tube line
- Spotlight transect and active anabat surveys (excluding surveys shown in Figure 2-5)
- Winter bird surveys

Figure 2-5 Threatened species survey locations (map d)

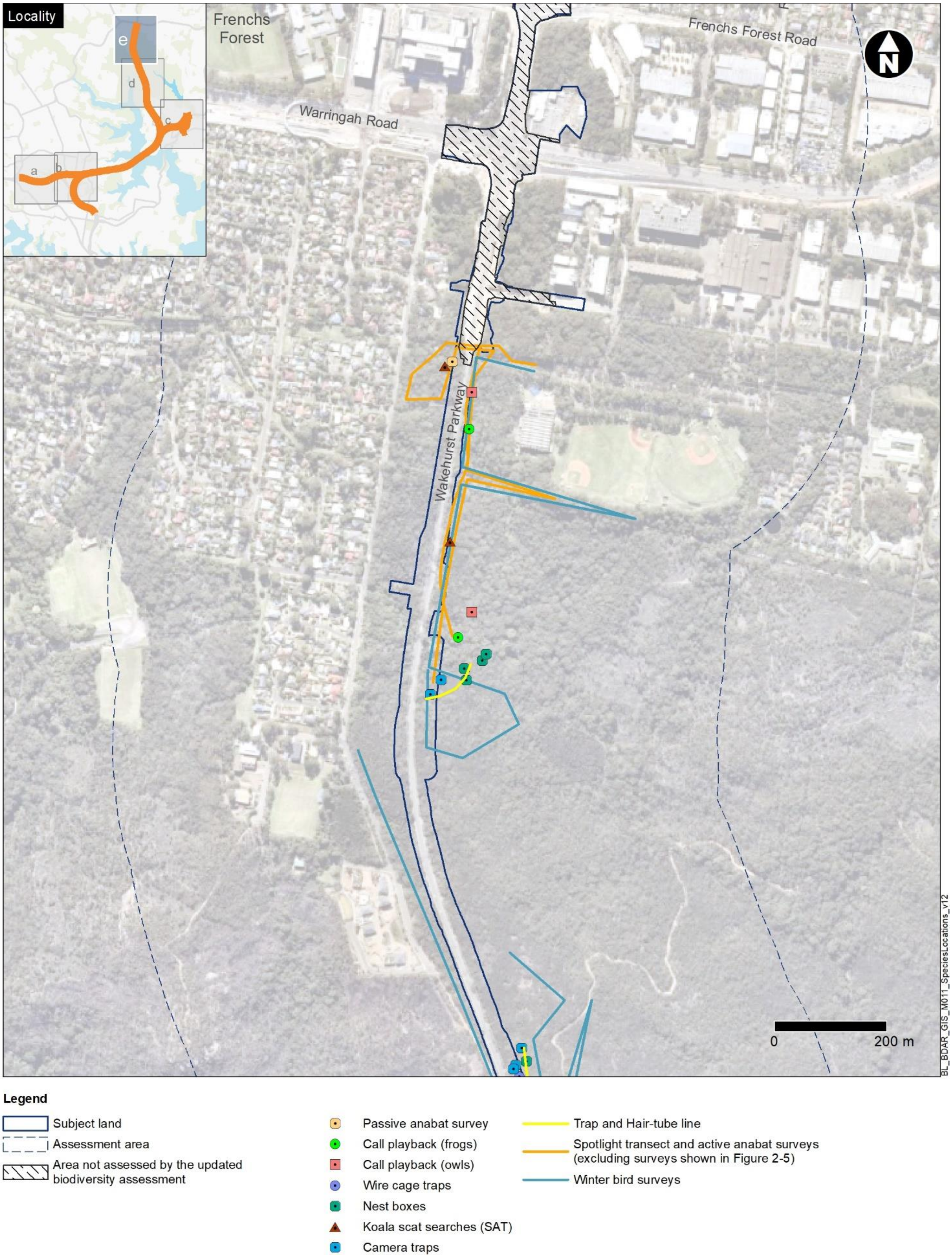


Figure 2-5 Threatened species survey locations (map e)

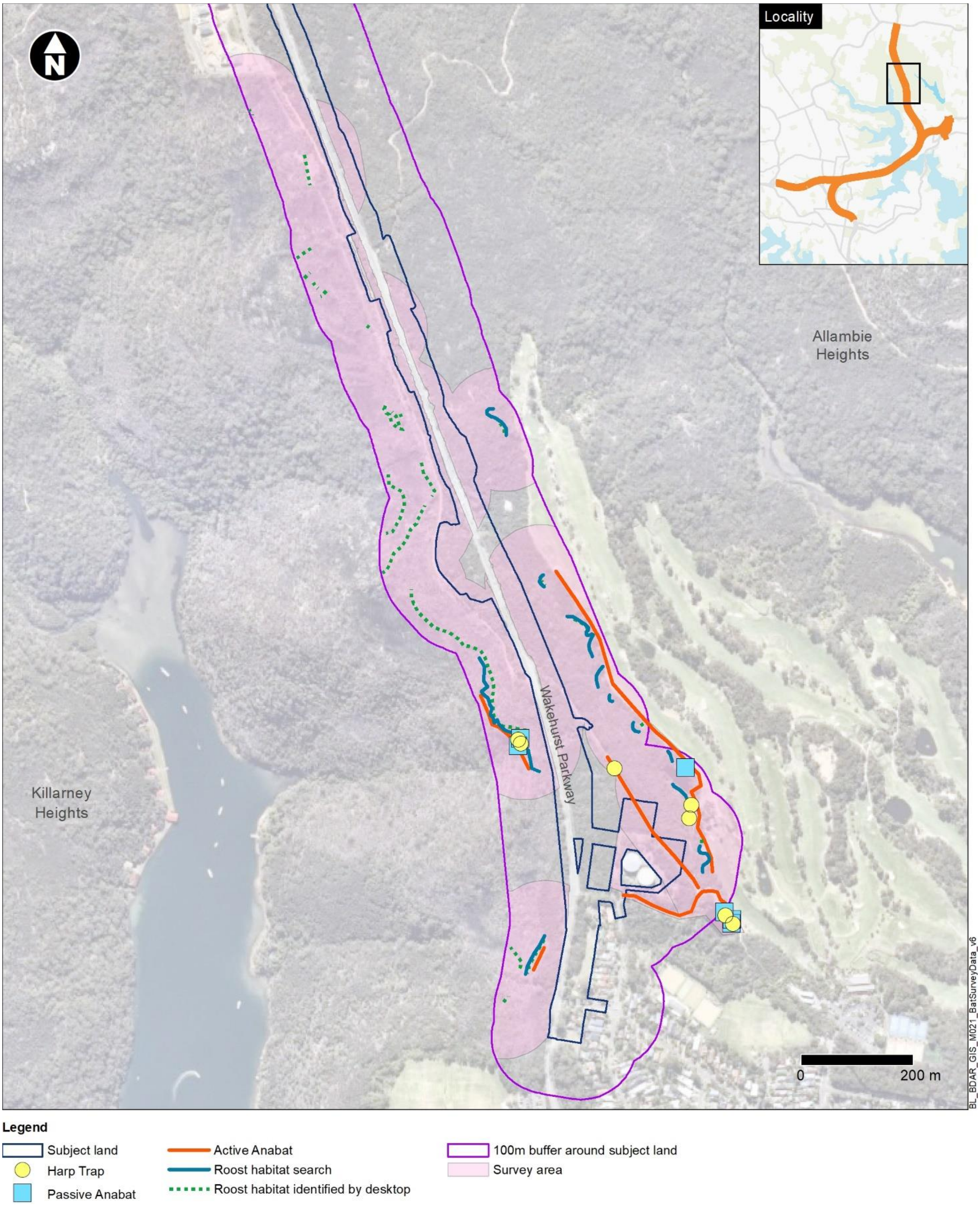


Figure 2-6 Targeted surveys for Large-eared Pied Bat (*Chalinolobus dwyeri*)

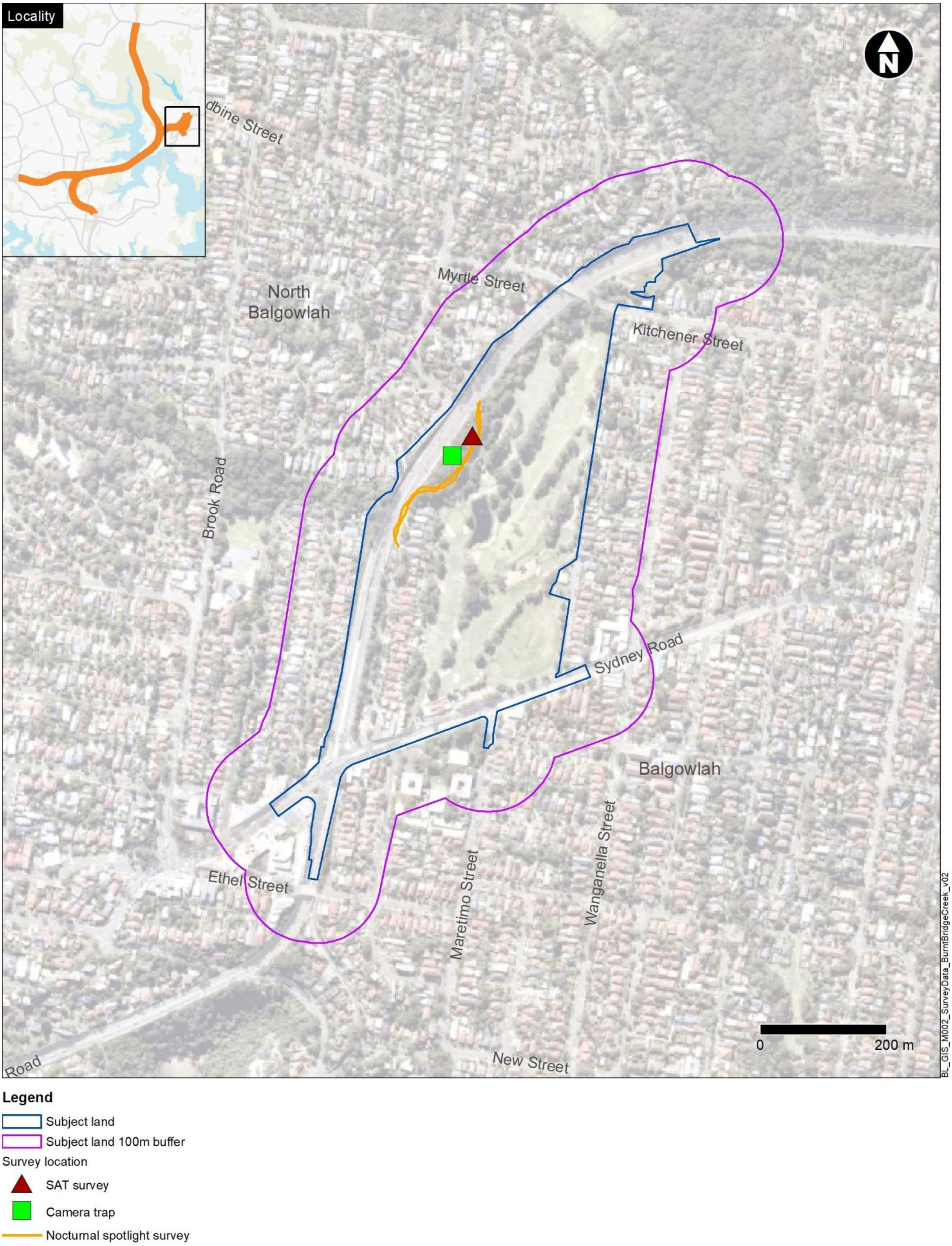
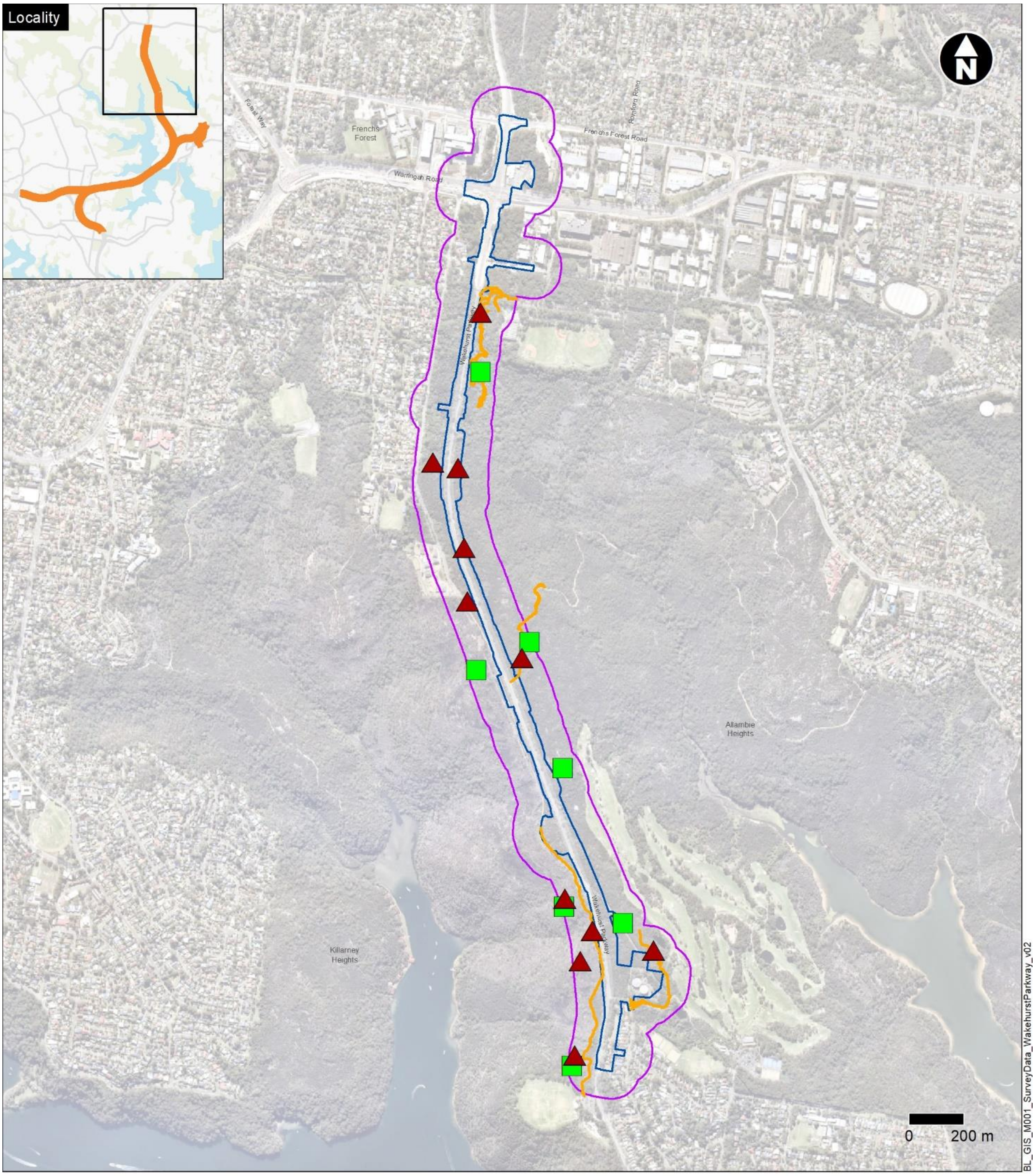


Figure 2-7 Targeted surveys for Koala (Phascolarctos cinereus) (map a)



Legend

Subject land

Subject land 100m buffer

Survey location

SAT survey

Camera trap

Nocturnal spotlight survey

Figure 2-7 Targeted surveys for Koala (Phascolarctos cinereus) (map b)

2.7 Fauna habitat assessment

2.7.1 Terrestrial habitat assessment

Habitat assessments were carried out to assess the likelihood of threatened species (those species known or predicted to occur within the locality, as identified during the literature and database searches) to occur within the subject land.

Habitat characteristics assessed included:

- Structure and floristics of the canopy, understorey and ground vegetation, including the presence of flowering and fruiting trees providing potential foraging resources
- Presence of hollow-bearing trees providing roosting and breeding habitat for arboreal mammals, birds and reptiles
- Presence of the ground cover vegetation, leaf litter, rock outcrops and fallen timber and potential to provide protection for ground-dwelling mammals, reptiles and amphibians
- Presence of waterways (ephemeral or permanent) and water bodies.

2.7.2 Intertidal habitat assessment

Ground truthing of the distribution of intertidal habitats was carried out by Arcadis ecologists on 5 July 2018. The purpose of this ground truthing was to verify the presence of habitats that may be used by threatened shorebirds and waders, including mud and sandflats, rocky shores and mangroves.

2.7.3 Aquatic habitat assessment

A freshwater aquatic habitat assessment has been completed by Cardno (2020a) (Annexure D).

The freshwater aquatic habitat assessment was based on water quality and geomorphology studies carried out for *Beaches Link and Gore Hill Freeway Connection Technical working paper: Surface water quality and hydrology* (Jacobs, 2020a). The assessment was informed by the results of inspections carried out at 13 locations across the six waterways (or their catchments) that fall within the subject land: Willoughby Creek, Flat Rock Creek, Burnt Bridge Creek, Manly Creek, Manly Dam and Trefoil Creek. Site names and location details are listed in Table 2.7 and described in detail in Annexure D. The sites included a 100 metre reach of waterway centred at each location point.

WSP ecologists also visited Flat Rock Creek and Burnt Bridge Creek in spring/summer of 2016, and the description of these waterways, as provided in *HarbourLink Terrestrial Biodiversity Survey Report* (WSP, 2018), has been incorporated into this updated biodiversity assessment.

Table 2.7 Locations of waterway inspections

Site code	Site name	Site location relative to subject land
2b	Willoughby Creek downstream	Downstream of the subject land
3a	Burnt Bridge Creek upstream	Upstream of the subject land
3b	Burnt Bridge Creek downstream	Downstream of the subject land
3c, 3d and 3e	Burnt Bridge Creek along the proposed realignment	Along the length of the subject land
5a	Flat Rock Creek upstream	Upstream of the subject land

Site code	Site name	Site location relative to subject land
5b	Flat Rock Creek downstream	Downstream of the subject land, upstream of Quarry Creek
5c	Flat Rock Creek downstream	Downstream of the subject land and site 5b
5d	Existing aboveground watercourse within the northern extent of Flat Rock Reserve	Along the north-eastern boundary of the Flat Rock Drive construction support site (BL2)
6b	Manly Dam mid-dam	Downstream of the subject land
6c	Manly Dam wall	Downstream of the subject land and 6b
7b	Manly Creek downstream	Downstream of the subject land and upstream of Manly Dam
8b	Trefoil Creek downstream	Downstream of the subject land
9	Wakehurst Golf Course dam	Downstream of the Wakehurst Parkway east construction support site (BL13)

In addition, following exhibition of the environmental impact statement, targeted field survey of freshwater ecology at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek was carried out in May 2021 to inform a revised assessment of potential impacts on freshwater ecology from predicted groundwater baseflow reductions. The field survey and revised assessment was completed by Cardno and is documented in Attachment A of Annexure G. Relevant information from the field survey and revised assessment has been incorporated into this updated biodiversity assessment and have been used to update information provided in Annexure D where required.

2.7.4 Marine habitat assessment

A separate report has been prepared that describes the marine environments within the subject land and assesses potential impacts of the project on marine fauna species that may inhabit these environments (refer to the *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b)) provided as Appendix T of the Beaches Link and Gore Hill Freeway Connection project environmental impact statement). The information presented in this technical paper that is relevant to wandering seabirds, shorebirds and Little Penguin has been incorporated in this updated biodiversity assessment where relevant.

2.8 Personnel

This updated biodiversity assessment has been prepared by Arcadis ecologists Kate Carroll and Jane Rodd, Andrew Cook (South Swell) and Georgina Cowley (Arcadis). Early iterations of the *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) were prepared/reviewed by personnel listed in Table 2.8 . An overview of the qualifications and roles of all personnel involved in the preparation of the updated biodiversity assessment and *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) are provided in Table 2.8. This updated biodiversity assessment has been substantially informed by habitat assessments and field investigations conducted by WSP (2018), with content from WSP incorporated primarily into Sections 2 and 3 of this updated biodiversity assessment. Arcadis has carried out additional or supplementary field investigations where required.

All work was carried out under the appropriate licences, including scientific licences as required under Part 2 of the BC Act.

Table 2.8 Personnel involved in preparation of biodiversity assessment

Personnel	Qualifications	Role
Jane Rodd	Bachelor of Science (Ecology), BAM accredited assessor (No. BAAS17030)	Senior Ecologist – site inspections, report preparation
Laura Hoffman	Bachelor of Science (Hons) (Ecology)	Senior Ecologist – site inspections, report preparation
Kate Carroll	Bachelor of Science (Hons) (Ecology), BAM accredited assessor (No. BAAS17070)	Senior Ecologist – site inspections, report preparation
Sian Tetther	Bachelor of Science	Graduate Ecologist – report preparation
Peter Rand	Bachelor of Applied Science	Environment Technical Director – report review
Dr Elvira Lanham	Bachelor of Environmental Science (Life Sciences), PhD (Ecology and Evolutionary Biology), BAM accredited assessor (No. BAAS20012)	Principal Ecologist – report review
Nathan Banks	Bachelor of Zoology	Ecologist – field surveys, report preparation
Jessica Rooke	Bachelor of Science (Advanced) (Hons)	Ecologist – field surveys
Carl Cordern	Bachelor of Environmental Management	Ecologist – field surveys
Taylor Bliss-Henaghan	Bachelor of Science (Zoology), Master of Conservation Biology	Graduate Ecologist – field surveys, report preparation
Kristen Branks	Bachelor of Science (Physical Geography/Geology), Master of Science (Environmental Earth Science)	Graduate Environmental Consultant – field surveys
Rittick Borah	Bachelor of Science (Hons), Masters of Remote Sensing and GIS	GIS
Ryan McManus	Bachelor of Science (Environmental Management and SIS)	GIS
Georgina Cowley	Bachelor of Marine Science	GIS
Selga Harrington (WSP)	Bachelor of Science (Hons), BAM accredited assessor	External report review
Caitlin Bennett (Jacobs)	Bachelor of Science (Environmental Biology), Master of Urban and Regional Planning, City/Urban, Community and Regional Planning	Principal Environmental Planner – report review
Andrew Cook (South Swell)	Bachelor of Applied Science (Fisheries)	Director – report review

2.9 Biodiversity impact calculations

The biodiversity impacts of the project have been calculated in accordance with the BAM (OEH, 2017a), using the BAM credit calculator or the relevant equations specified in the BAM. The impacts of a development and gains in biodiversity values at biodiversity stewardship sites are measured in biodiversity credits. Credits are calculated based on three primary factors:

- The biodiversity risk weighting that applies to the PCT, TEC or threatened species
- The condition of the PCT, TEC or threatened species habitat to be cleared, based on the vegetation integrity score calculated for the vegetation zone(s)
- The area of habitat or number of individuals to be cleared.

For flora species credits that are calculated based on number of individuals, only the biodiversity risk weighting and number of individuals are used to calculate credit values.

The biodiversity risk weighting applied to each PCT, TEC or threatened species is used to evaluate the ecological risks to threatened entities from the biodiversity offsets scheme. Biodiversity risk weightings range from 1 (low) to 3 (very high). Biodiversity risk weightings range from 1 (low) to 3 (very high). The biodiversity risk weighting is comprised of two components (OEH, 2017a):

- Sensitivity to loss – this considers the increased threat posed to an entity from offsetting the loss of habitat or population, and
- Sensitivity to potential gain – this considers the ability of a species to respond to improvements in habitat condition at an offset site.

The vegetation integrity score is a measure of the condition of native vegetation and is assessed for each vegetation zone by calculating the scores for a range of condition attributes collected in plots within the vegetation zone against the benchmark values for the associated PCT. The further assessment of native vegetation is not required beyond Section 5.4 of the BAM (OEH, 2017a), and an assessment of threatened species habitat according to Section 6.2 and Paragraph 6.2.1.4 of the BAM (OEH, 2017a) is not required if an assessor determines that a PCT has a vegetation integrity of:

- Less than 15 if the PCT is a Critically Endangered Ecological Community (CEEC) or Endangered Ecological Community (EEC)
- Less than 17 if the PCT is threatened species habitat or vulnerable ecological community, or
- Less than 20 if the PCT is not representative of a TEC or associated with threatened species habitat.

The calculation of biodiversity risk weighting and vegetation integrity scores are described in further detail in the BAM (OEH, 2017a).

2.10 Limitations

Limitations of this updated biodiversity assessment are as follows:

- This assessment is based on the condition of the subject land at the time of field investigations and the project design and constructability at the date of publication of this document
- This updated biodiversity assessment considers terrestrial flora and fauna, reptiles and seabirds only. Freshwater and marine fish, mammals and reptiles have been assessed separately by a qualified and experience aquatic ecologist. The freshwater aquatic assessment is provided in Annexure D of this report, while the marine aquatic assessment is appended to the environmental impact statement. The results of these assessments have been included in this updated biodiversity assessment where relevant (ie where results pertain to shorebirds, wandering seabirds and the Little Penguin)
- Assessment of the biodiversity values of the Port of Newcastle construction support site (BL15) were limited to desktop only with no field verification carried out
- Targeted surveys for the Large-eared Pied Bat were constrained by the absence of optimal locations for placement of the harp traps. To optimise the chance of trapping microbats, traps

need to be placed in a regular microbat flyway that funnels bats into the trap. The ridgetop location of much of the potential habitat meant that such 'flyway funnels' were scarce, with bats generally flying well above the canopy and ridgetops. Harp traps were moved to different locations to increase the probability of capture and were placed in areas chosen as most likely to capture microbats. They were placed adjacent to rocky features containing potential roost habitat, in a power line easement, an access track and in clearings adjacent to dams. No microbats were caught in the traps though microbat activity was observed on detectors

- Some light rain occurred during and prior to Koala SAT surveys in June/July 2021. Rain can wash away and/or break down scat, though scat observed on site was generally observed to be intact during SAT surveys.

The limitations on other field assessments identified by WSP (2018) are as follows:

- Detailed desktop assessment was carried out before field surveys to identify the threatened biodiversity likely to occur in the locality and determine the field survey effort required for the scale of the project and its ecological context for a constraint's assessment. However, the precise range of habitats used by some species is not well understood. Furthermore, the discovery of previously unknown populations of threatened species, even well outside their known range, is always possible. This applies particularly to cryptic species of plants and animals and plant species which can persist as soil seedbanks and easily go undetected despite intensive survey (WSP, 2018)
- No sampling technique can totally eliminate the possibility that a species is present within the subject land. For example, some species of plant may be present in the soil seed bank and some fauna species use habitats on a sporadic or seasonal basis and may not be present within the subject land during surveys. As the actual distribution and the range of habitat used by some species is not fully understood, there is always a small possibility that other species could occur within the study despite being considered to have a low likelihood of occurrence based on their known range and known habitats (WSP, 2018)
- Access was restricted within some parts of the subject land (eg steep cliffs, private properties), and subsequently, some areas could not be inspected and therefore potential biodiversity values in these locations could not be verified. Where access on foot was restricted or limited but adjacent areas were accessible, vegetation community boundaries, condition and threatened flora and fauna habitat attributes were determined from a distance, often with the aid of binoculars. Where the vegetation could not be viewed, existing vegetation mapping of the area, aerial photography and photographs on Google Street View were reviewed
- The conclusions in this report are based upon data acquired for the subject land and the known distribution and habitat preferences of species. The conclusions are, therefore, merely indicative of the likely biodiversity values of the subject land, based on information available at the time of preparing the report, including the presence or otherwise of species. It should be recognised that, as more information becomes available, assessment of the likely presence of threatened species could change with time (WSP, 2018).

3 Existing Environment

Elements of this section of the updated biodiversity assessment have drawn upon *HarbourLink Terrestrial Biodiversity Survey Report* (WSP, 2018).

3.1 Landscape features

The BAM requires the assessment of landscape features to help describe the biodiversity values of the subject land and assess the impacts of the project. Landscape features of the subject land are shown on Figure 3-1 and summarised in Table 3.1.

Table 3.1 Landscape features

Landscape feature	Subject land
IBRA bioregions and subregions	The subject land is located within the Sydney Basin Bioregion and the Pittwater Subregion classified under Interim Biogeographic Regionalisation for Australia (IBRA).
NSW landscape regions (Mitchell landscapes)	The subject land intersects areas of the following Mitchell landscapes: • Belrose Coastal Slopes – 43.68 hectares • Pennant Hills Ridges – 14.26 hectares. The Belrose Coastal Slopes landscape was used in the credit calculator as the majority of the subject land occur within this Mitchell landscape.
Native vegetation extent in the assessment area	A buffer of 500 metres was applied to the subject land, in accordance with the methodology for assessing linear shaped developments. The application of the 500-metre buffer resulted in an assessment area of around 1399 hectares, as shown in Figure 3-1. The current percentage of native vegetation cover in the assessment area, based on OEH (2016) vegetation mapping, is around 26 per cent (around 367 hectares out of the 1399-hectare assessment area).
Cleared areas	The majority of the subject land is highly urbanised and has mostly been cleared and developed for residential, commercial and industrial land uses.
Rivers and streams	Three waterbodies or watercourses (or their catchments) occur within the subject land: • Middle Harbour • Flat Rock Creek (1st order stream upstream of the Quarry Creek confluence and a 2nd order waterway downstream) • Burnt Bridge Creek (1st order stream).
Wetlands	There are no wetlands listed under *State Environmental Planning Policy (Coastal Management) 2018* or wetlands of international importance within or near the subject land. The closest Wetland of International importance (Ramsar) is Towra Point nature reserve, located around 20 kilometres south of the subject land (refer to EPBC Protected Matters Search Tool results in Annexure B). There are minor wetlands downstream of the subject land adjoining Manly Creek.

Landscape feature	Subject land
Connectivity features	There is limited terrestrial habitat connectivity in the subject land, most of which is highly urbanised and is characterised by intensive residential, commercial and industrial land uses. Fully structured native vegetation adjoins the Wakehurst Parkway in the north of the subject land; this vegetation is continuous with larger tracts of native vegetation contained within Garigal National Park (to the west) and Manly Warringah War Memorial State Park (to the east). However, this area of habitat is currently transected by the Wakehurst Parkway, which forms a barrier to the movement of some fauna species.
Areas of geological significance and soil hazard features	The subject land does not include any areas of geological significance, although some rocky areas adjoining the Wakehurst Parkway and Middle Harbour include sandstone outcrops, caves and crevices. The largest area of soil landscape mapped in the subject land is the Lambert soil landscape, mapped along the Wakehurst Parkway (Chapman et al., 2009), which has a very high soil erosion potential, with seasonally perched water tables. The majority of the subject land is not characterised by significant undulating topography and the soil erosion hazard is unlikely to be significant.
Areas of outstanding biodiversity value	Areas of outstanding biodiversity value (AOBVs), as defined under the BC Act, are currently limited to areas previously declared as critical habitat under the TSC Act. There are no AOBVs within the subject land. The closest AOBV is critical habitat for the Little Penguin population in Sydney's North Harbour, around 5.5 kilometres north-east of the subject land.

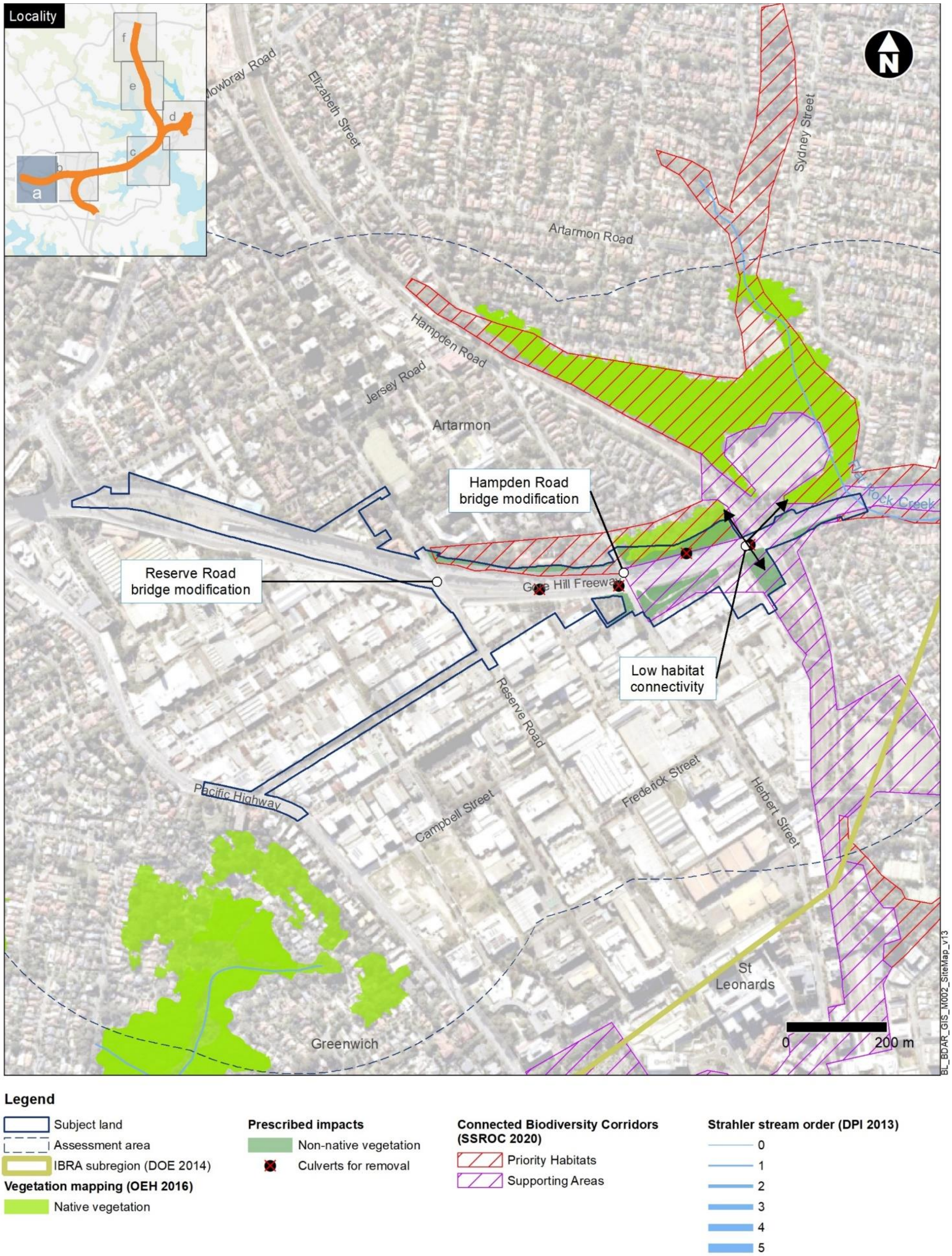


Figure 3-1 Site map (map a)

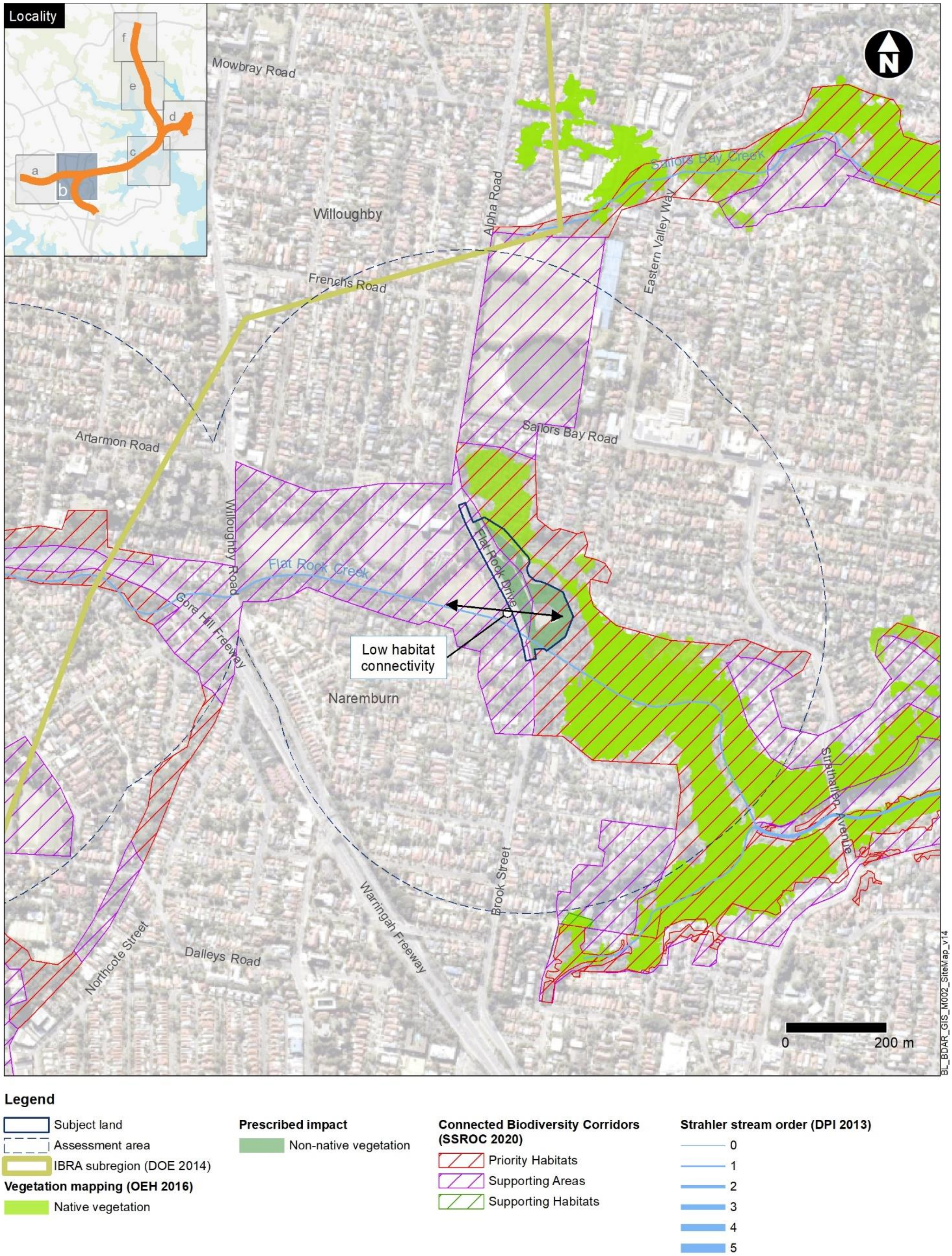


Figure 3-1 Site map (map b)

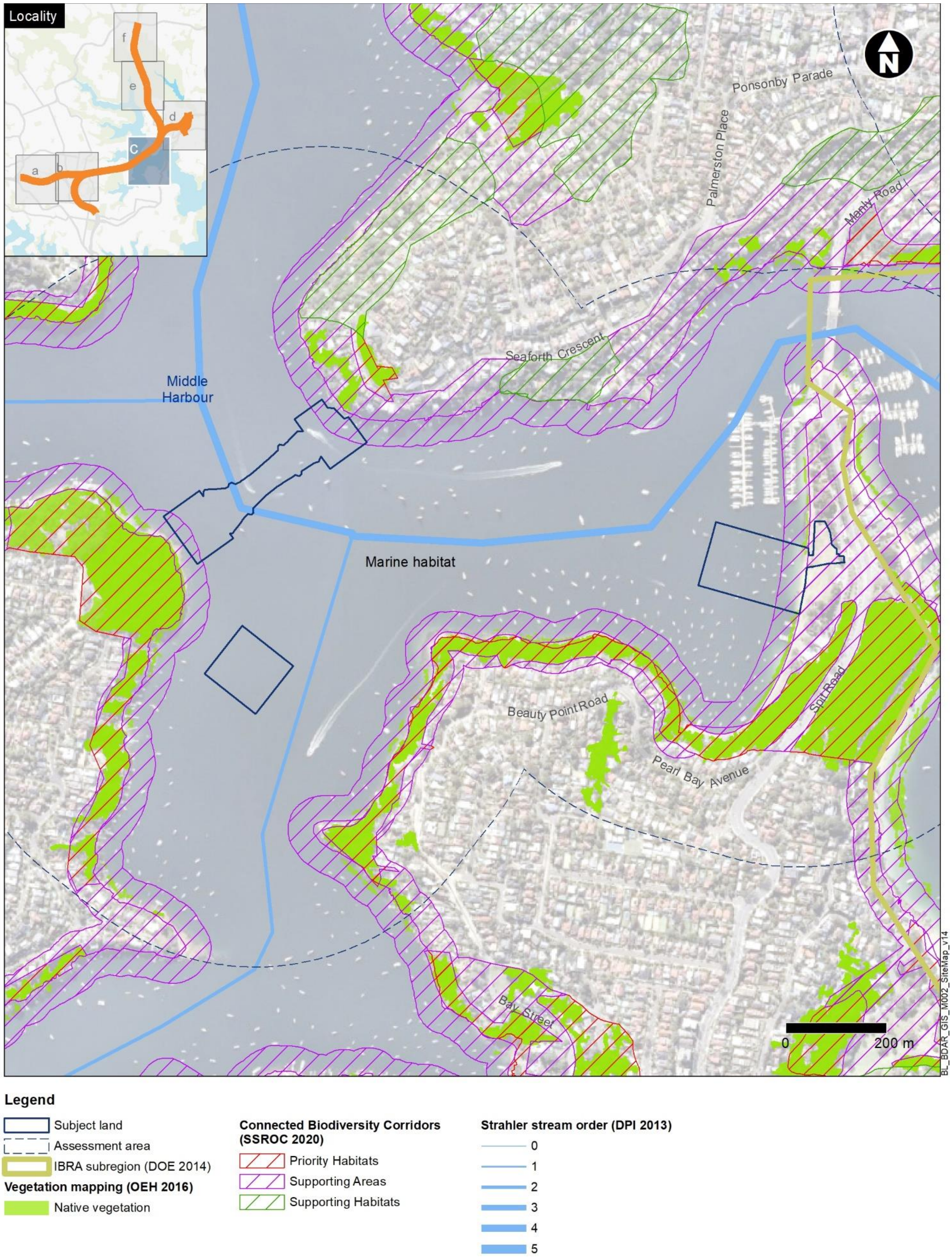


Figure 3-1 Site map (map c)

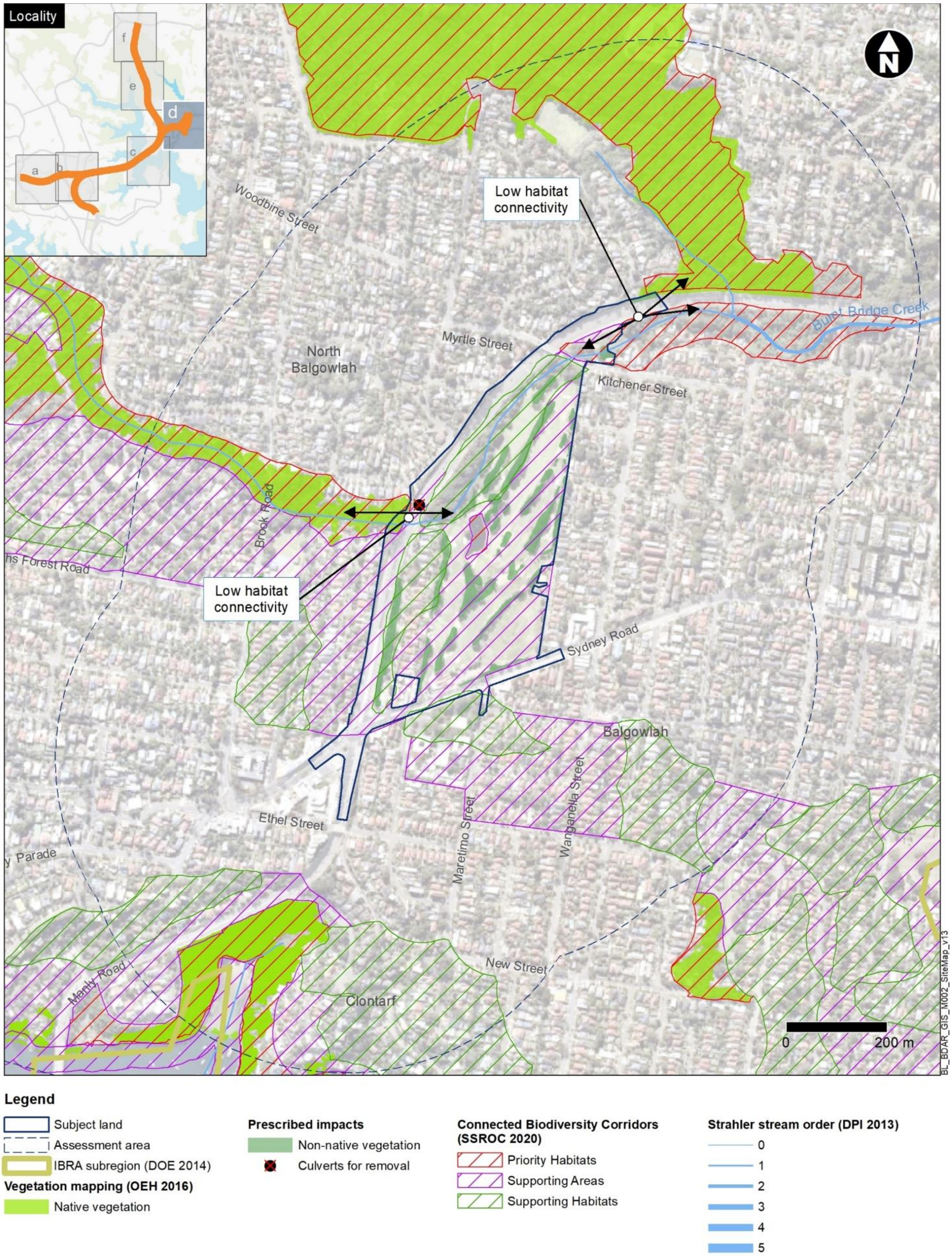


Figure 3-1 Site map (map d)

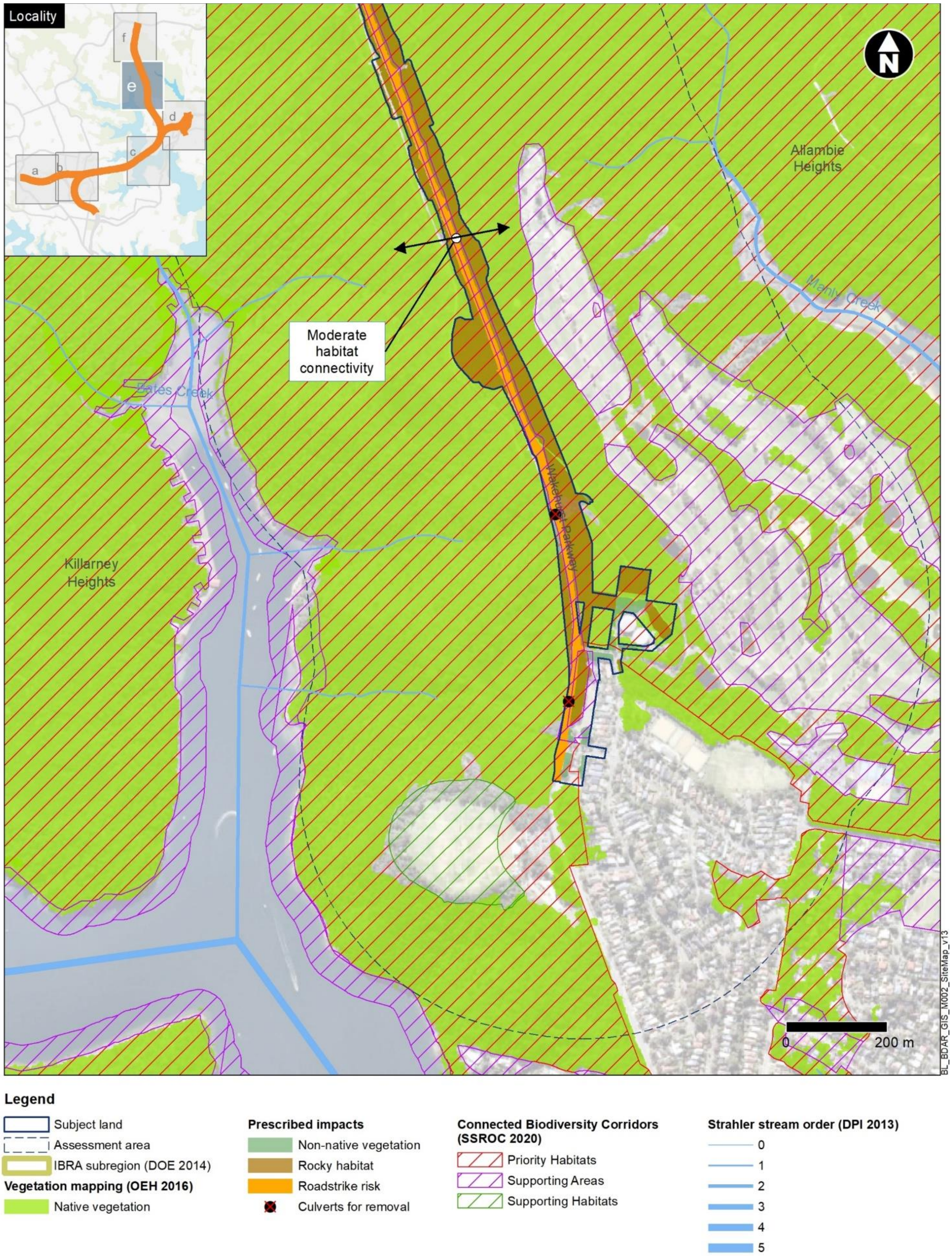


Figure 3-1 Site map (map e)

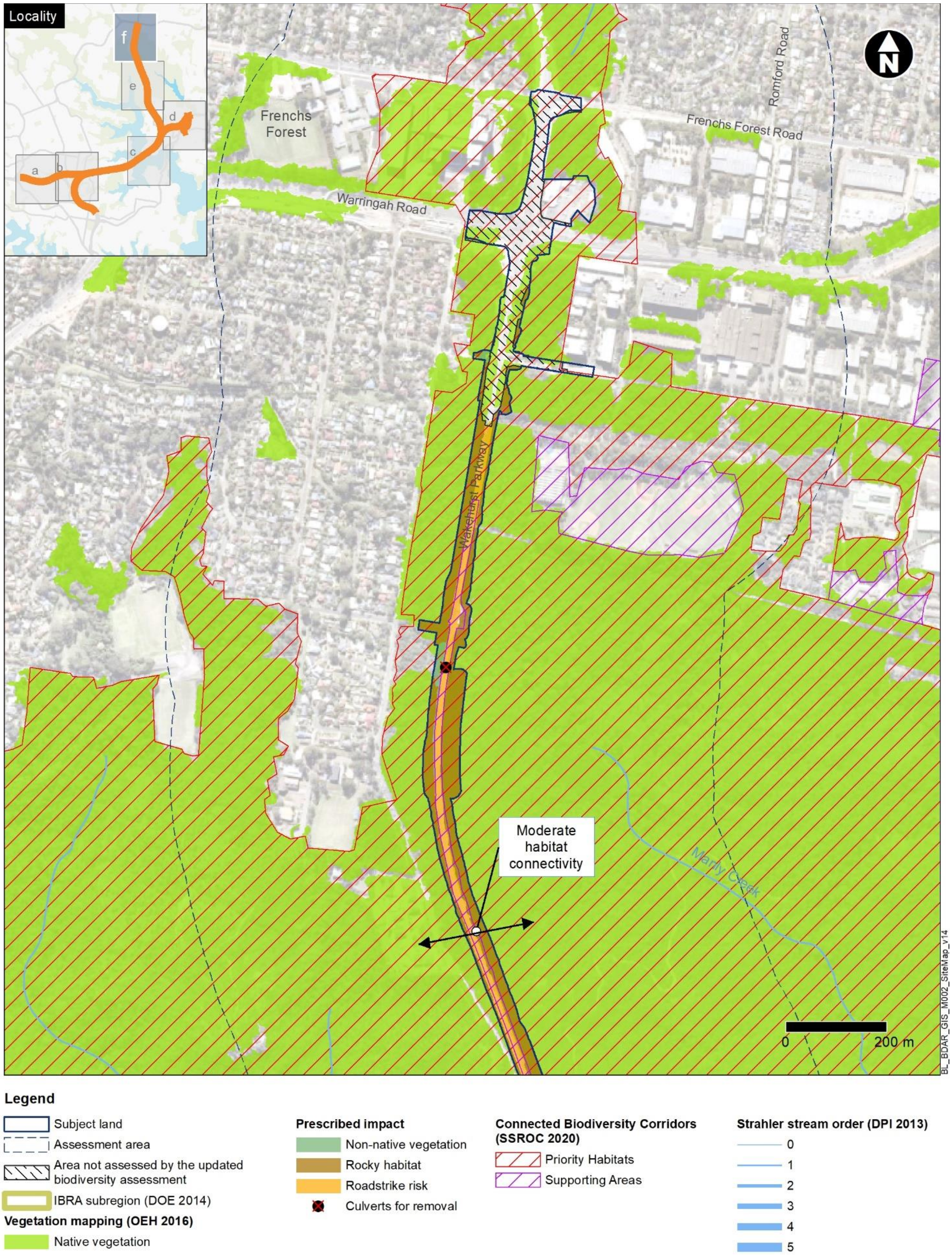


Figure 3-1 Site map (map f)

3.2 Existing vegetation mapping

OEH (2016) mapped the vegetation of the Sydney Metropolitan Catchment Management Authority (CMA) area, which encompasses the subject land. Ten vegetation map units were mapped by OEH (2016) within the subject land, comprising eight native vegetation types and two non-native vegetation types. The vegetation map units mapped within the subject land by OEH (2016), the corresponding PCTs and area within the subject land are listed in Table 3.2 and shown in Figure 3-2. The Urban Exotic/Native vegetation class was applied to polygons greater than 0.1 hectares in size and with a greater than 70 per cent urban land use, with evidence of both exotic and native species in the upper or lower strata. These areas include trees in private residential gardens, street trees in road verges and median strips, and other small isolated stands (OEH, 2016).

Table 3.2 Vegetation mapped in the subject land (OEH, 2016)

OEH (2016) map unit	Corresponding Plant Community Type (PCT)	Area (ha) mapped within the subject land*
S_DSF04: Coastal Enriched Sandstone Dry Forest	PCT 1776: Smooth-barked Apple - Red Bloodwood open forest on enriched sandstone slopes around Sydney and the Central Coast	0.57
S_DSF08: Coastal Sandstone Riparian Forest	PCT 1780: Sydney Peppermint / Coachwood - Water Gum open forest in protected sandstone gullies around Sydney and the Central Coast	0.09
S_DSF09: Coastal Sandstone Gully Forest	PCT 1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	0.66
S_DSF11: Sydney North Exposed Sandstone Woodland	PCT 1783: Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	3.49
S_DSF14: Sydney Ironstone Bloodwood-Silvertop Ash Forest	PCT 1786: Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (EEC)	0.97
S_HL08: Coastal Sandstone Heath-Mallee	PCT 1824: Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	6.78
S_WSF06: Coastal Shale-Sandstone Forest	PCT 1845: Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	1.14
S_SW03: Seagrass Meadows	PCT 1913: Seagrass meadows of the estuaries and lagoons of the New South Wales coast	0.01
Subtotal - native vegetation		**13.71**
Urban_E/N: Urban Exotic/Native	N/A	8.96
Weed_Ex: Weeds and Exotics	N/A	0.60
Total of all vegetation in subject land		**23.27**

*Excludes areas of vegetation mapped within approved footprint of Northern Beaches Hospital road upgrade project

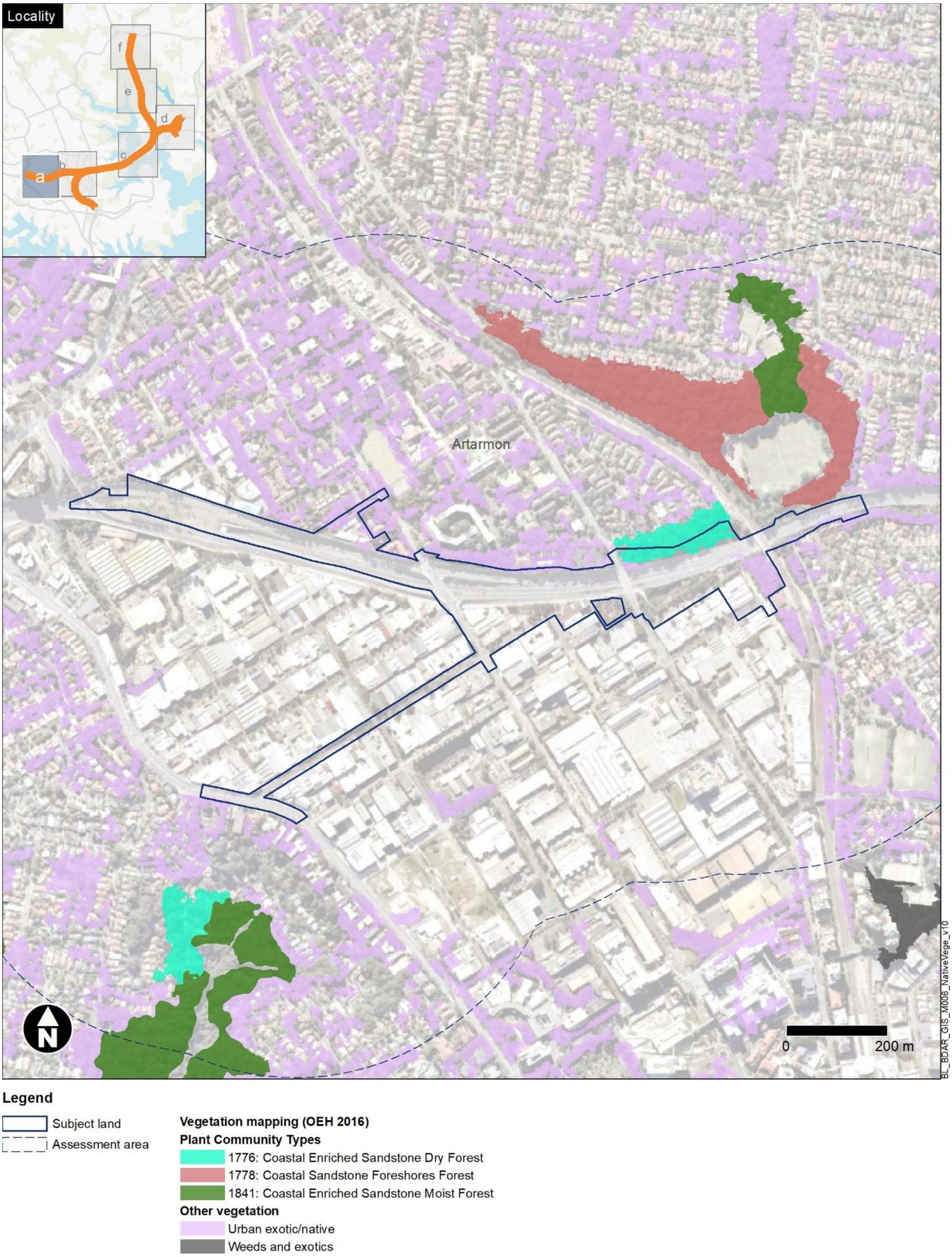


Figure 3-2 Distribution of native vegetation as mapped by OEH (2016) (map a)

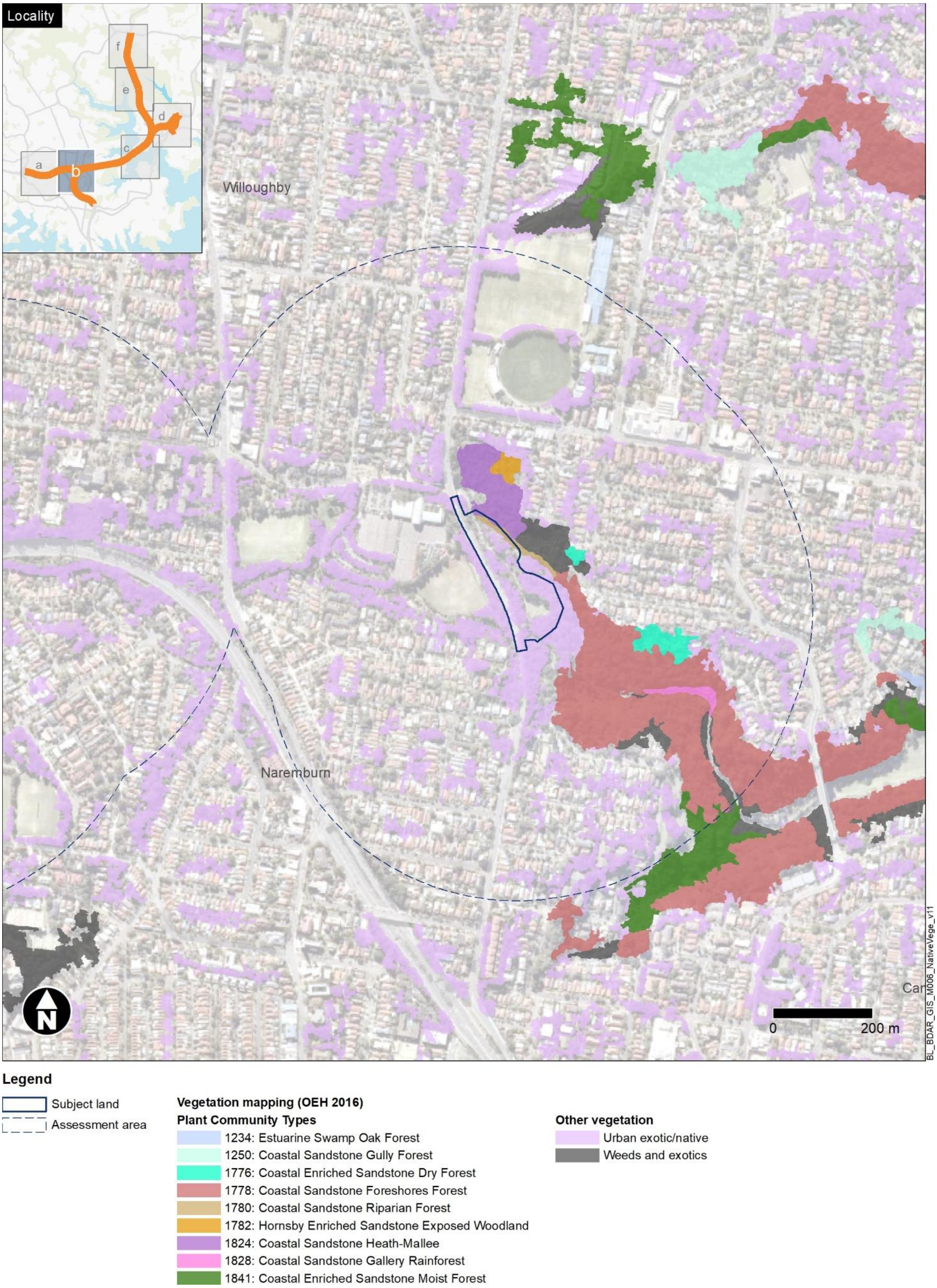
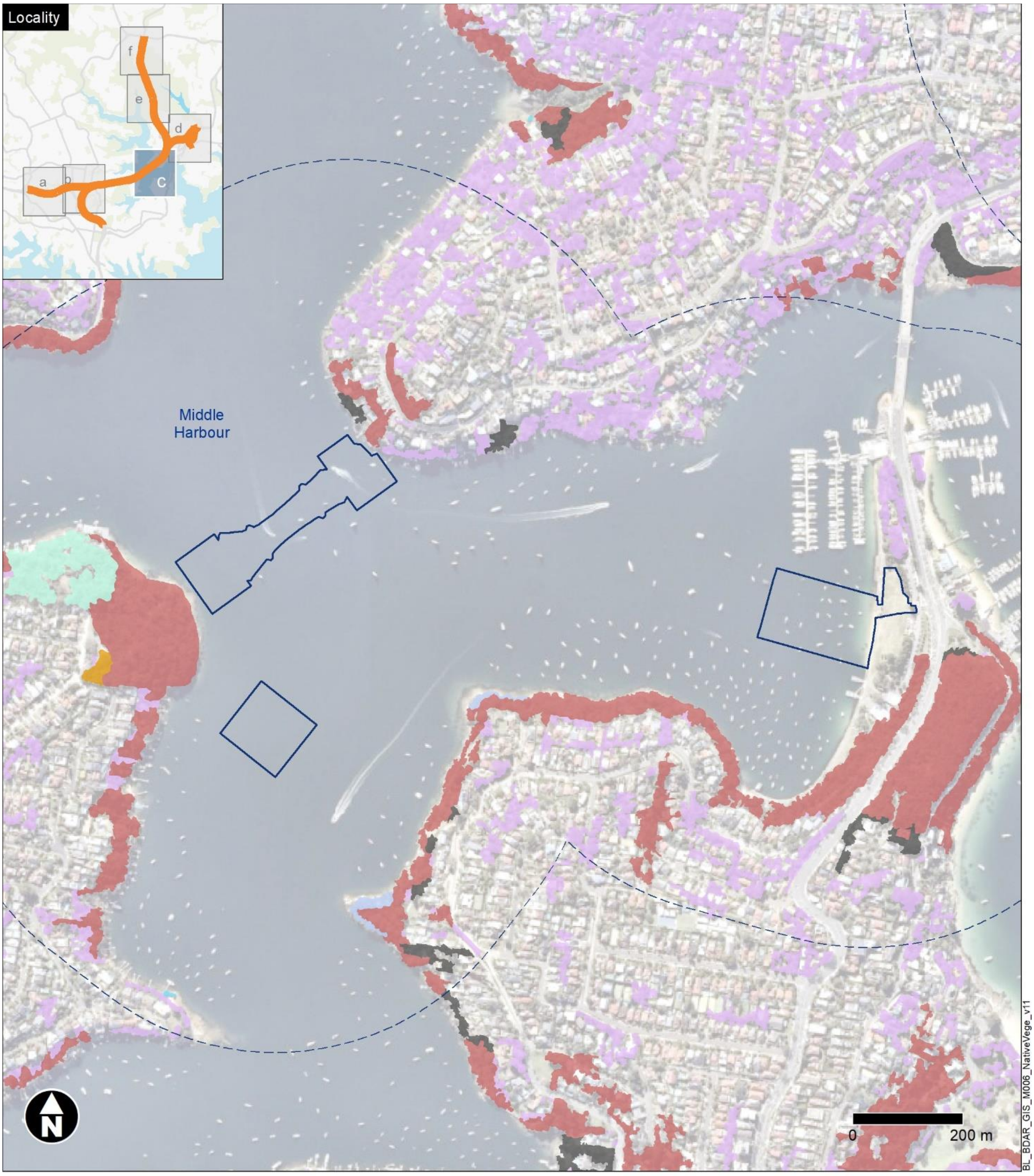


Figure 3-2 Distribution of native vegetation as mapped by OEH (2016) (map b)



Legend

Subject land

Assessment area

Vegetation mapping (OEH 2016)

Plant Community Types

1234: Estuarine Swamp Oak Forest

1250: Coastal Sandstone Gully Forest

1778: Coastal Sandstone Foreshores Forest

1782: Hornsby Enriched Sandstone Exposed Woodland

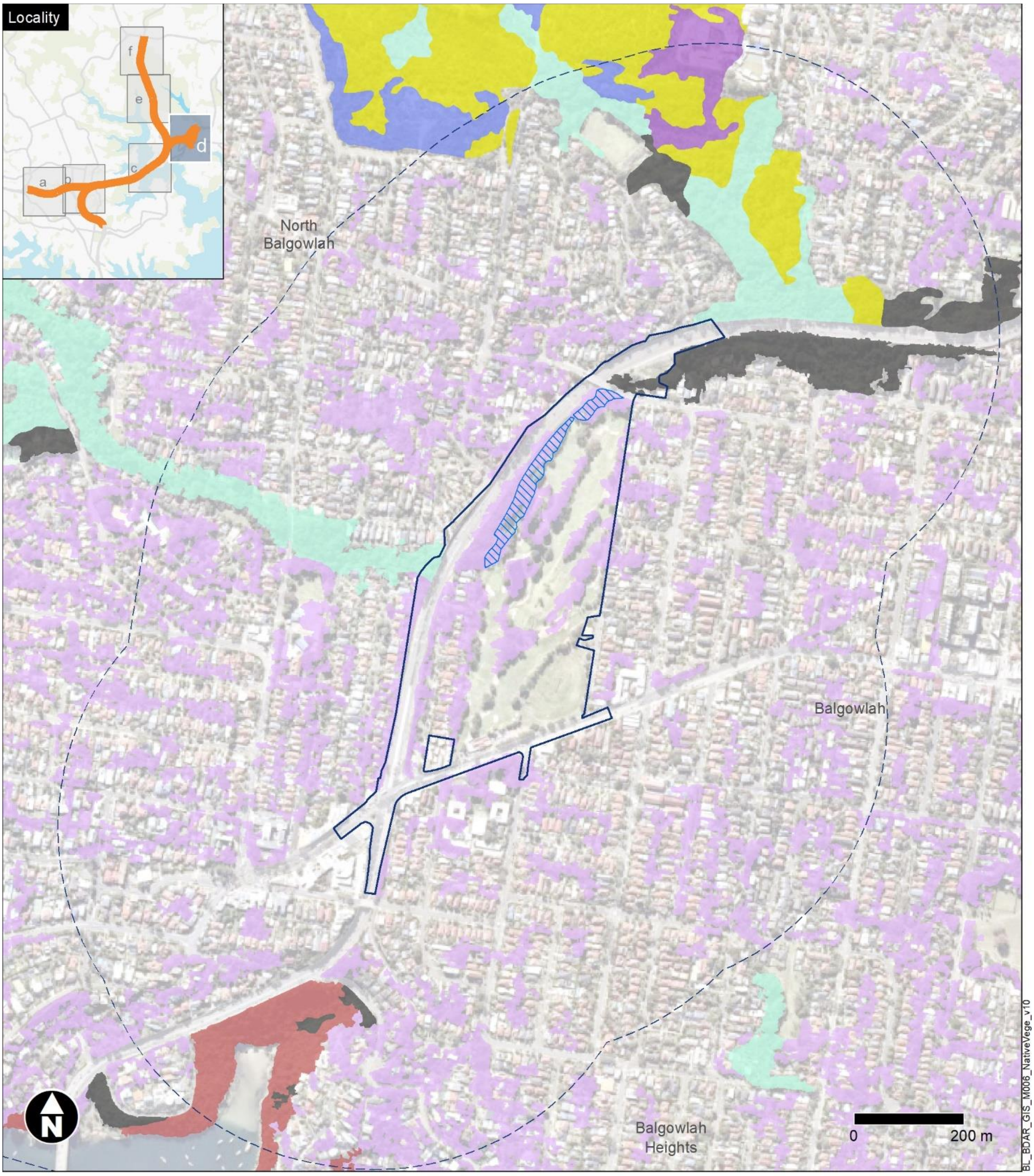
920: Estuarine Mangrove Forest

Other vegetation

Urban exotic/native

Weeds and exotics

Figure 3-2 Distribution of native vegetation as mapped by OEH (2016) (map c)



Legend

- Subject land
- Assessment area
- Exclusion zone

Vegetation mapping (OEH 2016)

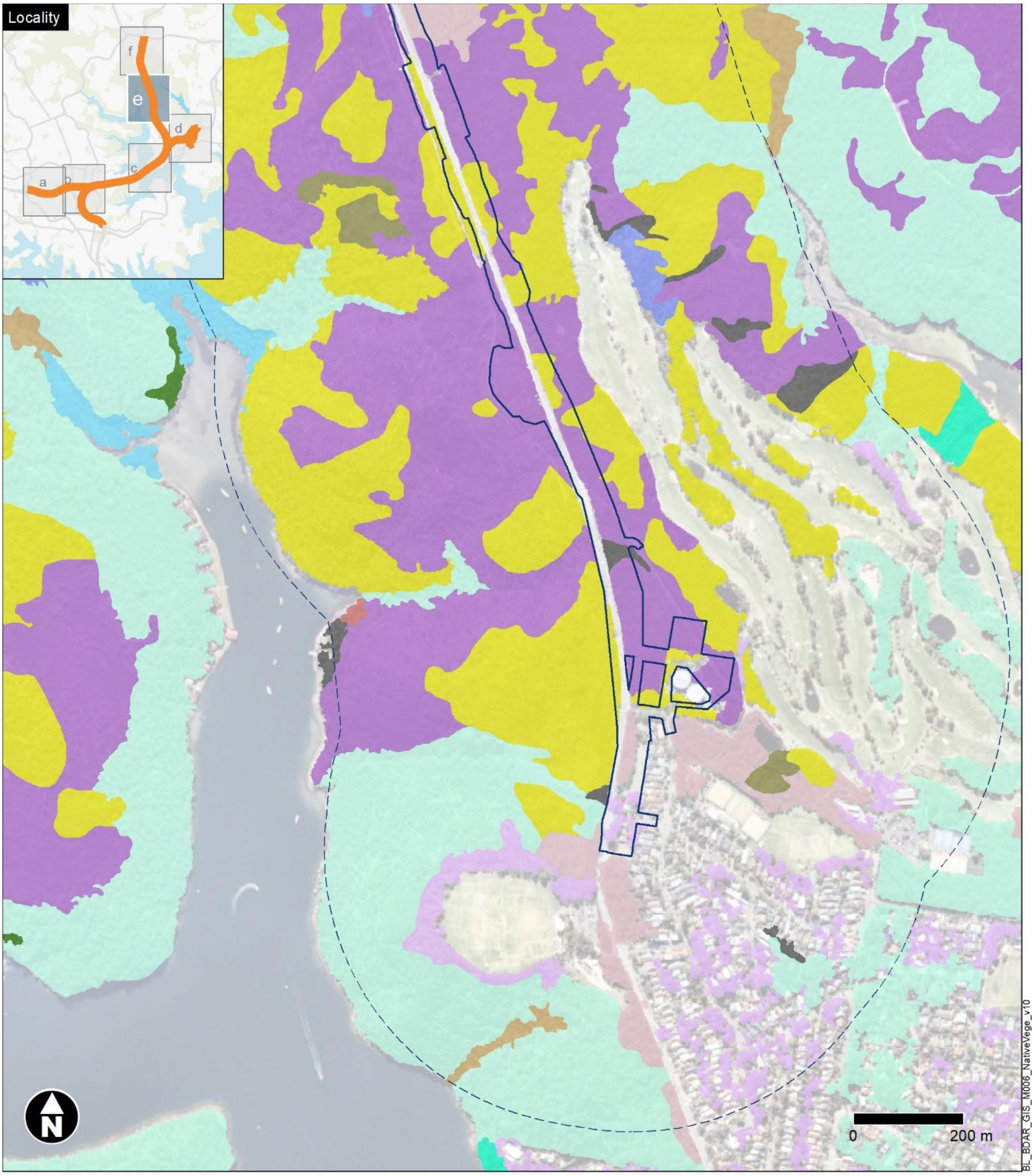
Plant Community Types

- 1250: Coastal Sandstone Gully Forest
- 1778: Coastal Sandstone Foreshores Forest
- 1783: Sydney North Exposed Sandstone Woodland
- 1824: Coastal Sandstone Heath-Mallee
- 881: Coastal Sandstone Rock Plate Heath

Other vegetation

- Urban exotic/native
- Weeds and exotics

Figure 3-2 Distribution of native vegetation as mapped by OEH (2016) (map d)



Legend

Subject land

Assessment area

Vegetation mapping (OEH 2016)

Plant Community Types

- 1250: Coastal Sandstone Gully Forest
- 1776: Coastal Enriched Sandstone Dry Forest
- 1778: Coastal Sandstone Foreshores Forest
- 1780: Coastal Sandstone Riparian Forest
- 1783: Sydney North Exposed Sandstone Woodland
- 1786: Sydney Ironstone Bloodwood-Silvertop Ash Forest
- 1803: Coastal Upland Damp Heath Swamp
- 1824: Coastal Sandstone Heath-Mallee
- 1841: Coastal Enriched Sandstone Moist Forest
- 881: Coastal Sandstone Rock Plate Heath
- 920: Estuarine Mangrove Forest

Other vegetation

- Urban exotic/native
- Weeds and exotics

Figure 3-2 Distribution of native vegetation as mapped by OEH (2016) (map e)

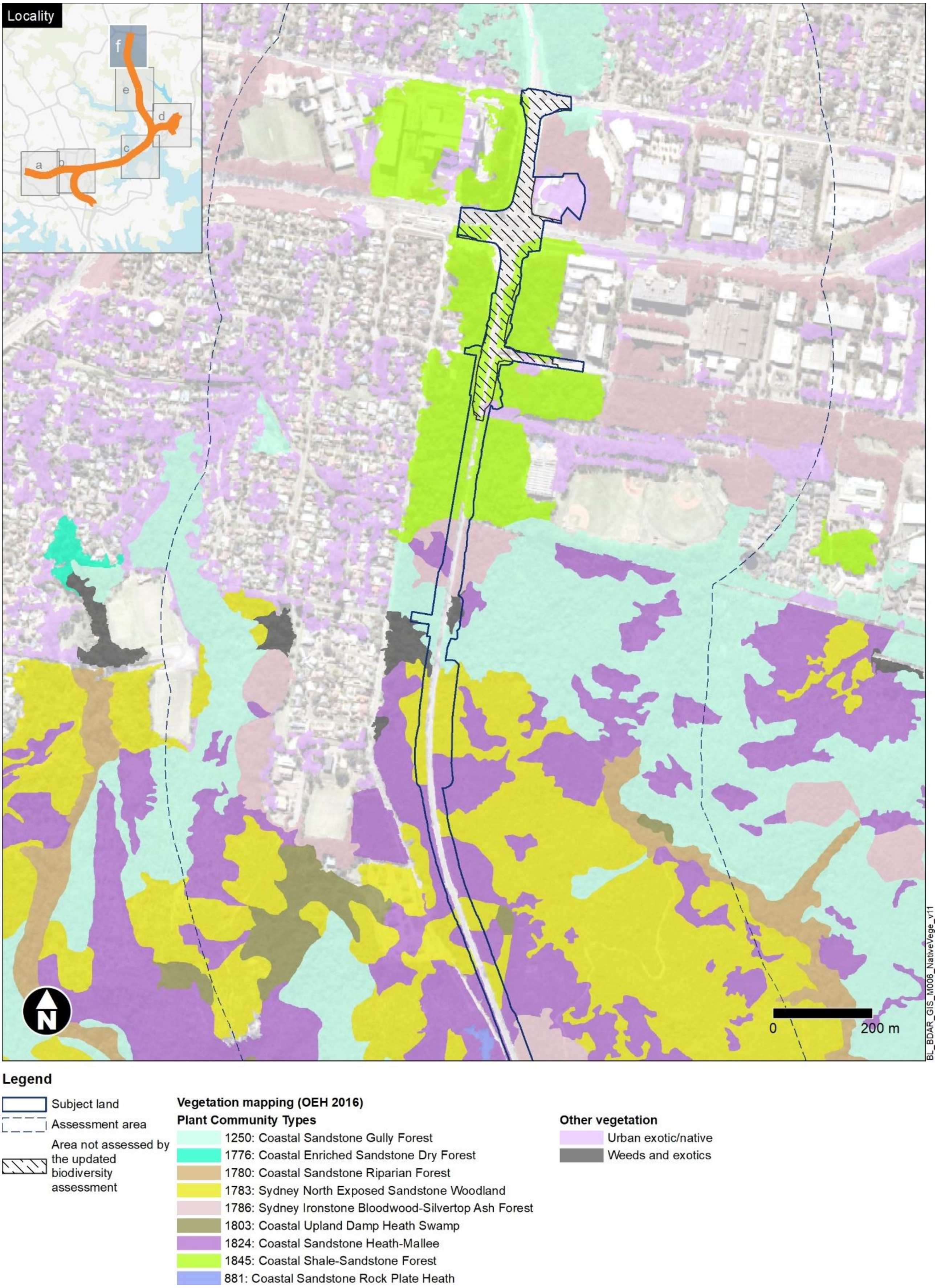


Figure 3-2 Distribution of native vegetation as mapped by OEH (2016) (map f)

3.3 Plant Community Types

The vegetation of the subject land was mapped following ground truthing of the existing vegetation mapping by OEH (2016).

WSP (2018) and Arcadis identified and mapped six Plant Community Types (PCTs) and four disturbed vegetation types within the subject land (refer to Table 3.3 and Figure 3-3). PCT descriptions provided in this section have been sourced from WSP (2018), with some amendments.

Table 3.3 PCTs and other vegetation identified in the subject land by WSP (2018) and Arcadis

PCT code	PCT name	Corresponding OEH (2016) map unit	Conservation status	Area (ha) mapped within the subject land
1250	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	S_DSF09: Coastal Sandstone Gully Forest	Not listed	1.08 ha
1783	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	S_DSF11: Sydney North Exposed Sandstone Woodland	Not listed	4.23 ha
1786	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (EEC)	S_DSF14: Sydney Ironstone Bloodwood-Silvertop Ash Forest	Endangered (BC Act): Duffys Forest Ecological Community in the Sydney Basin Bioregion	1.21 ha
1824	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	S_HL08: Coastal Sandstone Heath-Mallee	Not listed	6.18 ha
1841	Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	S_WSF_02: Coastal Enriched Sandstone Moist Forest	Not listed	1.79 ha
1845	Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	S_WSF06: Coastal Shale-Sandstone Forest	Not listed	0.39 ha
Total Native Vegetation				**14.88 ha**

PCT code	PCT name	Corresponding OEH (2016) map unit	Conservation status	Area (ha) mapped within the subject land
N/A	N/A - Native Revegetation	N/A	N/A	1.29 ha
N/A	N/A - Native Plantings	N/A	N/A	0.36 ha
N/A	N/A - Urban Exotic/Native	N/A	N/A	4.89 ha
N/A	N/A - Weeds and Exotics	N/A	N/A	0.26 ha
Total Other Vegetation				**6.80 ha**

Legend

Subject land

Assessment area

Plant community types and other vegetation

Plant community types

PCT 1841 Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region

Other vegetation

Native Plantings

Urban Exotic/Native

Figure 3-3 Distribution of Plant Community Types and other vegetation in the subject land (map a)

Figure 3-3 Distribution of Plant Community Types and other vegetation in the subject land (map b)

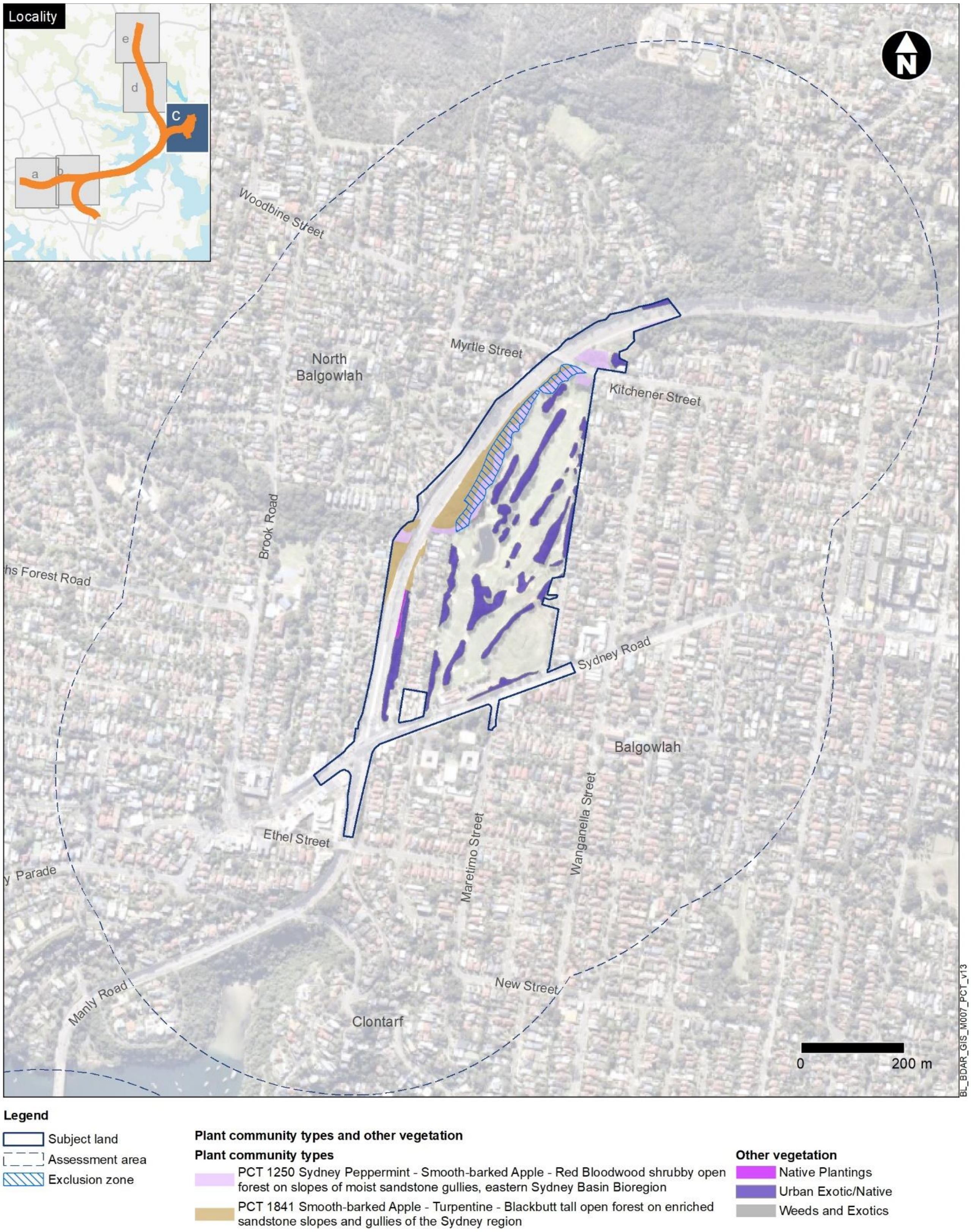


Figure 3-3 Distribution of Plant Community Types and other vegetation in the subject land (map c)

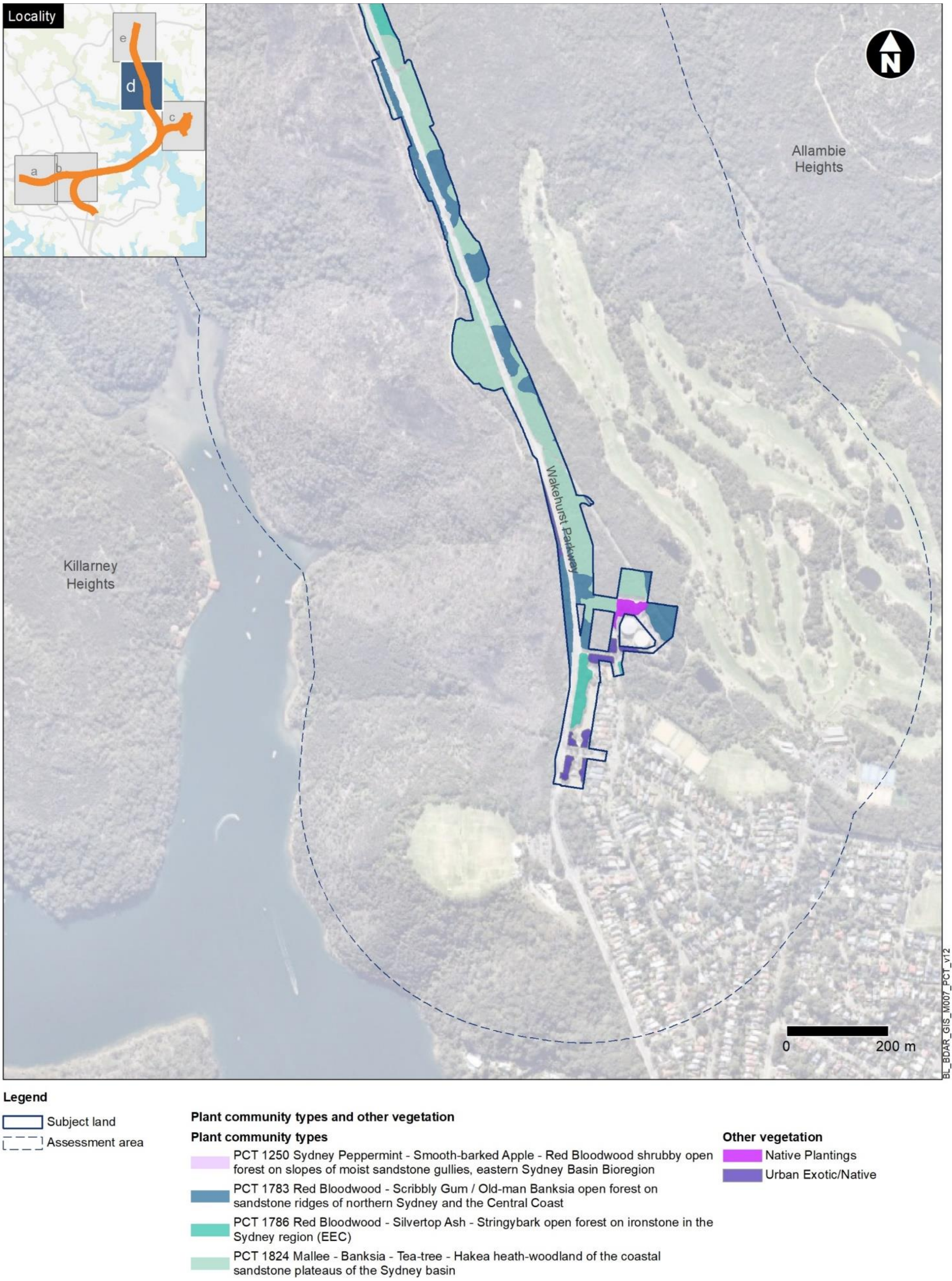


Figure 3-3 Distribution of Plant Community Types and other vegetation in the subject land (map d)

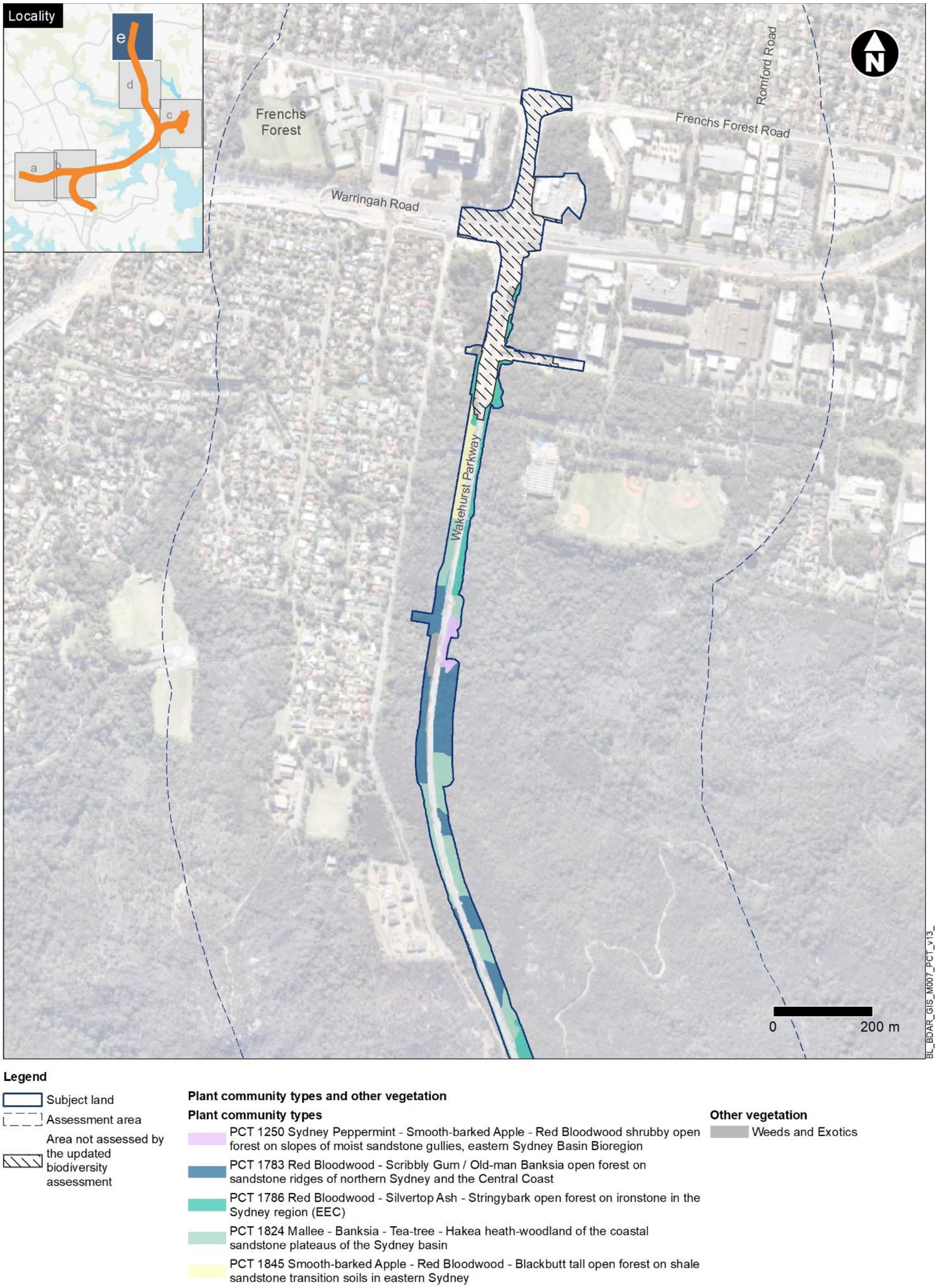


Figure 3-3 Distribution of Plant Community Types and other vegetation in the subject land (map e)

Justification for assigning Plant Community Types

The identification of PCTs in the subject lands was based on:

- Previous regional mapping as an equivalent vegetation type
- Landscape position
- Characteristic tree species present
- Structure and species composition consistent with descriptions in VIS database (DPIE (EES) 2020b) and other published references such as OEH (2016).

Quantitative analysis of the vegetation quadrat data was carried out to test the justifications for assigning PCTs. The vegetation data was compared with the lists of positive diagnostic species for the vegetation communities mapped in the subject land, as specified in OEH (2016). The vegetation data analyses are listed in Table 3.4.

For each vegetation community, the minimum number of positive diagnostic species expected to be recorded in a sample site has been calculated (OEH, 2016). The presence of the minimum number of positive diagnostic species in a sample site is strong evidence that the sample belongs to the vegetation community. It is necessary for identification using this method that the total number of native species recorded in the sample site exceeds a specified minimum. Species-poor sites cannot be tested (OEH, 2016).

For quadrats where either the minimum number of native species for the mapped PCT or the minimum number of positive diagnostic species for any PCT are recorded, the cell containing the relevant value is shaded grey in Table 3.4. Low species counts in some quadrats in comparison with the minimum number of species required for identification of the mapped PCT meant that some areas of vegetation in the subject land could not be reliably identified using analysis of positive diagnostic species. Conversely, some quadrats with high species counts met the positive diagnostic species criteria for multiple PCTs.

Table 3.4 Vegetation data analysis

PCT			1250	1292	1783	1786	1824	1841	1845
Equivalent OEH (2016) map unit			DSF09	DSF08	DSF11	DSF14	HL08	WSF02	WSF06
Minimum native species			45	32	41	42	42	33	39
Minimum positive diagnostic species			32	10	27	29	31	17	20
Mapped PCT	Quadrat	Number of native species	Number of positive diagnostic species						
1250	BB13	46	27	12	5	10	3	13	11
	BB5	30	5	2	3	1	2	7	2
	BB7	34	9	3	2	4	1	9	6
1783	P18	34	21	4	18	14	14	4	12
	P24	50	35	7	33	33	25	4	17
	P25	50	34	9	30	31	20	8	20
	A05	32	23	1	19	20	16	6	0
1786	BB14	43	29	3	26	24	24	4	14

PCT			1250	1292	1783	1786	1824	1841	1845
Equivalent OEH (2016) map unit			DSF09	DSF08	DSF11	DSF14	HL08	WSF02	WSF06
Minimum native species			45	32	41	42	42	33	39
Minimum positive diagnostic species			32	10	27	29	31	17	20
Mapped PCT	Quadrat	Number of native species	Number of positive diagnostic species						
	P20	46	29	11	15	22	10	9	20
	A01	28	11	3	7	8	7	7	8
1824	P19	41	21	1	27	14	25	1	7
	P22	27	13	3	19	10	19	2	3
	P23	43	24	8	25	15	21	3	6
	A04	25	15	0	18	15	13	4	0
1841	BB19	49	9	5	0	4	0	22	8
	BB10	33	7	2	4	4	1	12	0
	BB6	26	6	2	1	0	0	10	4
1845	P17	44	19	6	9	16	8	11	16
	P26	44	25	9	17	22	12	13	19
N/A (Native revegetation)	A02	37	10	1	6	6	3	11	0
	A03	33	10	1	5	7	4	10	0

3.3.1 Vegetation zones

Nine vegetation zones were identified, eight of which align to the native PCTs mapped in the subject land (Figure 3-4). One vegetation zone comprises revegetation in the Flat Rock Drive construction support site (BL2), which is not clearly consistent with any PCT. For the purpose of biodiversity credit calculation, the native revegetation zone has been assigned to PCT 1841, which is the closest mapped PCT.

Each PCT has only one corresponding vegetation zone, except for PCTs 1250 and 1786 which each have two vegetation zones based on different scores for vegetation integrity.

The vegetation zones and vegetation integrity scores (as determined using the BAM credit calculator) for each PCT are listed in Table 3.5. All PCTs identified in the subject land had vegetation integrity scores greater than the threshold score of 20, with most scoring over 50. Descriptions of each PCT/vegetation zone are provided in Section 3.3.1.1 to Section 3.3.1.4.

Table 3.5 Vegetation integrity score for each zone

Vegetation zone	Vegetation zone code	Plant Community Type (PCT)	Vegetation integrity score	Area within subject land (ha)
PCTs				
1	1250 - Moderate/Good – Good	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion (1250)	82.5	0.20
2	1250 - Moderate/Good – Moderate	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion (1250)	54	0.88
3	1783 - Moderate/Good	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast (1783)	62.9	4.23
4	1786 - Moderate/Good – Good	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (1786)	69.1	0.84
5	1786 - Moderate/Good – Moderate	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (1786)	40.5	0.37
6	1824 - Moderate/Good	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin (1824)	66.4	6.18
7	1841 - Moderate/Good	Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region (1841)	65.3	1.79
8	1845 - Moderate/Good	Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney (1845)	78.1	0.39
Other vegetation				
9	Native Revegetation	N/A – Revegetation (benchmarks for PCT 1841 used to determine vegetation integrity score)	37.7	1.29

Figure 3-4 Vegetation zones (map a)

Figure 3-4 Vegetation zones (map b)

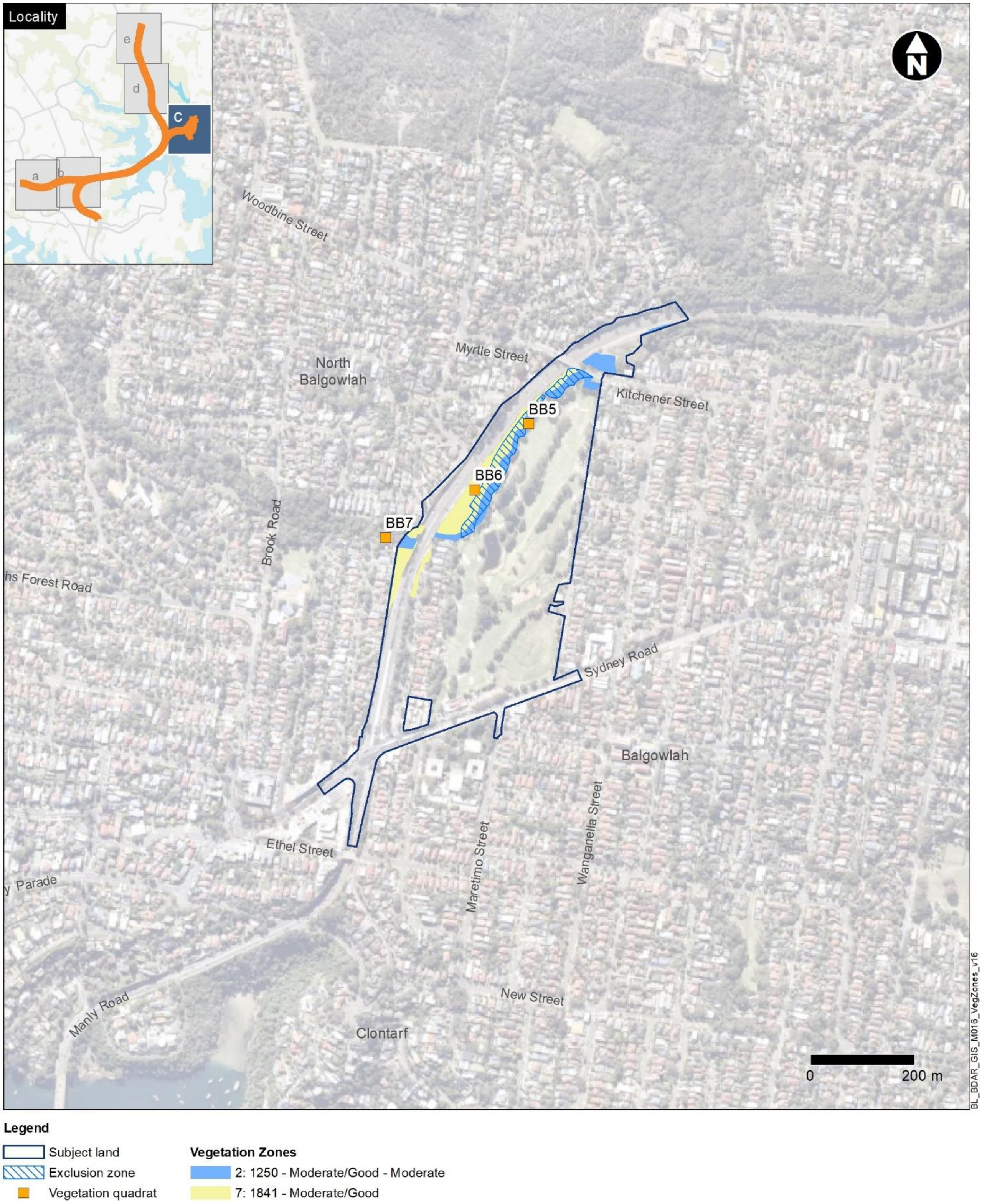


Figure 3-4 Vegetation zones (map c)

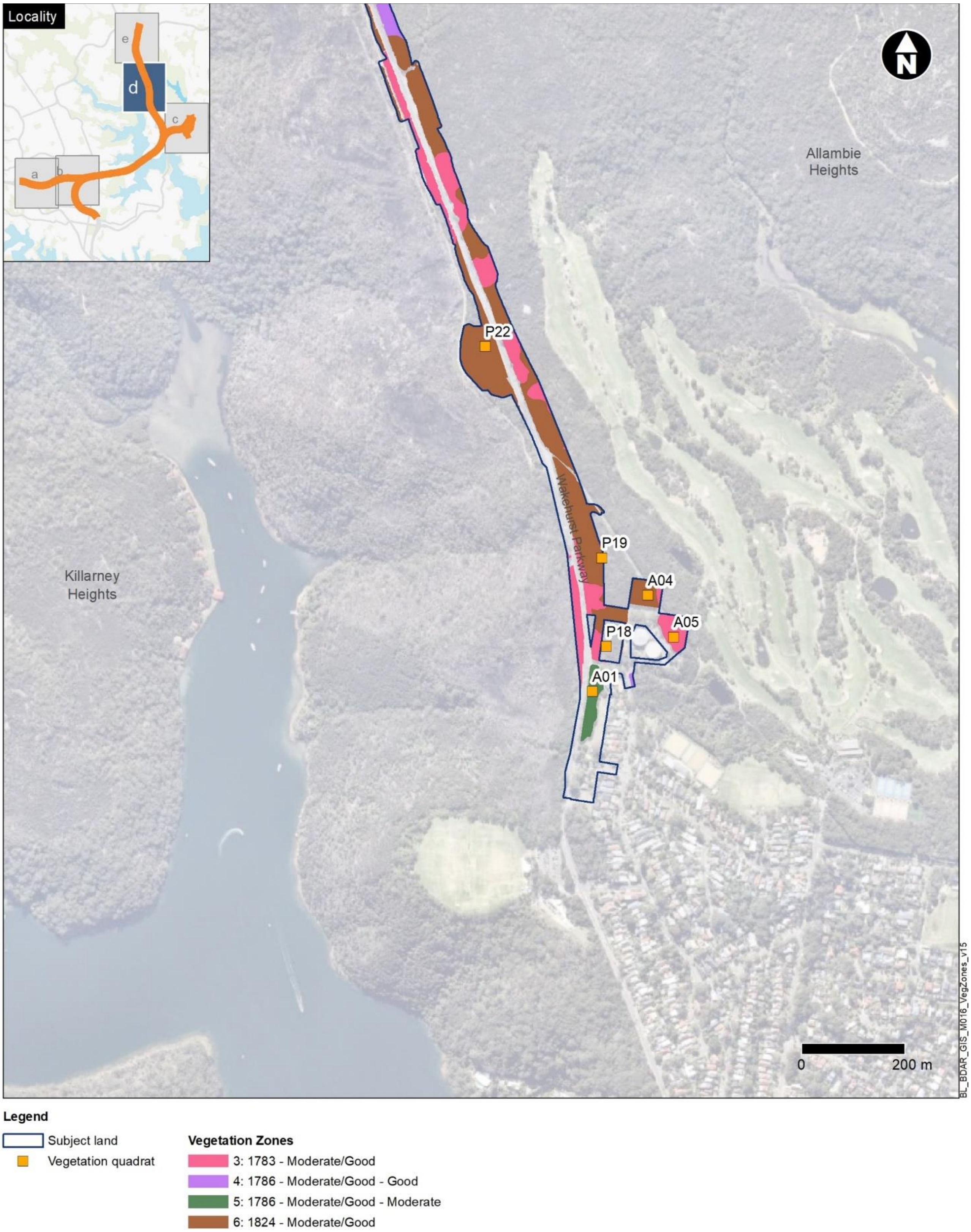


Figure 3-4 Vegetation zones (map d)

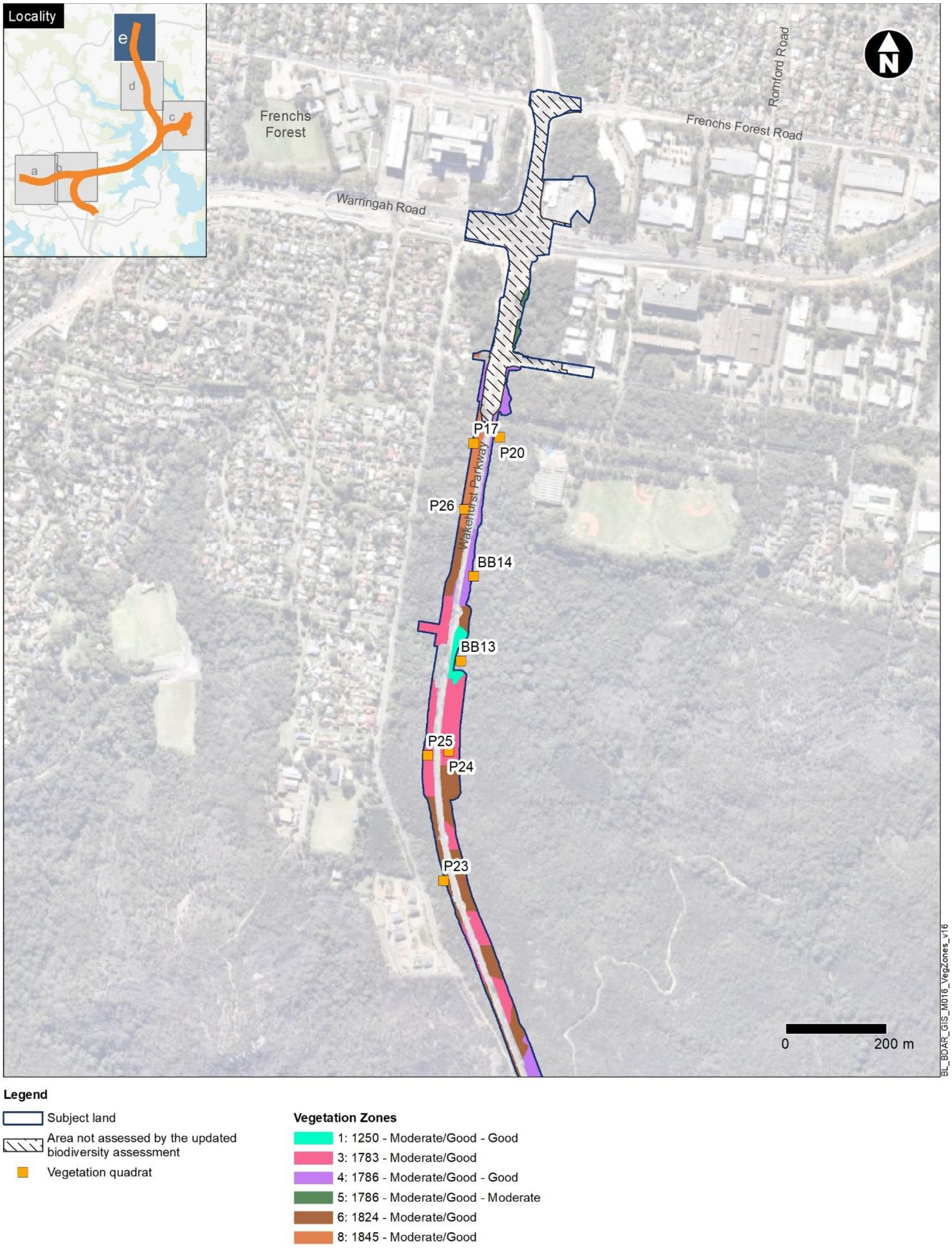


Figure 3-4 Vegetation zones (map e)

3.3.1.1 Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney basin bioregion

Vegetation formation: Dry Sclerophyll Forests (Shrubby sub-formation)

Vegetation class: Sydney Coastal Dry Sclerophyll Forests

PCT: 1250

Conservation status: Not listed

Estimate of per cent cleared: 30 per cent cleared in the Sydney Metropolitan CMA area

Condition: Moderate/Good condition

Extent in the subject land: 1.08 hectares

Plots completed in Moderate/Good – Good vegetation zone: BB13

Table 3.6 PCT 1250 – Condition scores and vegetation integrity score for plot BB13

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
87.8	66.5	96.2	82.5

Plots completed in Moderate/Good – Moderate vegetation zone: BB05, BB07

Table 3.7 PCT 1250 – Condition scores and vegetation integrity score for plots BB05, BB07

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
62.7	33.8	74.5	54

Description: Within the subject land this community occurs on sandy soils influenced by Hawkesbury Sandstone and alluvium geologies. The community was recorded adjoining the Wakehurst Parkway, within a steep gully forming the head of a tributary of Manly Creek, and in a modified form at Burnt Bridge Creek.

The vegetation in the Moderate/Good – Good vegetation zone adjoining Wakehurst Parkway consisted of a sparse canopy of *Angophora costata* (Sydney Red Gum) and *Eucalyptus piperita* (Sydney Peppermint) with a diverse range of small trees and shrub species forming a relatively thick mid-storey. Dominant weed species recorded include *Cinnamomum camphora* (Camphor Laurel), *Ochna serrulata* (Mickey Mouse Plant), *Ligustrum sinense* (Small-leaved Privet), *Araujia sericea* (Moth Vine), *Senna pendula var. glabrata* (Easter Cassia), *Lantana camara* (Lantana) and *Asparagus aethiopicus* (Ground Asparagus).

The vegetation in the Moderate/Good – Moderate vegetation zone adjoining Burnt Bridge Creek comprises regrowth and revegetation of previously cleared and disturbed areas, as shown in historical aerial photographs (see Section 3.4.1.1). These areas experience moderate to high levels of disturbance and are intersected by walking paths and roads as well as rubbish, stormwater debris and erosion of substrates and creek banks. It is likely that these factors have contributed to the diversity of exotic plant species recorded within the subject land. However, weed coverage is generally restricted to the mid-storey and groundcover with only three exotic canopy trees recorded.

Weed species included *Celtis sinensis* (Chinese Celtis), *Cotoneaster glaucophyllus* (Glaucous Cotoneaster), *Ligustrum lucidum* (Broad-leaved Privet), *Ligustrum sinense*, *Phoenix canariensis* (Canary Island Date), *Erythrina x sykesii* (Coral Tree), *Solanum mauritianum* (Wild Tobacco Tree), *Ricinus communis* (Castor Oil Plant) and *Lantana camara*. Vines and ground covers included

Anredera cordifolia (Madeira Vine), *Ipsteromoea indica* (Blue Morning Glory), *Delairea odorata* (Cape Ivy) and *Asparagus aethiopicus*. A variety of herbaceous weeds were present across the subject land with higher densities of *Tradescantia fluminensis* (Wandering Jew), *Alstroemeria psittacina* (Parrot Lily) and *Ehrharta erecta* (Panic Veldtgrass).

The vegetation integrity score for PCT 1250 and the condition scores that determine this are provided in Table 3.6 and Table 3.7. The site-specific structure, floristics and condition of the PCT are shown in Table 3.8.

Table 3.8 PCT 1250 – site-specific structure, floristics and condition

Structure (native species only)			Dominant species (native and exotic)
Growth form	Average height and height range (m)	Average cover and cover range (%)	
Trees	12.5 (8–17)	28 (23-35)	*Angophora costata*, *Eucalyptus piperita, Eucalyptus robusta, Eucalyptus pilularis*
Small trees	6 (2–10)	45 (30–60)	*Banksia serrata* (Old-man Banksia), *Elaeocarpus reticulatus* (Blueberry Ash), *Callicoma serratifolia* (Black Wattle), *Ceratopetalum gummiferum* (Christmas Bush), *Homalanthus populifolius* (Bleeding Heart), *Allocasuarina littoralis* (Black She-oak), *Tristaniopsis laurina, Glochidion ferdinandi* (Cheese Tree), *Cyathea cooperi* (Australian Tree Fern)
Shrubs	2.5 (0.1–5)	18 (8-36)	*Banksia marginata, Epacris longiflora, Grevillea linearifolia, Acacia brownii* (Heath Wattle), *Pittosporum undulatum* (Sweet Pittosporum), *Lambertia formosa* (Mountain Devil), *Leptospermum trinervium* (Slender Tea-tree), *Dodonaea triquetra* (Large-leaf Hop-bush), *Banksia ericifolia* (Heath Banksia), *Podocarpus spinulosus, Breynia oblongifolia* (Coffee Bush), *Hakea salicifolia* (Willow-leaved Hakea)
Ground covers	0.75 (0–1.5)	24 (18-30)	*Tetratheca thymifolia* (Black-eyed Susan), *Lomandra longifolia* (Spiny-headed Mat-rush), *Lepidosperma laterale* (Variable Sword-sedge), *Gonocarpus teucrioides* (Raspwort), *Gahnia erythrocarpa, Gahnia sieberiana, Sticherus flabellatus* (Umbrella Fern), *Platylobium formosum* (Handsome Flat-pea), *Empodisma minus* (Spreading Rope-rush), *Pteridium esculentum* (Bracken), *Histiopteris incisa* (Bats Wing Fern), *Imperata cylindrica* (Blady Grass), *Dianella caerulea var. producta, Commelina cyanea, Gonocarpus teucrioides, Calochlaena dubia* (Rainbow Fern)
Vines/ climbers and epiphytes	0.15 (0.1–10)	7 (1-13)	*Smilax glyciphylla* (Sweet Sarsparilla), *Billardiera scandens* (Appleberry)

Plate 2 PCT 1250 Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion (Photo: WSP, 2018)

3.3.1.2 Red Bloodwood – scribbly gum/old-man banksia open forest on sandstone ridges of Northern Sydney and the Central Coast

Vegetation formation: Dry Sclerophyll Forests (shrubby sub-formation)

Vegetation class: Sydney Coastal Dry Sclerophyll Forests

PCT: 1783

Conservation status: Not listed

Estimate of per cent cleared: 30 per cent cleared in the Sydney Metropolitan CMA area

Condition: Moderate/Good condition

Extent in the subject land: 4.23 hectares

Plots completed in vegetation zone: P18, P25, P24, A05

Table 3.9 PCT 1783 – Condition scores and vegetation integrity score

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
85.9	63.8	45.5	62.9

Description: This community occurred along the Wakehurst Parkway and in Northbridge on dry sandy soils derived from Hawkesbury Sandstone. Along the Wakehurst Parkway the community is subjected to disturbance such as walking paths, edge effects associated with the road and powerline easements, and minor weed incursions.

The vegetation integrity score for PCT 1783 and the condition scores that determine this are provided in Table 3.9. The site-specific structure, floristics and condition of the PCT are shown in Table 3.10.

Table 3.10 PCT 1783 – site-specific structure, floristics and condition

Structure (native species only)			Dominant species (native and exotic)
Growth form	**Average height and height range (m)**	**Average cover and cover range (%)**	
Trees	13 (10–16)	10 (0–20)	*Angophora costata*, *Corymbia gummifera* (Red Bloodwood), *Eucalyptus haemastoma* (Broad-leaved Scribbly Gum)
Small trees	8 (6–8)	15 (10–20)	*Allocasuarina distyla* (Scrub She-oak), *Allocasuarina littoralis*
Shrubs	2.5 (2–3)	35 (30–40)	*Hakea gibbosa* (Hairy Hakea), *Phebalium squamulosum* (Scaly Phebalium), *Dodonaea triquetra, Banksia ericifolia, Hakea dactyloides* (Finger Hakea)
Ground covers	0.5 (0.1–1)	15 (0–30)	*Entolasia stricta* (Wiry Panic), *Lepidosperma laterale, Imperata cylindrica, Lomandra longifolia, Lepyrodia scariosa, Ochna serrulata, Sida rhombifolia* (Paddys Lucerne)
Vines/ climbers and epiphytes	-	-	Nil.

Source: WSP (2018)

Plate 3 PCT 1783 Red Bloodwood – Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast (Photo: WSP, 2018)

3.3.1.3 Red Bloodwood – Silvertop ash – stringybark open forest on ironstone in the Sydney region

Vegetation formation: Dry Sclerophyll Forests (Shrubby sub-formation)

Vegetation class: Sydney Coastal Dry Sclerophyll Forests

PCT: 1786

Conservation status: BC Act: Endangered: Duffys Forest Ecological Community in the Sydney Basin Bioregion

Estimate of per cent cleared: 71 per cent cleared in the Sydney Metropolitan CMA area

Condition: Moderate/Good condition

Extent in the subject land: 1.21 hectares

Plots completed in Moderate/Good – Good vegetation zone: BB14, P20

Table 3.11 PCT 1786 – Condition scores and vegetation integrity score for plots BB14, P20

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
90.2	80.4	45.4	69.1

Plots completed in Moderate/Good – Moderate vegetation zone: A01

Table 3.12 PCT 1786 – Condition scores and vegetation integrity score for plots A01

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
44.2	29.6	50.6	40.5

Description: The community within the subject land occurred on sandy soils derived from sandstone geology and was generally found on the upper slopes supporting a diverse range of small trees, shrubs and ground covers. This community was recorded from along the Wakehurst Parkway and subsequently experiences moderate levels of disturbances in the form of walking paths, edge effects associated with the road and minor weed incursions.

The vegetation in the Moderate/Good – Good vegetation zone consists of an open-forest with shrubby understorey and a grassy and herbaceous ground layer with a diverse mixture of native grass, herb, sedge and fern species.

Vegetation in the Moderate/Good – Moderate zone consists of scattered over-mature eucalypts with a dense mid-storey of *Allocasuarina littoralis* and a comparatively sparse ground layer dominated by *Allocasuarina* leaf litter, with low native groundcover species diversity and no observable eucalypt recruitment.

The vegetation integrity scores for PCT 1786 and the condition scores that determine this are provided in Table 3.11 and Table 3.12. The site-specific structure, floristics and condition of the PCT are shown in Table 3.13.

Table 3.13 PCT 1786 – site-specific structure, floristics and condition

Structure (native species only)			Dominant species (native and exotic)
Growth form	Average height and height range (m)	Average cover and cover range (%)	
Trees	16 (10–22)	25 (10–40)	*Corymbia gummifera*, *Eucalyptus haemastoma*, *Eucalyptus sieberi* (Silvertop Ash), *Eucalyptus capitellata* (Brown Stringybark), *Eucalyptus oblonga* (Stringybark), *Corymbia maculata* (Spotted Gum)
Small trees	4 (3–5)	30 (10–60)	*Allocasuarina littoralis*, *Banksia serrata*, *Banksia ericifolia*
Shrubs	1.5 (0.5–3)	25 (10–40)	*Leptospermum trinervium, Persoonia levis* (Broad-leaved Geebung), *Banksia spinulosa* (Hairpin Banksia), *Lomatia silaifolia* (Crinkle Bush), *Platysace linearifolia*, *Acacia myrtifolia* (Red-stemmed Wattle), *Grevillea speciosa* (Red Spider Flower), *Hakea dactyloides*, *Leptospermum arachnoides, Hakea teretifolia* (Needlebush), *Boronia pinnata*
Ground covers	0.8 (0.1–1.5)	40 (20–60)	*Entolasia stricta*, *Lindsaea linearis* (Screw Fern), *Dampiera stricta* (Blue Dampiera), *Lomandra obliqua*, *Lepidosperma laterale*, *Xanthosia tridentata* (Rock Xanthosia), *Micrantheum ericoides, Dianella caerulea* (Blue Flax-lily), *Hovea linearis*

Structure (native species only)			Dominant species (native and exotic)
Growth form	Average height and height range (m)	Average cover and cover range (%)	
Vines/ climbers and epiphytes	N/A	N/A	*Billardiera scandens, Cassytha pubescens* (Devil's Twine)

Source: WSP (2018)

Plate 4 PCT 1786 Red Bloodwood – Silvertop Ash – Stringybark open forest on ironstone in the Sydney region (Photo: WSP, 2018)

3.3.1.4 Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin

Vegetation formation: Heathlands

Vegetation class: Sydney Coastal Heaths

PCT: 1824

Conservation status: Not listed

Estimate of per cent cleared: 10 per cent cleared in the Sydney Metropolitan CMA area

Condition: Moderate/Good condition

Extent in the subject land: 6.18 hectares

Plots completed in vegetation zone: P19, P22, P23, A04

Table 3.14 PCT 1824 – Condition scores and vegetation integrity score

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
84.9	64.2	53.9	66.4

Description: Within the subject land this community was associated with wetter areas on sandy soils derived from sandstone geology. The canopy was generally sparse consisting of *Eucalyptus racemosa* (Narrow-leaved Scribbly Gum), *Eucalyptus haemastoma* and *Eucalyptus punctata* (Grey Gum). The shrub cover was predominantly dense with *Leptospermum* spp, *Melaleuca armillaris* and *Banksia ericifolia* subsp. *ericifolia*. There are few shrub species and little shrub cover. The vegetation integrity score for PCT 1824 and the condition scores that determine this are provided in Table 3.14. The site-specific structure, floristics and condition of the associated vegetation to the PCT are shown in Table 3.15.

Exotic cover was generally low to moderate which included *Andropogon virginicus* (Whiskey Grass), *Ehrharta erecta*, *Cinnamomum camphora*, *Asparagus aethiopicus*, *Ochna serrulata*, *Nephrolepis cordifolia* (Fishbone Fern), *Chlorophytum comosum* (Spider Plant) and *Araujia sericea*.

Table 3.15 PCT 1824 – site-specific structure, floristics and condition

Structure (native species only)			Dominant species (native and exotic)
Growth form	Average height and height range (m)	Average cover and cover range (%)	
Trees	9 (6–12)	30 (20–40)	*Eucalyptus racemosa, Eucalyptus haemastoma*, *Banksia serrata*, *Eucalyptus paniculata* (Grey Ironbark), *Eucalyptus pilularis*, *Eucalyptus punctata*, *Syncarpia glomulifera* (Turpentine)
Shrub 1	2.5 (1–4)	15 (10–20)	*Melaleuca armillaris, Pittosporum undulatum, Leptospermum squarrosum, Leptospermum polygalifolium, Banksia ericifolia sub. ericifolia*
Shrub 2	0.75 (0.5–1)	3 (1–5)	*Dodonaea triquetra, Epacris pulchella* (Wallum Heath) and *Hakea gibbosa*

Structure (native species only)			Dominant species (native and exotic)
Growth form	Average height and height range (m)	Average cover and cover range (%)	
Ground covers	0.55 (0.1–1)	55 (10–90)	*Lomandra longifolia, Dianella caerulea*, *Commelina* cyanea, *Actinotus minor* (Lesser Flannel Flower), *Imperata cylindrica*, *Asparagus aethiopicus, Microlaena stipoides* var. *stipoides* (Weeping Grass), *Ehrharta erecta*, *Lindsaea linearis*, *Lepyrodia scariosa, Andropogon virginicus*
Vines/ climbers and epiphytes	N/A	N/A	Nil

Source: WSP (2018)

Plate 5 PCT 1824 Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin (Photo: WSP, 2018)

3.3.1.5 Smooth-barked Apple – Turpentine – Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney Region

Vegetation formation: Wet Sclerophyll Forest (Shrubby sub-formation)

Vegetation class: North Coast Wet Sclerophyll Forest

PCT: 1841

Conservation status: Not listed

Estimate of per cent cleared: 67 per cent cleared in the Sydney Metropolitan CMA area

Condition: Moderate/Good condition

Extent in the subject land: 1.79 hectares

Plots completed in vegetation zone: BB06, BB10, BB19

Table 3.16 PCT 1841 – Condition scores and vegetation integrity score

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
69.9	61	65.2	65.3

Description: Within the subject land this community occurs on sandy soils with slight loam components derived from Hawkesbury Sandstone geology. These areas varied in gradient from gentle to steep and were typically situated within close proximity to a water course (such as Burnt Bridge Creek and Flat Rock Creek). Rainforest species such as *Pittosporum undulatum*, *Pittosporum revolutum*, *Elaeocarpus reticulatus* and *Glochidion ferdinandi* made up the majority of the small trees and shrub layer while ferns, grasses and sedges dominated the forest floor.

An occurrence of this community at Artarmon Park and Artarmon Oval comprised a canopy dominated by *Syncarpia glomulifera* and *Eucalyptus saligna* (Sydney Blue Gum). The mid-stratum was dominated by a distinctive mesic shrub and small tree layer that included species such as *Pittosporum undulatum*, *Myrsine variabilis, Breynia oblongifolia*, *Glochidion ferdinandi*, *Homalanthus populifolius* and in some instances *Ceratopetalum gummiferum*.

Areas of the community adjoining the drainage line in Flat Rock Reserve have also been subject to bushland management, and a larger aea to the west of the creek which loosely meets the description of this community comprises reconstructed native vegetation. This vegetation is discussed separately in section 3.4.1.1. The occurrence of this community adjoining Burnt Bridge Creek comprises regrowth and revegetation of previously cleared and disturbed areas, as shown on historical aerial photographs (see Section 3.4.1.1).

The vegetation integrity score for PCT 1841 and the condition scores that determine this are provided in Table 3.16. The site-specific structure, floristics and condition of the associated vegetation to the PCT are shown in Table 3.17.

Within the subject land this community was in moderate to good condition. Across the subject land dominant weed species included *Lantana camara*, *Ehrharta erecta*, *Asparagus aethiopicus*, *Acetosa sagittata* (Rambling Dock), *Tradescantia fluminensis*, *Ligustrum sinense*, *Ageratina riparia* (Mist Flower) and *Ochna serrulata*.

Table 3.17 PCT 1841 – site-specific structure, floristics and condition

Structure (native species only)			Dominant species
Growth form	Average height and height range (m)	Average cover and cover range (%)	
Trees	13.5 (5–22)	35 (15–55)	*Angophora costata*, *Syncarpia glomulifera*, *Eucalyptus saligna, Eucalyptus resinifera*, *Eucalyptus umbra*, *Syncarpia glomulifera*, *Allocasuarina littoralis*, *Eucalyptus piperita*
Small trees	4.5 (3–6)	35 (10–60)	*Pittosporum undulatum*, *Elaeocarpus reticulatus*, *Glochidion ferdinandi* and *Syzygium paniculatum*
Shrubs	2.75 (0.5–3)	27.5 (10–45)	*Pittosporum revolutum*, *Pittosporum undulatum*, *Dodonaea triquetra*, *Breynia oblongifolia*, *Polyscias sambucifolia* (Elderberry Panax)
Ground covers	1.05 (0.1–2)	60 (20–90)	*Entolasia stricta*, *Lomandra longifolia, Dianella caerulea*, *Themeda triandra* (Kangaroo Grass), *Microlaena stipoides* var. *stipoides*, *Imperata cylindrica*, *Pteridium esculentum*, *Dichondra repens* (Kidney Weed), *Calochlaena dubia*, *Lepidosperma laterale*
Vines/ climbers and epiphytes	N/A	N/A	*Cissus hypoglauca* (Giant Water Vine), *Smilax glycinoides* (Sweet Sarsaparilla), *Eustrephus latifolia* (Wombat Berry)

Source: WSP (2018)

Plate 6 PCT 1841 Smooth-barked Apple – Turpentine – Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region – Artarmon (Photo: WSP, 2018)

3.3.1.6 Smooth-barked Apple – Red Bloodwood – Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney

Vegetation formation: Wet Sclerophyll Forests (Grassy sub-formation)

Vegetation class: Northern Hinterland Wet Sclerophyll Forests

PCT: 1845

Conservation status: Not listed

Estimate of per cent cleared: 92 per cent cleared in the Sydney Metropolitan CMA area

Condition: Moderate/Good condition

Extent in the subject land: 0.39 hectares

Plots completed in vegetation zone: P17, P26

Table 3.18 PCT 1845 – Condition scores and vegetation integrity score

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
90.7	78.1	67.4	78.1

Description: The community within the subject land occurred on sandy soils derived from sandstone geology and was generally found on the upper slopes supporting a diverse range of small trees, shrubs and ground covers. This community was recorded from the roadside areas in the northern part of the Wakehurst Parkway section of the subject land, and subsequently experiences moderate levels of disturbances in the form of walking paths, edge effects associated with the road and minor weed incursions. The community comprises a canopy dominated by eucalypts with a dense midlayer of *Allocasuarina littoralis* and a ground layer dominated by graminoids and ferns. Within the subject land this community was in moderate to good condition.

The vegetation integrity score for PCT 1845 and the condition scores that determine this are provided in Table 3.18. The site-specific structure, floristics and condition of the PCT are shown in Table 3.19.

Table 3.19 PCT 1845 – site-specific structure, floristics and condition

Structure (native species only)			Dominant species (native and exotic)
Growth form	Average height and height range (m)	Average cover and cover range (%)	
Trees	8 (6–10)	20 (0–40)	*Eucalyptus sieberi, Eucalyptus haemastoma, Corymbia gummifera, Eucalyptus capitellata*
Small trees	3 (2–4)	45 (10–80)	*Allocasuarina littoralis*, *Banksia serrata*
Shrubs	1.5 (1–2)	10.5 (1–20)	*Persoonia levis, Lambertia formosa, Boronia pinnata, Hakea dactyloides, Lasiopetalum ferrugineum, Petrophile pulchella, Hakea gibbosa, Hakea sericea, Banksia spinulosa*
Ground covers	0.8 (0.1–1.5)	35 (10–60)	*Lepidosperma laterale, Lomandra obliqua, Xanthorrhoea media, Billardiera scandens*, *Entolasia stricta, Dampiera stricta, Lindsaea linearis, Lomandra obliqua*
Vines/ climbers and epiphytes	N/A	N/A	*Billardiera scandens*, *Cassytha pubescens*

Source: WSP (2018)

Plate 7 PCT 1845 Smooth-barked Apple – Red Bloodwood – Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney (Photo: WSP, 2018)

3.4 Other vegetation types

A total of 6.80 hectares of vegetation that is not consistent with the definition of any PCT was mapped and described by WSP (refer to Figure 3-3) within the subject land, comprising:

- 1.29 hectares of native revegetation
- 0.36 hectares of native plantings
- 4.89 hectares of urban exotic/native
- 0.26 hectares of weeds and exotics.

Vegetation descriptions have been taken from WSP (2018), with some minor amendments.

3.4.1.1 Native revegetation

The Flat Rock Drive construction support site (BL2) is located within Flat Rock Reserve, a council reserve containing native revegetation. Flat Rock Reserve supported a municipal waste landfill site until 1985. The site was capped with clay in 1998 and has since been progressively revegetated. The historical disturbance and subsequent revegetation of this area can be seen on historical aerial photographs, as shown on Figure 3-5.

Flat Rock Reserve now supports about 14 hectares of bushland, all of which is subject to long-term bushland management. The *Draft Flat Rock Gully Reserve Action Plan* (Willoughby City Council, 2018) identifies three native vegetation types as occurring in the reserve: Coastal Sandstone Foreshores Forest (equivalent to PCT 1778), Coastal Enriched Sandstone Moist Forest (equivalent to PCT 1841) and Hornsby Enriched Sandstone Exposed Woodland (equivalent to PCT 1782).

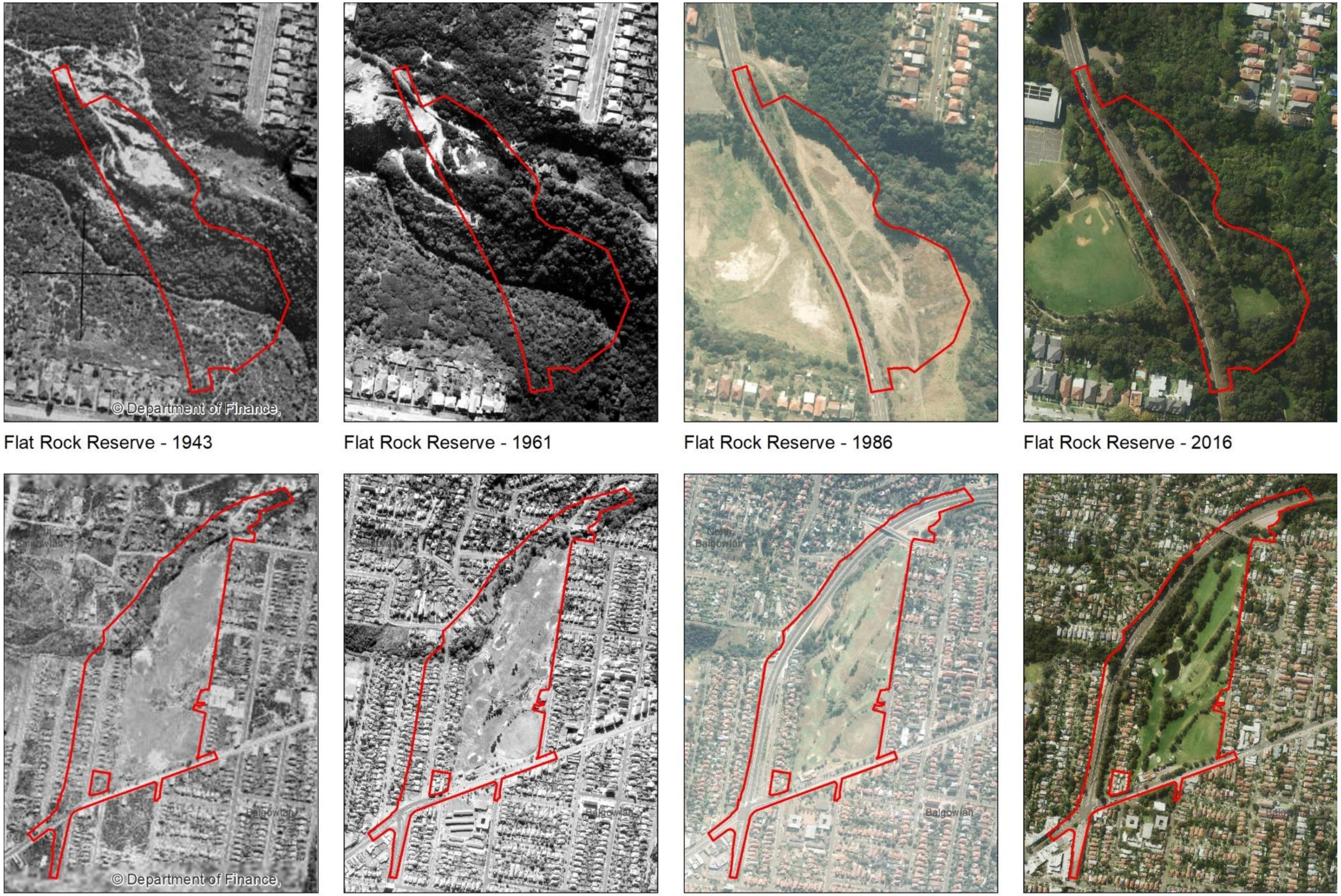
The Flat Rock Drive construction support site (BL2) contains mature native revegetation, with local native tree species including *Angophora costata, Corymbia maculata*, *Eucalyptus pilularis* and *Syncarpia glomulifera* frequently observed. The midstorey contained numerous mature small trees and tall shrubs including *Pittosporum undulatum, Glochidion ferdinandi, Elaeocarpus reticulatus, Tristaniopsis laurina, Acacia linifolia* and *Banksia spinulosa.* The southern part of the site includes a large area of cleared, mown exotic grassland.

The vegetation on the Flat Rock Drive construction support site (BL2) does not clearly fit the description of any PCTs known to occur the locality. The soils of this site have been imported, and a range of local native species have been planted. As such, the vegetation in the subject land has been assigned to the adjoining PCT *Smooth-barked Apple – Turpentine – Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney Region* (PCT 1841) for the purpose of assessment using the BAM credit calculator. PCT 1841 has previously been identified as occurring nearby in Flat Rock Reserve (Willoughby City Council, 2018), occupies a similar landscape position and the characteristic canopy and understorey species of this PCT are present within the vegetation zone.

The vegetation integrity score for the native revegetation vegetation zone, as calculated against the benchmarks for PCT 1841, and the condition scores that determine this are provided in Table 3.20.

Table 3.20 Native revegetation – Condition scores and vegetation integrity score (based on PCT 1841 benchmarks)

Composition condition score	Structure condition score	Function condition score	Vegetation integrity score
60.6	15.1	58.9	37.7



Flat Rock Reserve - 1943

Flat Rock Reserve - 1961

Flat Rock Reserve - 1986

Flat Rock Reserve - 2016

Burnt Bridge Creek - 1943

Burnt Bridge Creek - 1970

Burnt Bridge Creek - 1986

Burnt Bridge Creek - 2016

Figure 3-5 Historical aerial photographs of the subject land at Flat Rock Reserve and Burnt Bridge Creek

3.4.1.2 Native plantings

This vegetation association occurs within highly disturbed areas which have been subject to landscaping following development of infrastructure (eg roads, rail, and electricity easements), recreational facilities (eg sports fields, walking tracks), parking areas as well as residential and commercial areas. These landscaped areas have commonly been planted out with native species using horticultural specimens with unknown genetic origins.

Native plantings include a range of hardy native species such as Eucalypts, Grevilleas, Acacias, Callistemons, *Breynia oblongifolia*, *Bursaria spinosa* (Blackthorn), *Kunzea ambigua* (Tick Bush), Banksias and Hakeas.

3.4.1.3 Urban exotic/native

This vegetation occurs as highly modified landscaped vegetation in gardens, parks and road verges within the subject land. These areas generally contain planted native and exotic horticultural specimens or isolated remnant trees. This vegetation association has been previously mapped within the subject land (OEH, 2016).

Species recorded within this vegetation type include *Casuarina glauca* (Swamp Oak), *Grevillea species, Callistemon species, Murraya paniculata* (Murraya), *Eucalyptus microcorys* (Tallowwood), *Nerium oleander* (Oleander), *Acacia podalyriifolia* (Queensland Silver Wattle) and *Lophostemon confertus* (Brush Box).

3.4.1.4 Weeds and exotics

This vegetation type generally occurs as exotic grasslands or dense thickets of woody weeds within parks and road verges. This vegetation type has been previously mapped within the subject land (OEH, 2016).

These areas are generally dominated by exotic perennial grasses (eg *Pennisetum clandestinum* (Kikuyu), *Ehrharta erecta*, *Axonopus fissifolius* (Narrow-leaved Carpet Grass), exotic herbs (eg *Plantago lanceolata* (Lamb's Tongues), *Hypochaeris radicata* (Catsear), *Trifolium* spp. (Clover) and woody exotic shrubs (eg *Lantana camara*, *Ligustrum* spp. (Privet)). A small number of native groundcover species (eg *Microlaena stipoides var. stipoides*, *Dichondra repens*) are also found in this vegetation type. However, these species occur in low densities. The occasional remnant or planted trees also occur as scattered individuals.

3.5 Threatened ecological communities

A search of the Threatened Biodiversity Data Collection identified 20 TECs listed under the BC Act as known or likely to occur within the Sydney Basin – Pittwater IBRA subregion.

A search of the Department of the Agriculture, Water and the Environment (DAWE) EPBC Protected Matters Search Tool on 3 April 2020 identified 12 TECs listed under the EPBC Act that are known or likely to occur within 10 kilometres of the subject land. The TECs identified in each database search and their potential to occur in the subject land are listed in Annexure A.

One TEC listed as Endangered under the BC Act was identified in the subject land: Duffys Forest Ecological Community in the Sydney Basin Bioregion. Another TEC listed as Endangered under the BC Act, Coastal Upland Swamp in the Sydney Basin Bioregion, has been mapped near the alignment by OEH (2016). These TECs are described in further detail below.

Two TECs were considered to have potential to occur within the subject land at Artarmon Park/Oval:

- Sydney Turpentine-Ironbark Forest – listed as Endangered under the BC Act and Critically Endangered under the EPBC Act
- Blue Gum High Forest in the Sydney Basin Bioregion – listed as Critically Endangered under the BC Act and EPBC Act.

As part of the *Artarmon Park Plan of Management*, Willoughby City Council identified the potential occurrence of Blue Gum High Forest in the Sydney Basin Bioregion in this location (Ian Perkins Consultancy Services, 1996). WSP (2018) conducted a comprehensive investigation of this area, including detailed plot and transect survey (BB19, BB21), analysis of historic aerial photos, a review of geology and soil landscape mapping and detailed analysis and comparison of plot data to Blue Gum High Forest in the Sydney Basin Bioregion (PCT 1237) and Sydney Turpentine-Ironbark Forest (PCT 1281).

It was concluded, based on the recorded plot data and geological site setting, that this vegetation is consistent with PCT 1841 as described by OEH (2016). The presence of enriched clay material with Hawkesbury Sandstone geology is consistent with this community description and is consistent with historic accounts of this vegetation type within the lower elevated areas of Artarmon that exhibit sandstone rock outcropping (Benson and Howell, 1990). It was concluded that this vegetation does not fall within the definition of either the Sydney Turpentine-Ironbark Forest or Blue Gum High Forest in the Sydney Basin Bioregion TECs (WSP, 2018).

3.5.1 Duffys Forest Ecological Community in the Sydney Basin Bioregion

Duffys Forest Ecological Community in the Sydney Basin Bioregion (Duffys Forest TEC) is listed as Endangered under the BC Act. This community corresponds with the PCT 1786/ME98/Red Bloodwood – Silvertop Ash – Stringybark open forest on ironstone in the Sydney region, which was recorded in and adjoining the subject land along the Wakehurst Parkway between Judith Street and Warringah Road (Figure 3-6).

Duffys Forest TEC is an open forest or woodland community that is situated on ridgetops, plateaus, upper slopes and mid slopes in association with shale lenses and lateritic soils in Hawkesbury Sandstone. The community is known to occur in the Ku-ring-gai, Hornsby and Northern Beaches (formerly Warringah, Pittwater and Manly) local government areas (OEH, 2017b).

A comparison of the vegetation mapped as PCT 1786 in the subject land with the relevant paragraphs of the final determination for Duffys Forest TEC was carried out (Table 3.21).

Table 3.21 Comparison of areas mapped as PCT 1786 in the subject land with final determination

Final determination identification attributes	Final determination paragraph extract	Comparison with areas mapped as Duffys Forest TEC
Bioregion	Sydney Basin bioregion	The subject land is within the Sydney Basin Bioregion
Location	Paragraph 2. The Duffys Forest Ecological Community has been reported from the Warringah, Pittwater, Ku-ring-gai, Hornsby and Manly local government areas, although it may occur elsewhere in the Sydney Basin Bioregion.	Part of the subject land is within the Northern Beaches local government area, in an area that was formerly the Warringah local government area.
Floristic composition	Paragraph 3. Duffys Forest Ecological Community is characterised by the following assemblage of vascular plant species: 73 species listed.	In the three quadrats sampling this community, the following numbers of listed characteristic species were recorded: BB14: 32 species P20: 28 species A01: 14 species

Final determination identification attributes	Final determination paragraph extract	Comparison with areas mapped as Duffys Forest TEC
	Paragraph 5. Smith and Smith (2000) give a list of diagnostic plant species for Duffys Forest Ecological Community and describe how the community can be distinguished from surrounding ecological communities. Diagnostic species provide a guide to identification of the community, but care should be taken in the application and interpretation of diagnostic plant species because of sampling limitations; the reduction in species diversity in degraded sites; and the fact that some species may only be present at a site at sometimes as a part of the soil seedbank or as dormant buds/tubers.	The species list provided by Smith and Smith (2000) was not informative when reviewed against the vegetation data collected in the subject land, due to low native species counts in the vegetation plots. Between 0 and 5 diagnostic species for Duffys Forest TEC were recorded in each of the three quadrats sampling mapped areas of this community. It is noted that only one diagnostic species for the similar vegetation types for which Smith and Smith (2000) lists diagnostic species was recorded in the same quadrats.
Characteristic tree species	Not specifically described; however, the following eucalypt species are included in the list of characteristic species in Paragraph 3: *Angophora costata* *Eucalyptus capitellata* *Eucalyptus (Corymbia) gummifera* *Eucalyptus haemastoma* *Eucalyptus sieberi*	One or more of the listed characteristic eucalypt species were recorded in each quadrat sampling this community: BB14: *Corymbia gummifera, Eucalyptus capitellata* P20: *Angophora costata, Corymbia gummifera, Eucalyptus sieberi* A01: *Eucalyptus capitellata, Eucalyptus sieberi*
Structure	Paragraph 2: It has the structural form predominantly of open-forest to woodland.	The native vegetation in the subject land generally has the structural form of open-forest.
Soils and landscape position	Paragraph 2: occurs on the ridgetops, plateaus, upper slopes and occasionally mid slopes on Hawkesbury Sandstone geology, typically in association with laterite soils and soils derived from shale and laminite lenses.	The subject land includes areas on the ridgetops, plateaus, upper slopes and midslopes on Hawkesbury geology. Some areas within the subject land are on laterite soils, with lateritic gravel observed at the surface within mapped locations of the community.
Vegetation mapping	Paragraph 7 lists a number of vegetation mapping reports and species recovery plans, including Smith and Smith (2000). All are dated between 1985 and 2000.	Smith and Smith (2000) describe and map Duffys Forest TEC vegetation adjoining Seaforth Oval and along the southern side of Aquatic Drive on both sides of the Wakehurst Parkway.

The vegetation mapped as PCT 1786 within the subject land meets the criteria in the final determination for Duffys Forest TEC for location, soils and landscape position, and structure, and most of the mapped patches were also mapped by sources referenced in Paragraph 7 of the final determination. The vegetation contains listed characteristic species for the Duffys Forest TEC, including characteristic tree species. Analysis of the floristic composition of the community using diagnostic species, both with the Smith and Smith (2000) methodology and the OEH (2016) list of positive diagnostic species, was inconclusive, even in quadrats with high native species counts and sampling good quality vegetation that has previously been mapped as Duffys Forest TEC in multiple studies.

On balance, the vegetation within the subject land mapped as PCT 1786 is considered consistent with Duffys Forest TEC as listed under the BC Act.

3.5.2 Coastal Upland Swamp in the Sydney Basin Bioregion

Coastal Upland Swamp in the Sydney Basin Bioregion is listed as Endangered under the BC Act and the EPBC Act. This TEC was not mapped or identified within the subject land. However, the TEC has been mapped near the subject land by OEH (2016), with the closest mapped area around 30 metres to the east of the subject land near the Wakehurst Parkway.

The areas mapped by OEH (2016) as Coastal Upland Damp Heath Swamp (map unit S_FrW01) that are within 500 metres of the subject land were reviewed using aerial photography, and some areas were ground truthed during site inspections.

The area of Coastal Upland Swamp mapped by OEH (2016) located around 30 metres east of the subject land was inspected by WSP and Arcadis on 23 March 2018. The vegetation in this location was observed to consist of heathy woodland and dense stands of *Allocasuarina littoralis,* and is not consistent with Coastal Upland Swamp.

The area of Coastal Upland Swamp mapped by OEH (2016) to the north of Bantry Bay Oval, about 135 metres south-east of the subject land, was inspected by Arcadis on 19 June 2019. A drainage soak extends across this area, draining northwards into to the large dam to the north of the mapped patch. Most of the mapped patch consists of heathy woodland, some of which includes eucalypt cover, and boggy areas with a canopy of mesic species such as *Cyathea* spp. (Tree Ferns) and *Glochidion ferdinandii* (Cheese Tree), and dense ground cover dominance by the weedy non-local native fern *Nephrolepis cordifolia* (Fishbone Fern). This vegetation is not consistent with Coastal Upland Swamp.

A small area of vegetation overlapping the south-east of this mapped patch contains some characteristics of Coastal Upland Swamp, with boggy areas that are likely to be permanently waterlogged, based on the dominance of sedges and high cover of *Gleichenia dicarpa* (Pouched Coral Fern) in the ground layer. This area is devoid of eucalypts but includes scattered tall shrubs of *Banksia ericifolia* (Heath-leaved Banksia) and *Allocasuarina littoralis* (Forest She-oak). This small area covers around 0.07 hectares and is considered to form part of the Coastal Upland Swamp TEC for the purposes of this assessment.

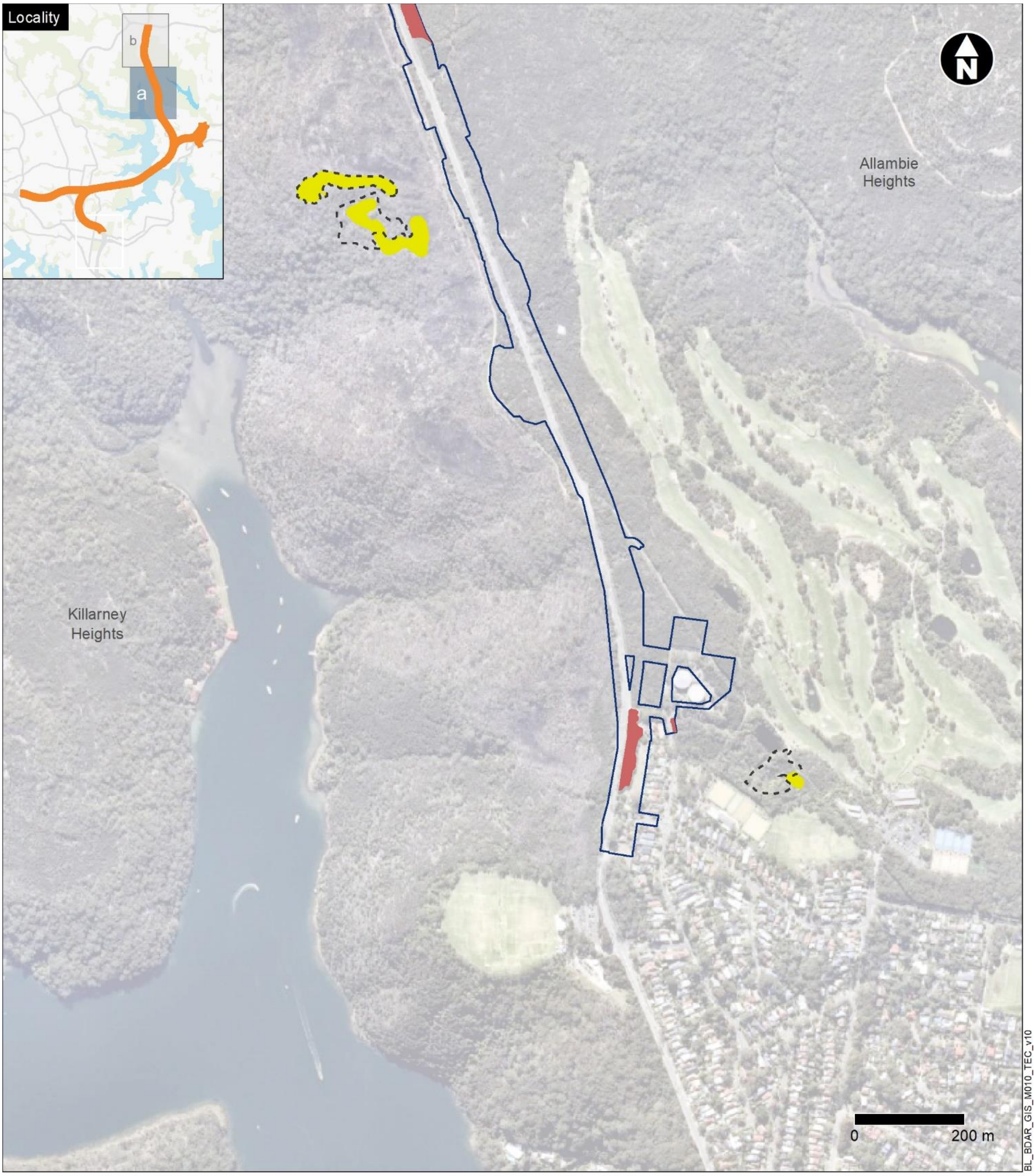
Almost all of the Coastal Upland Swamp mapped to the west of the subject land (at Wakehurst Parkway) is located within Garigal National Park. One of the mapped patches in the north of Garigal Park, to the south of Grattan Crescent, has been partially cleared for residential development, as shown on the current aerial photograph (Figure 3-6). The closest mapped patch of Coastal Upland Swamp in Garigal National Park to the subject land is about 95 metres to the west. This patch was inspected in June 2021.

The area of Coastal Upland Swamp inspected to the west of Wakehurst Parkway (and surrounding areas in Garigal National Park) were burnt in 2017, based on review of historical aerial imagery available on Google Earth. The area inspected is characterised by descending sandstone benches and cliffs supporting regenerating shrubland, with a high volume of fallen dead trunks and branches, presumably from fire-killed shrubs. Tree cover and regrowth within the regenerating shrubland appears to be low, although some areas within the area mapped as Coastal Upland Swamp by OEH (2016) are Eucalypt-dominated heathy forest. Soils are damp and boggy with seepage and minor overland flows observed on the lower benches.

The areas of regenerating shrubland is characterised by a tall shrub layer, mostly comprising dead stems of *Banksia ericifolia*, *Allocasuarina distyla*, and *Hakea teretifolia*; a low shrub layer including *Leptospermum squarrosum*, *Hibbertia linearis*, *Pultenaea tuberculata*, *Platysace linearifolia*, *Epacris microphylla* and *Xanthosia tridentata*; and a ground layer dominated by sedges and herbs, such as

Gonocarpus tetragynus, *Schoenus apogon*, *Lepyrodia scariosa*, *Empodisma minus*, *Lepidosperma forsythii*, *Entolasia stricta*, and *Actinotus minor*.

The extent of the Coastal Upland Swamp as mapped by OEH (2016) in the area inspected to the west of Wakehurst Parkway has been revised following site inspection and aerial photograph interpretation (refer to Figure 3-6). The revised extent is an estimation, given the regenerating stage of the vegetation in this area. The northern patch was not inspected in detail and has not been amended but appears based on aerial photo review to be consistent with a regenerating shrubland structure. It is possible that the boundaries of the Coastal Upland Swamp and adjoining woodland will further shift over time in response to climatic patterns and fire regimes.



Legend

Subject land

Duffys Forest Ecological Community in the Sydney Basin Bioregion

Coastal Upland Swamp - mapped by OEH (2016)

Coastal Upland Swamp - revised following ground truthing

Figure 3-6 Threatened ecological communities (map a)

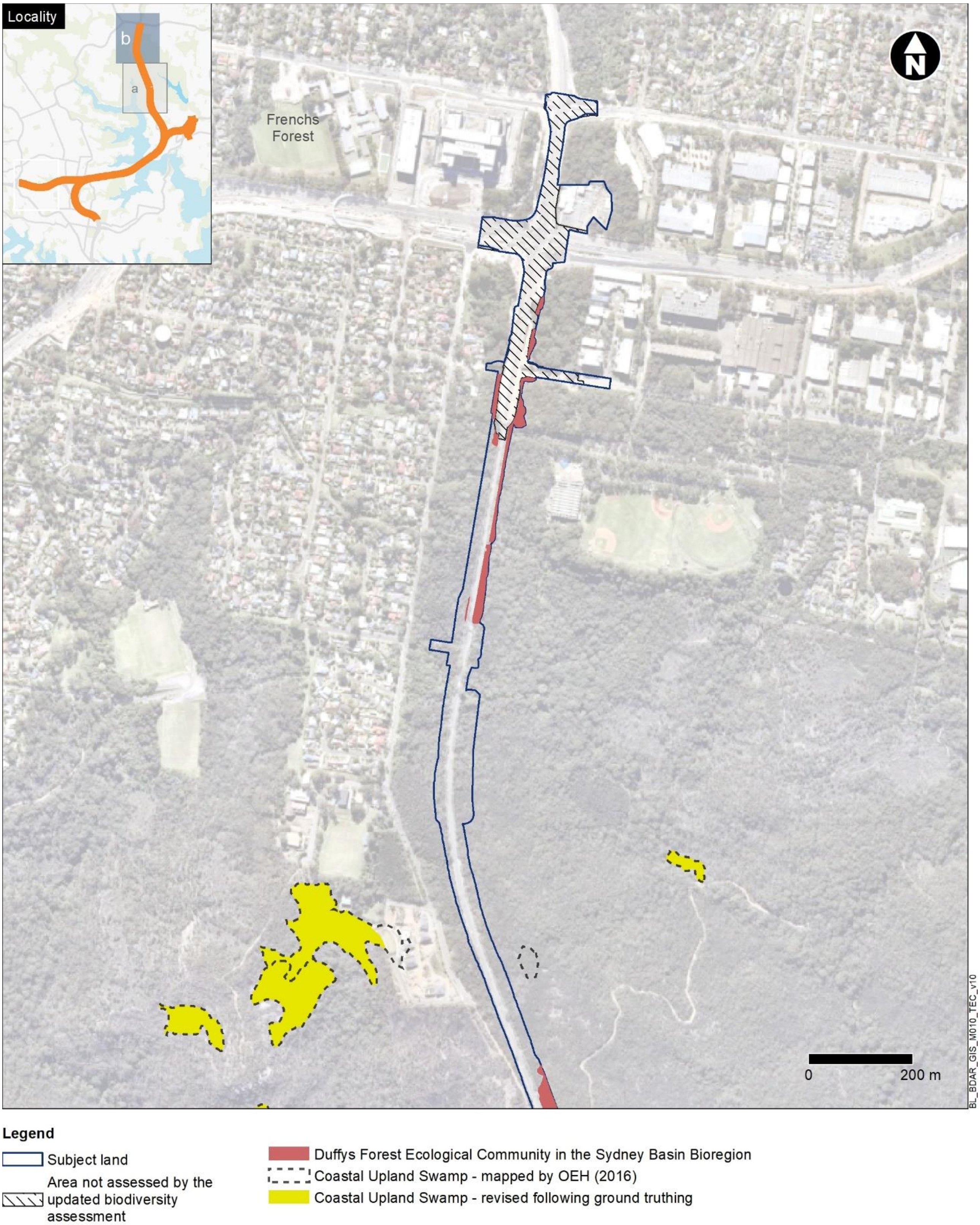


Figure 3-6 Threatened ecological communities (map b)

3.6 Threatened species

A number of threatened flora and fauna species were predicted to occur in the subject land, based on review of candidate threatened species generated by the BAM credit calculator, and the results of database searches.

Two threatened flora species and two threatened fauna species were recorded in the subject land during targeted surveys for the project. An additional seven threatened fauna species were considered highly likely to occur in the subject land, due to the presence of potential habitat and/or the species being previously recorded in (or near) the subject land.

Threatened species predicted and known to occur in the subject land are discussed in further detail below.

3.6.1 Threatened flora species

3.6.1.1 Species credit species

The BAM credit calculator identified 43 candidate threatened flora species credit species. The geographic distribution and habitat requirements of each species were reviewed, and a total of 19 candidate threatened flora species were confirmed on the basis of presence of suitable potential habitat (Table 3.22).

Justification for the likelihood of occurrence determined for each species is provided in Annexure A of this report.

Table 3.22 Candidate threatened flora species

Scientific name	Common name	BC Act status*	EPBC Act status*	Sensitivity to gain class#	Biodiversity risk weighting#
Acacia bynoeana	Bynoe's Wattle	E	V	High	2
Acacia terminalis subsp. *terminalis*	Sunshine Wattle	E	E	Moderate	2
Callistemon linearifolius	Netted Bottle Brush	V	-	High	2
Epacris purpurascens var. purpurascens	-	V	-	Moderate	1.5
Eucalyptus camfieldii	Camfield's Stringybark	V	V	High	2
Genoplesium baueri	Bauer's Midge Orchid	E	E	Moderate	3
Grevillea caleyi	Caley's Grevillea	CE	E	High	3
Haloragodendron lucasii	-	E	E	Very High	3
Hibbertia puberula	-	E	-	High	2
Lasiopetalum joyceae	-	V	V	High	2
Leptospermum deanei	-	V	V	Moderate	1.5
Microtis angusii	Angus's Onion Orchid	E	E	High	2

Scientific name	Common name	BC Act status*	EPBC Act status*	Sensitivity to gain class#	Biodiversity risk weighting#
Persoonia hirsuta	Hairy Geebung	E	E	High	2
Pimelea curviflora var. curviflora	-	V	V	High	2
Prostanthera junonis	Somersby Mintbush	E	E	High	2
Prostanthera marifolia	Seaforth Mintbush	CE	CE	High	3
Rhodamnia rubescens	Scrub Turpentine	CE	CE	High	3
Syzygium paniculatum	Magenta Lilly Pilly	E	V	Moderate	2
Tetratheca glandulosa	-	V	-	High	2

*V=Vulnerable, E=Endangered, CE=Critically Endangered
See section 2.9 for definitions of these terms

3.6.1.2 Species recorded within 1.5 kilometres of the subject land

In addition to the BAM credit calculator outputs (as described in Section 3.6.1.1), the Secretary's environmental assessment requirements require assessment of all threatened species recorded recently (since 1990) within 1.5 kilometres of the subject land.

Fourteen threatened flora species listed under the BC Act have been recorded recently (since 1990) within 1.5 kilometres of the subject land (Table 3.23). Eleven of these 14 species were identified as potential candidate species by the BAM credit calculator, as listed in Table 3.22. Of these, all 11 were confirmed as candidate species on the basis of a moderate to high likelihood of occurrence (see Annexure A for justification of likelihood of occurrence of each species). These species were subject to targeted seasonal surveys in accordance with the BAM.

The three additional threatened flora species recorded within 1.5 kilometres of the subject land, that were not identified by the BAM calculator, are *Eucalyptus nicholii, Hibbertia superans* and *Macadamia integrifolia. Eucalyptus nicholii* and *Macadamia integrifolia* have a low likelihood of occurrence, and would occur only as planted non-local native species. *Hibbertia superans* is considered to have a low likelihood of occurrence within or near the subject land, based on the known distribution and habitat requirements of this species.

Table 3.23 Threatened flora species recorded within 1.5 kilometres of the subject land since 1990 (DPIE (EES) 2020a)

Scientific name	Common name	BC Act status*	EPBC Act status*	Identified by BAM credit calculator	Likelihood of occurrence	Candidate species
Acacia terminalis subsp. *terminalis*	Sunshine Wattle	E	E	Yes	Moderate	Yes
Callistemon linearifolius	Netted Bottle Brush	V		Yes	Known	Yes
Epacris purpurascens var. purpurascens		V		Yes	Moderate	Yes

Scientific name	Common name	BC Act status*	EPBC Act status*	Identified by BAM credit calculator	Likelihood of occurrence	Candidate species
Eucalyptus camfieldii	Camfield's Stringybark	V	V	Yes	Moderate	Yes
Eucalyptus nicholii	Narrow-leaved Black Peppermint	V	V	No	Low (only as planted non-local native)	No
Hibbertia superans		E		No	Low	No
Macadamia integrifolia	Macadamia Nut		V	No	Low (only as planted non-local native)	No
Microtis angusii	Angus's Onion Orchid	E	E	Yes	Moderate	Yes
Pimelea curviflora var. curviflora		V	V	Yes	Moderate	Yes
Prostanthera junonis	Somersby Mintbush	E	E	Yes	Moderate	Yes
Prostanthera marifolia	Seaforth Mintbush	CE	CE	Yes	Moderate	Yes
Rhodamnia rubescens	Scrub Turpentine	CE	CE	No	Moderate	Yes
Syzygium paniculatum	Magenta Lilly Pilly	E	V	Yes	Known	Yes
Tetratheca glandulosa		V		Yes	High	Yes

*V=Vulnerable, E=Endangered, CE=Critically Endangered

There are also records of nine fungi species recorded recently (since 1990) within 1.5 kilometres of the subject land (Table 3.24). All of these species were also identified as potential candidate species by the BAM credit calculator. In the region, these fungi species are only known to occur in the Lane Cove Bushland Park, and all are considered to have a low likelihood of occurrence in the subject land.

Table 3.24 Threatened fungi species recorded within 1.5 kilometres of the subject land (Bionet Atlas Database)

Scientific name	BC Act status*	EPBC Act status*	Identified by BAM credit calculator	Likelihood of occurrence	Candidate species
Camarophyllopsis kearneyi	E		Yes	Low	No
Hygrocybe anomala var. ianthinomarginata	V		Yes	Low	No
Hygrocybe aurantipes	V		Yes	Low	No
Hygrocybe austropratensis	E		Yes	Low	No
Hygrocybe collucera	E		Yes	Low	No
Hygrocybe griseoramosa	E		Yes	Low	No
Hygrocybe lanecovensis	E		Yes	Low	No
Hygrocybe reesiae	V		Yes	Low	No
Hygrocybe rubronivea	V		Yes	Low	No

*V=Vulnerable, E=Endangered

3.6.1.3 Threatened flora species recorded in the subject land

Two threatened flora species listed under the EPBC Act and/or BC Act were recorded within the subject land by WSP (2018) (refer to Table 3.25 and Figure 3-7).

Table 3.25 Threatened flora recorded in the subject land

Species	BC Act status*	EPBC Act status*	Occurrence in subject land	Type of credit
Callistemon linearifolius (Netted Bottle Brush)	V	-	Known to occur in the subject land. Four planted individuals recorded at Burnt Bridge Creek Deviation.	Species credit species
Syzygium paniculatum (Magenta Lilly Pilly)	E	V	Known to occur in the subject land. One remnant individual was recorded at the Wakehurst Parkway, 11 planted individuals recorded at Burnt Bridge Creek Deviation and two planted individuals at Flat Rock Creek Reserve. Of these, the one remnant individual and four of the planted individuals are located within or at the edge of the subject land.	Species credit species

*V=Vulnerable, E=Endangered

3.6.1.3.1 Callistemon linearifolius (Netted Bottle Brush)

Callistemon linearifolius is listed as a Vulnerable species under the BC Act.

Four individuals of *Callistemon linearifolius* were located within landscaped/planted areas with a mulched understorey. Some specimens had stakes attached to them and appeared to have been planted in linear rows. This species is commonly grown and cultivated in the horticultural industry. These planted individuals are not of conservation significance and are not assessed further using the BAM.

3.6.1.3.2 Syzygium paniculatum (Magenta Lilly Pilly)

Syzygium paniculatum is listed as an Endangered species under the BC Act and as a Vulnerable species under the EPBC Act.

Eleven individuals of *Syzygium paniculatum* were recorded at Burnt Bridge Creek Deviation, located within landscaped/planted areas with a mulched understorey. Some specimens had stakes attached to them and appeared to have been planted in linear rows. This species is commonly grown and cultivated in the horticultural industry. These planted individuals are not of conservation significance and are not assessed further using the BAM.

Two individuals of *Syzygium paniculatum* were recorded to the east of the subject land at Flat Rock Reserve. The reserve has been extensively planted, and it is likely that these specimens are planted. The two individuals are located about 18 metres from the subject land.

One individual of *Syzygium paniculatum* was recorded next to the Wakehurst Parkway in PCT 1250. The species is not known to be associated with this vegetation type and it is considered unlikely to occur naturally at this location. However, there is no evidence that this specimen has been planted, and it may be of wild provenance. A species polygon was prepared for this record by applying a 30 metre buffer and clipping to the subject land (Figure 3-8). The species polygon covers an area of 0.1 hectares. The individual is mapped just outside the subject land, but due to GPS error it may be located within it, and is therefore assumed to be within the subject land for the purpose of this assessment.

3.6.1.4 Threatened flora species recorded in surveys near the subject land

Three additional threatened flora species were recorded during surveys conducted by WSP (2018) in areas close to the subject land (Figure 3-7): *Acacia terminalis* subsp. *terminalis, Tetratheca glandulosa* and *Epacris purpurascens* var. *purpurascens.*

An additional threatened species, *Prostanthera marifolia,* is known to occur in the locality of the subject land.

3.6.1.4.1 Acacia terminalis subsp. terminalis (Sunshine Wattle)

Acacia terminalis subsp. *terminalis* is listed as Endangered under the BC Act and EPBC Act.

Three individuals of *Acacia terminalis* subsp. *terminalis* were recorded in a small, isolated patch of PCT 1786 between the Wakehurst Parkway and Seaforth Oval car park, about 145 metres south of the subject land. This patch of vegetation is disturbed and subject to ongoing edge effects, weed incursion, trampling and rubbish dumping. The individuals in this location were also observed to be in poor health.

Another five individuals of *Acacia terminalis* subsp. *terminalis* were recorded by WSP (2018) around 170 metres west of the subject land, in vegetation along Burnt Bridge Creek.

The Threatened Biodiversity Data Collection (DPIE (EES), 2020c) identifies the PCTs 1250 and 1824 as being associated with *Acacia terminalis* subsp. *terminalis.* Although there are numerous records of the species within 10 kilometres of the subject land on Bionet (DPIE (EES), 2020a) most are located to the south east of the subject land, in locations closer to the coast. The subject land is considered likely to be at or near the limit of the known distribution of *Acacia terminalis* subsp. *terminalis.*

3.6.1.4.2 Tetratheca glandulosa

Tetratheca glandulosa is listed as Vulnerable under the BC Act. Three individuals of this species were recorded by WSP (2018) in bushland to the east of Wakehurst Parkway, around 47 metres east of the subject land (Figure 3-7).

The species has been recorded frequently within the locality and is associated with vegetation types (PCTs 1250, 1786, 1824 and 1845) that have been recorded throughout the subject land.

3.6.1.4.3 Epacris purpurascens var. purpurascens

Epacris purpurascens var. purpurascens is listed as Vulnerable under the BC Act. This species was recorded by WSP (2018) to the north of the subject land at Artarmon Park, where it occurs in several patches. The closest patch is located around 60 metres north of the subject land.

3.6.1.4.4 Prostanthera marifolia

Prostanthera marifolia is listed as Critically Endangered under the BC Act and EPBC Act. The species is currently only known from the suburb of Seaforth and has a very highly restricted distribution, with a single population fragmented by urbanisation into three small sites. It occurs in localised patches within or in close proximity to the endangered Duffys Forest ecological community (DPIE (EES), 2020d).

The largest population of *Prostanthera marifolia*, comprising the majority of individuals (referred to within the final determination for the species as the site that contains 76-83 per cent of the total population) is located over 600 metres from the subject land.

None of the previous records of the species are located within the subject land; the closest record to the subject land is about 32 metres to the west of the construction footprint. The location description for this record includes the information that it is on the western side of Wakehurst Parkway. As the subject land is on the eastern side of Wakehurst Parkway, it is likely that the record is outside the subject land and would not be impacted.

There is another record of one individual of *Prostanthera marifolia* within Garigal National Park, located over 80 metres from the subject land, and an additional record is located within the area surveyed during investigations for the project.

Targeted surveys recorded a single population of *Prostanthera* species within Duffys Forest vegetation in full flower near the Warringah Aquatic Centre in the north eastern portion of the Wakehurst Parkway section of the subject land. This species was determined to be *Prostanthera denticulata.* No other *Prostanthera* species were recorded during targeted surveys (WSP, 2018).

During targeted surveys near historic *Prostanthera marifolia* records around Seaforth Oval, specifically on the western side of the Wakehurst Parkway, it was found that dense stands of *Allocasuarina littoralis* have resulted in thick needle leaf litter and sparse to near absent ground stratum vegetation. Given the naturally acidic nature of *Allocasuarina* leaf litter, it is likely that the sparseness of the ground stratum is the result of higher soil acidity due to the dominance of *Allocasuarina littoralis* (WSP, 2018). These conditions, combined with increased edge effects and disturbance, may have limited the availability of suitable of habitat for *Prostanthera marifolia* in the area to the north of Seaforth Oval mapped as Duffys Forest between the Wakehurst Parkway and the Engravings Trail. Multiple seasonal targeted surveys for *Prostanthera marifolia* over two consecutive years in proximity to the previous record and in other areas of potential habitat did not detect the species. Known reference populations of local *Prostanthera* spp. were confirmed to be in flower at the time of the targeted surveys (WSP, 2018).

Legend

Subject land

Threatened species

Extent of occurrence of *Epacris purpurascens var purpurascens*

Figure 3-7 Threatened species recorded (WSP and Arcadis) (map a)

Figure 3-7 Threatened species recorded (WSP and Arcadis) (map b)

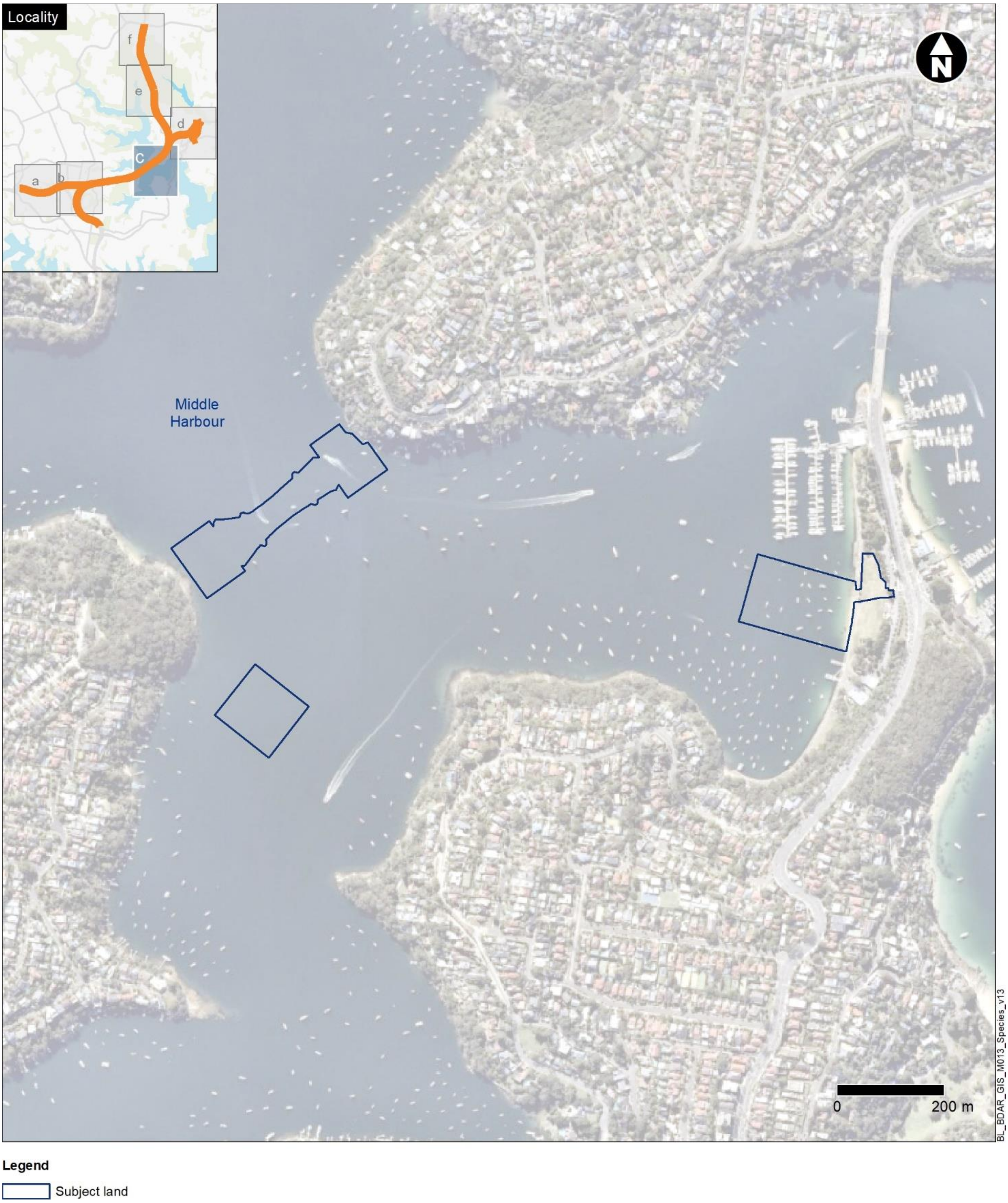


Figure 3-7 Threatened species recorded (WSP and Arcadis) (map c)

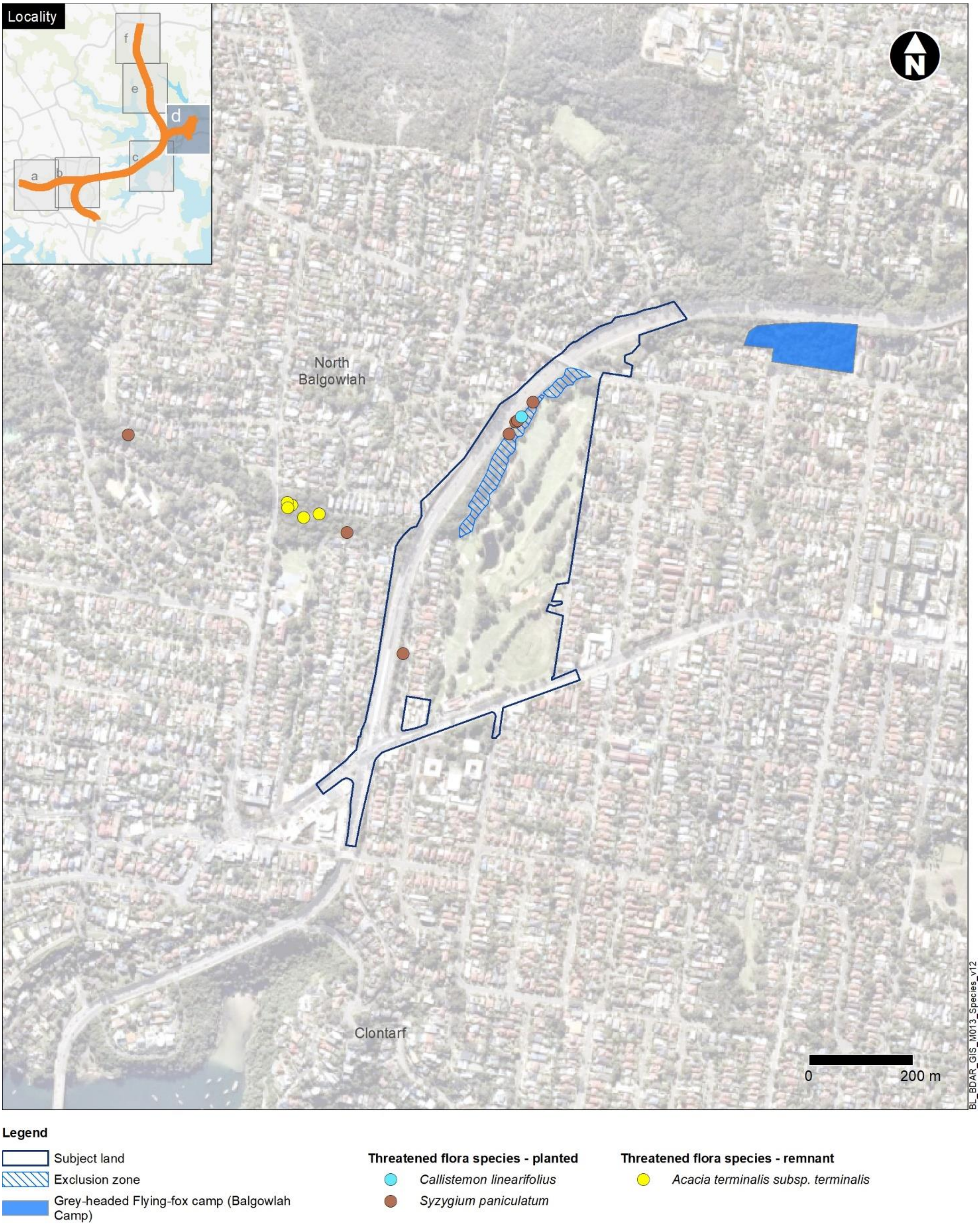


Figure 3-7 Threatened species recorded (WSP and Arcadis) (map d)

Figure 3-7 Threatened species recorded (WSP and Arcadis) (map e)

Figure 3-7 Threatened species recorded (WSP and Arcadis) (map f)

Legend

Subject land

Large-eared Pied Bat

Figure 3-8 Threatened species polygons (map a)

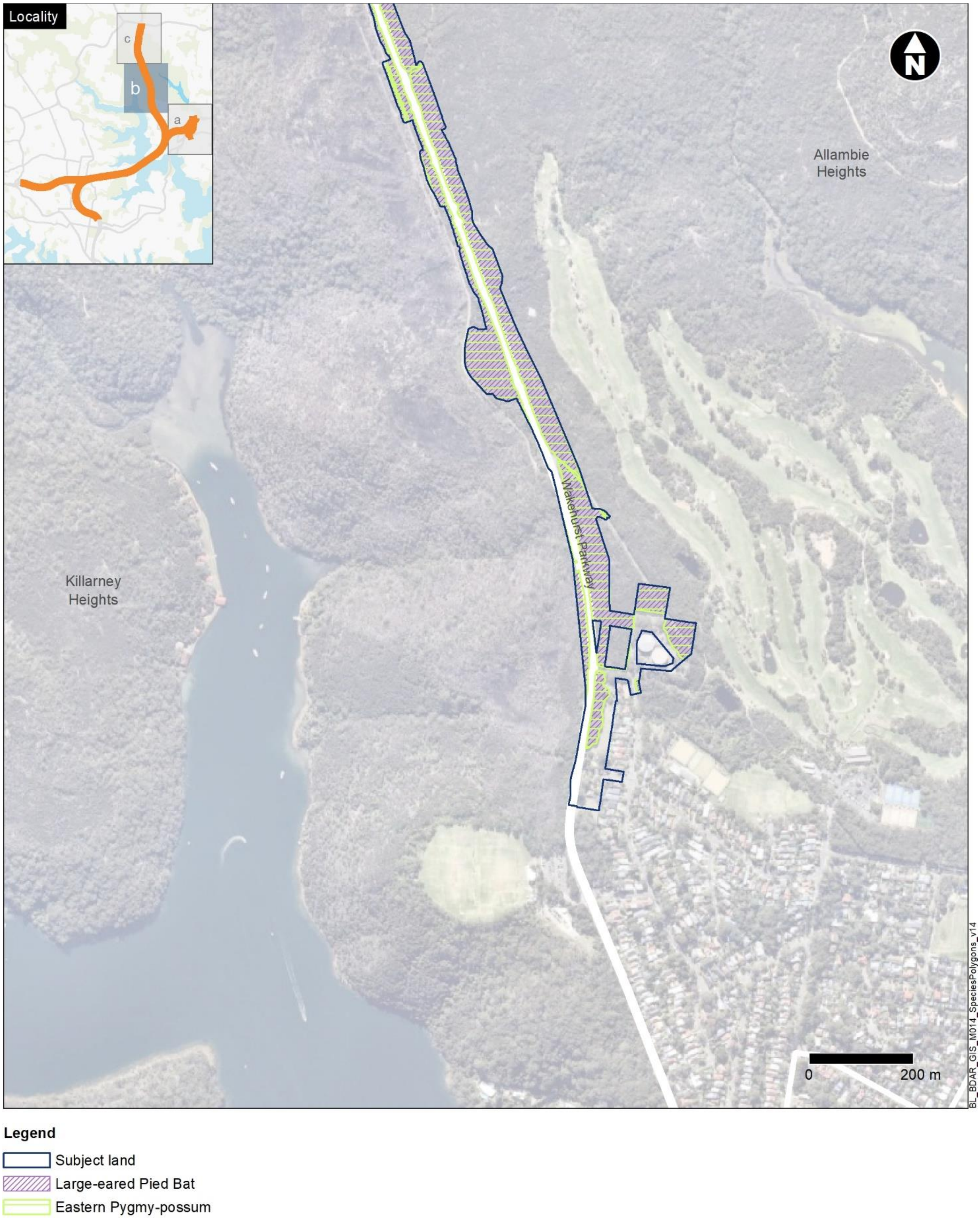
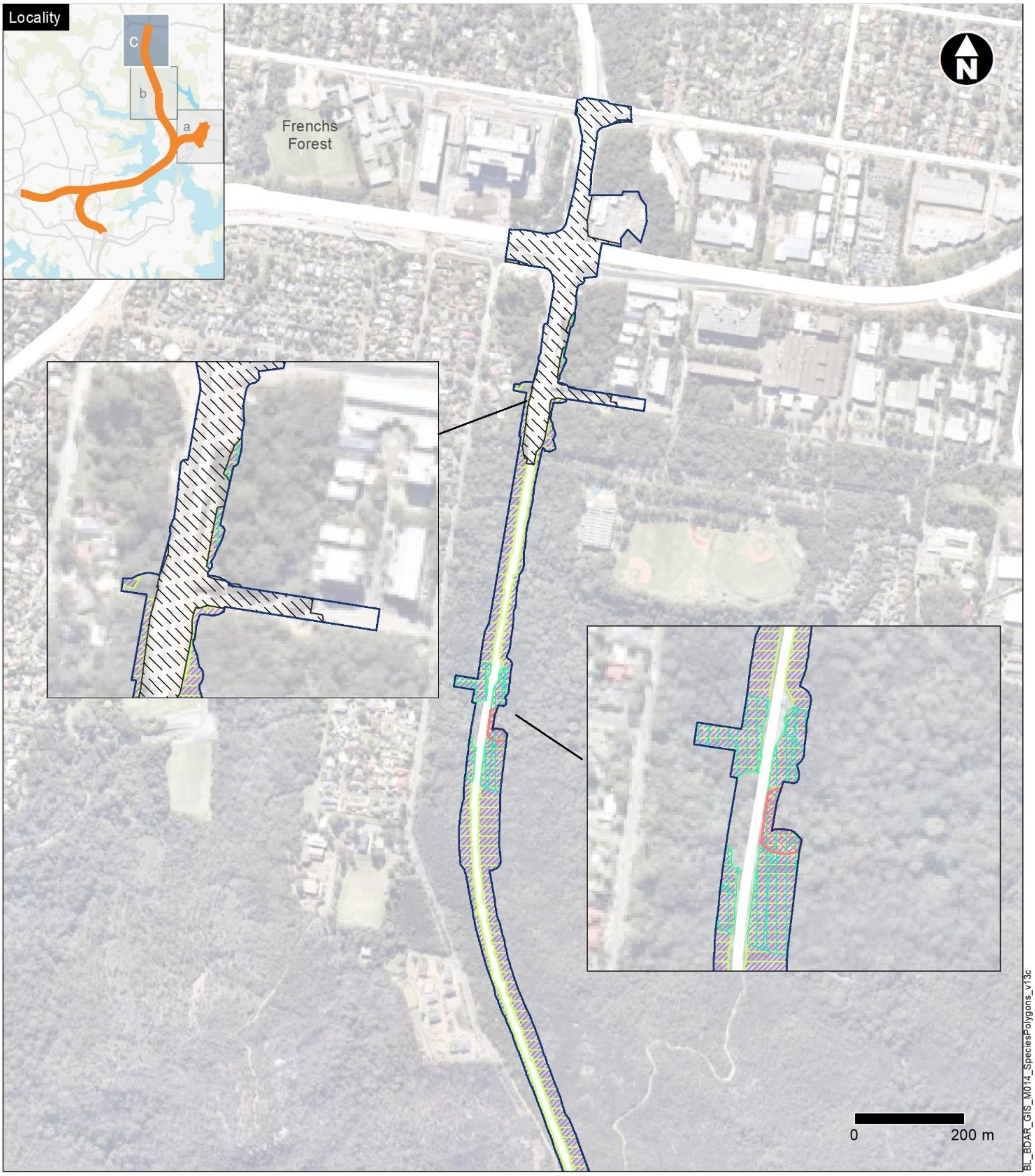


Figure 3-8 Threatened species polygons (map b)



Legend

- Subject land
- Area not assessed by the updated biodiversity assessment
- Large-eared Pied Bat
- Eastern Pygmy-possum
- Red-crowned Toadlet
- *Syzygium paniculatum*

Figure 3-8 Threatened species polygons (map c)

3.6.2 Threatened fauna species

3.6.2.1 Species credit species

The BAM credit calculator identified 36 candidate threatened fauna species credit species. The geographic distribution and habitat requirements of each species were reviewed and a total of 19 candidate threatened fauna species were confirmed (Table 3.26).

Of these 19 candidate threatened fauna species, 11 were recorded or considered highly likely to occur in the subject land, due to the presence of potential habitat:

- Red-crowned Toadlet (*Pseudophryne australis*)
- Large Bent-winged Bat (*Miniopterus orianae oceanensis*)
- Eastern Pygmy-possum (*Cercartetus nanus*)
- Little Bent-winged Bat (*Miniopterus australis*)
- Large-eared Pied Bat (*Chalinolobus dwyeri*)
- Southern Brown Bandicoot (*Isoodon obesulus obesulus*)
- Southern Myotis (*Myotis macropus*)
- White-bellied Sea-Eagle (*Haliaeetus leucogaster*)
- Powerful Owl (*Ninox strenua*)
- Grey-headed Flying-fox (*Pteropus poliocephalus*)
- Glossy Black-Cockatoo (*Calyptorhynchus lathami*).

Of these 11 species, six species are listed as both species credit and ecosystem credit species; Grey-headed Flying-fox, Powerful Owl, Glossy Black-Cockatoo, White-bellied Sea-Eagle, Little Bent-winged Bat and Large Bent-winged Bat. Though some of these species have been previously recorded in the subject land, no suitable breeding habitat, to which species credits would apply, was identified in the subject land. Accordingly, these six species are listed as ecosystem credit species in Section 3.6.2.2, and discussed in further detailed in Section 3.6.2.4.

A Grey-headed Flying-fox camp has been identified at a location in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the Kitchener Street construction support site (BL11).

The extent of the Grey-headed Flying-fox camp is shown in Figure 3-7. Database searches identified Eastern Pygmy-possum and Large-eared Pied Bat were previously recorded in the Wakehurst Parkway east construction support site (BL13) in 2018 (DPIE (EES), 2020a). In addition, the Eastern Pygmy-possum was recorded on two occasions during spotlight surveys targeting Koalas adjacent to Wakehurst Parkway outside of the subject land in June/July 2021.

Red-crowned Toadlet was assumed to be present in this assessment based on recent recordings of the species in the northern extent of the subject land during surveys for the Northern Beaches Hospital road upgrade project (SMEC, 2015).

Two threatened species credit fauna species, Southern Brown Bandicoot and Southern Myotis, were not recorded in the subject land following detailed targeted seasonal surveys. However, it is likely that these species occur in areas of habitat next to the subject land (such as in Garigal National Park and Manly Warringah War Memorial State Park) and may cross the subject land from time to time during foraging or dispersal activities.

Justification for the likelihood of occurrence determined for each species is provided in Annexure A of this report.

Marine seabirds are not included in the list of candidate species (as these species are not assessed under the BAM) and are instead described in Section 3.7.4.

Table 3.26 Candidate threatened fauna species

Common name	Scientific name	BC Act status*	EPBC Act status*	Sensitivity to gain class#	Biodiversity risk weighting#
Barking Owl (breeding habitat)	*Ninox connivens*	V	-	High	2
Large Bent-winged Bat (breeding habitat)	*Miniopterus orianae oceanensis*	V	-	Very high	3
Eastern Osprey (breeding habitat)	*Pandion cristatus* (syn. *P. haliaetus)*	V	-	Moderate	1.5
Eastern Pygmy-possum	*Cercartetus nanus*	V	-	High	2
Giant Burrowing Frog	*Heleioporus australiacus*	V	V	Moderate	1.5
Glossy Black-Cockatoo (breeding habitat)	*Calyptorhynchus lathami*	V	-	High	2
Green and Golden Bell Frog	*Litoria aurea*	E	V	High	2
Grey-headed Flying-fox (breeding habitat)	*Pteropus poliocephalus*	V	V	High	2
Koala (breeding habitat)	*Phascolarctos cinereus*	V	V	High	2
Large-eared Pied Bat	*Chalinolobus dwyeri*	V	V	Very high	3
Little Bent-winged Bat (breeding habitat)	*Miniopterus australis*	V	-	Very high	3
Little Eagle (breeding habitat)	*Hieraaetus morphnoides*	V	-	Moderate	1.5
Masked Owl (breeding habitat)	*Tyto novaehollandiae*	V	-	High	2
Powerful Owl (breeding habitat)	*Ninox strenua*	V	-	High	2
Red-crowned Toadlet	*Pseudophryne australis*	V	-	Moderate	1.5
Southern Brown Bandicoot (eastern)	*Isoodon obesulus*	E	E	High	2
Southern Myotis	*Myotis macropus*	V	-	High	2
Square-tailed Kite (breeding habitat)	*Lophoictinia isura*	V	-	Moderate	1.5
White-bellied Sea-Eagle (breeding habitat)	*Haliaeetus leucogaster*	V	-	High	2

*V=Vulnerable, E=Endangered, CE=Critically Endangered
See section 2.9 for definitions of these terms

3.6.2.2 Ecosystem credit species

The BAM credit calculator identified 36 threatened fauna species as predicted ecosystem credit species. The geographic distribution and habitat requirements of each species were reviewed and a total of 20 ecosystem credit species were confirmed (Table 3.27).

Five threatened ecosystem credit species were recorded during targeted surveys in or adjacent to the subject land:

- Grey-headed Flying-fox
- Rosenberg's Goanna
- Large Bent-winged Bat
- Little Bent-winged Bat
- Powerful Owl.

An additional four threatened ecosystem credit species are considered to have a high likelihood of occurrence due to the presence of potential habitat and/or the species being previously recorded in (or near) the subject land (DPIE (EES), 2020a):

- Glossy Black-Cockatoo
- White-bellied Sea-Eagle
- Eastern Coastal Free-tailed Bat
- Varied Sittella.

These species are discussed in further detailed in Section 3.6.2.4.

Justification for the likelihood of occurrence determined for each species is provided in Annexure A.

Table 3.27 Predicted threatened ecosystem credit species with potential habitat within the subject land

Common name	Scientific name	BC Act Status*	EPBC Act Status*	Sensitivity to gain class#	Associated PCTs
Barking Owl (foraging habitat)	*Ninox connivens*	V	-	High	1250, 1783, 1786, 1841, 1845
Dusky Woodswallow	*Artamus cyanopterus*	V	-	Moderate	1250, 1783, 1786, 1824, 1841, 1845
Large Bent-winged Bat (foraging habitat)	*Miniopterus orianae oceanensis*	V	-	High	1250, 1783, 1786, 1824, 1841, 1845
Eastern Coastal Free-tailed Bat	*Micronomus norfolkensis*	V	-	High	1250, 1783, 1786,1824, 1841, 1845
Eastern Osprey (foraging habitat)	*Pandion cristatus (syn. P. haliaetus)*	V	M	Moderate	1250, 1783, 1841
Glossy Black-Cockatoo (foraging habitat)	*Calyptorhynchus lathami*	V	-	High	1250, 1783, 1786 1824, 1841, 1845

Common name	Scientific name	BC Act Status*	EPBC Act Status*	Sensitivity to gain class#	Associated PCTs
Grey-headed Flying-fox (foraging habitat)	*Pteropus poliocephalus*	V	V	High	1250, 1783, 1786 1824, 1841, 1845
Little Bent-winged Bat (foraging habitat)	*Miniopterus australis*	V	-	High	1250, 1783, 1786, 1824, 1841, 1845
Little Eagle (foraging habitat)	*Hieraaetus morphnoides*	V	-	Moderate	1250, 1783, 1786, 1824, 1841, 1845
Little Lorikeet	*Glossopsitta pusilla*	V	-	High	1250, 1783, 1786, 1824, 1841, 1845
Masked Owl (foraging habitat)	*Tyto novaehollandiae*	V	-	High	1250, 1783, 1786, 1824, 1841, 1845
Powerful Owl (foraging habitat)	*Ninox strenua*	V	-	High	1250, 1783, 1786, 1841, 1845
Rosenberg's Goanna	*Varanus rosenbergi*	V	-	High	1250, 1783, 1786, 1824, 1841
Sooty Owl	*Tyto tenebricosa*	V	-	High	1250, 1824
Spotted-Tailed Quoll	*Dasyurus maculatus*	V	E	Moderate	1250, 1783, 1786, 1824, 1841, 1845
Square-tailed Kite (foraging habitat)	*Lophoictinia isura*	V	-	Moderate	1250, 1783, 1786, 1824, 1845
Swift Parrot (foraging habitat)	*Lathamus discolor*	E	CE	Moderate	1250, 1783, 1786, 1824, 1841, 1845
Varied Sittella	*Daphoenositta chrysoptera*	V	-	Moderate	1250, 1783, 1786, 1824, 1841, 1845
White-bellied Sea-Eagle (foraging habitat)	*Haliaeetus leucogaster*	V	-	High	1250, 1783, 1786, 1824
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	V	-	High	1250, 1841, 1845

* V=Vulnerable, E=Endangered, CE=Critically Endangered
# See section 2.9 for definitions of these terms
*V=Vulnerable, E=Endangered, CE=Critically Endangered, M=Migratory

3.6.2.3 Species recorded within 1.5 kilometres of the subject land

In addition to the BAM credit calculator outputs (as described in sections 3.6.2.1 and 3.6.2.2), the Secretary's environmental assessment requirements require assessment of all threatened species recorded recently (since 1990) within 1.5 kilometres of the subject land.

Thirty threatened fauna species listed under the BC Act have been recorded recently (since 1990) within 1.5 kilometres of the subject land (Table 3.28). One of the species identified, Loggerhead Turtle (*Caretta caretta*), is a marine species and has been addressed within *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b) and is not considered further in this report.

Nineteen of the species were identified as candidate species by the BAM credit calculator. Of these, 13 were confirmed as candidate species on the basis of a moderate to high likelihood of occurrence (or known occurrence) and, for species listed as both species credit and ecosystem credit species, the presence of species credit habitat features (see Annexure A for justification of likelihood of occurrence of each species and notes on presence/absence of breeding habitat representing species credit habitat in the case of species listed as both species credit and ecosystem credit species). These species were subject to targeted seasonal surveys in accordance with the BAM. Species listed as both ecosystem and species credit species were not considered to be candidate species where breeding habitat was known to be absent.

Table 3.28 Threatened fauna species recorded within 1.5 kilometres of the subject land (DPIE (EES) 2020a)

Common name	Scientific name	BC Act status*	EPBC Act status*	Identified by BAM credit calculator	Likelihood of occurrence	Ecosystem or species credit species	Candidate species
Barking Owl	*Ninox connivens*	V	-	Yes	Moderate	Species/Ecosystem	No
Black Bittern	*Ixobrychus flavicollis*	V	-	Yes	Low	Ecosystem	No
Bush Stone-curlew	*Burhinus grallarius*	E	-	Yes	Low	Species	No
Large Bent-winged Bat	*Miniopterus orianae oceanensis*	V	-	Yes	High	Species/Ecosystem	No
Eastern Coastal Free-tailed Bat	*Micronomus norfolkensis*	V	-	Yes	High	Species/Ecosystem	No
Eastern Osprey	*Pandion cristatus (syn. P. haliaetus*)	V	M	Yes	Moderate	Species/Ecosystem	Yes
Eastern Pygmy-possum	*Cercartetus nanus*	V	-	Yes	High	Species	Yes
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	V	-	Yes	High	Species/Ecosystem	Yes
Greater Broad-nosed Bat	*Scoteanax rueppellii*	V	-	Yes	Low	Ecosystem	No
Grey-headed Flying-fox	*Pteropus poliocephalus*	V	V	Yes	Known	Species/Ecosystem	Yes
Koala	*Phascolarctos cinereus*	V	V	Yes	Low	Species/Ecosystem	Yes
Large-eared Pied Bat	*Chalinolobus dwyeri*	V	V	Yes	High	Species	Yes
Little Bent-winged Bat	*Miniopterus australis*	V	-	Yes	High	Species/Ecosystem	No
Little Lorikeet	*Glossopsitta pusilla*	V	-	Yes	Moderate	Ecosystem	No
Masked Owl	*Tyto novaehollandiae*	V	-	Yes	Moderate	Species/Ecosystem	Yes
Powerful Owl	*Ninox strenua*	V	-	Yes	High	Species/Ecosystem	Yes
Red-crowned Toadlet	*Pseudophryne australis*	V	-	Yes	High	Species	Yes
Rosenberg's Goanna	*Varanus rosenbergi*	V	-	Yes	Known	Ecosystem	No

Common name	Scientific name	BC Act status*	EPBC Act status*	Identified by BAM credit calculator	Likelihood of occurrence	Ecosystem or species credit species	Candidate species
Scarlet Robin	*Petroica boodang*	V	-	Yes	Low	Ecosystem	No
Sooty Owl	*Tyto tenebricosa*	V	-	Yes	Low-moderate	Species/Ecosystem	No
Southern Brown Bandicoot (eastern)	*Isoodon obesulus*	E	E	Yes	High	Species	Yes
Southern Myotis	*Myotis macropus*	V	-	Yes	High	Species	Yes
Spotted-tailed Quoll	*Dasyurus maculatus*	V	E	Yes	Moderate	Ecosystem	No
Square-tailed Kite	*Lophoictinia isura*	V	-	Yes	Moderate	Species/Ecosystem	Yes
Superb Fruit-Dove	*Ptilinopus superbus*	V	V	Yes	Low	Ecosystem	No
Swift Parrot	*Lathamus discolor*	E	CE	Yes	Moderate	Species/Ecosystem	No
Varied Sittella	*Daphoenositta chrysoptera*	V	-	Yes	High	Ecosystem	No
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	V	-	Yes	High	Species/Ecosystem	Yes
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	V	-	Yes	Low-moderate.	Ecosystem	No

*V = Vulnerable, E = Endangered, EP + Endangered Population, M = Migratory

3.6.2.4 Threatened fauna species recorded or highly likely to occur within the subject land

Seven threatened fauna species listed under the EPBC Act and/or BC Act were recorded in or near the subject land by WSP (2018) and Arcadis (refer to Table 3.29 and Figure 3-7). An additional nine threatened fauna species were assumed or considered highly likely to occur in the subject land, due to the presence of potential habitat and/or the species being previously recorded in (or near) the subject land in the past 20 years (as assessed in Annexure A).

Table 3.29 Threatened fauna species recorded or highly likely to occur within the subject land

Species	BC Act status*	EPBC Act status*	Occurrence in subject land	Type of credit
Red-crowned Toadlet (*Pseudophryne australis*)	V	-	Assumed to be present in areas of suitable habitat adjoining the Wakehurst Parkway. This species was not identified in the subject land during targeted surveys. Recent surveys for Red-crowned Toadlet for the Northern Beaches Hospital road upgrade project (SMEC, 2015) recorded the species near the northern extent of the subject land.	Species credit species
Eastern Pygmy-possum (*Cercartetus nanus*)	V	-	This species was recorded on two occasions - 70 metres and 80 metres from the subject land - during spotlight surveys targeting Koalas in June/July 2021. It has also been recently recorded in the Wakehurst Parkway east construction support site (BL13) (DPIE (EES), 2020a).	Species credit species
Large-eared Pied Bat (*Chalinolobus dwyeri*)	V	V	High likelihood of occurrence in the subject land. This species was not recorded in the subject land during targeted surveys. However, it was recorded 125 metres from the subject land during targeted surveys by Arcadis in 2020 as part of this study and has been recently recorded (WSP 2018) in the Wakehurst Parkway east construction support site (BL13) (DPIE (EES), 2020a).	Species credit species
Southern Brown Bandicoot (*Isoodon obesulus obesulus*)	E	E	High likelihood of occurrence in habitat adjacent to the subject land. This species was not identified in the subject land during targeted surveys, however, the subject land offers potential foraging habitat.	Species credit species
Southern Myotis (*Myotis macropus*)	V	-	High likelihood of occurrence in habitat adjacent to the subject land. This species was not identified in the subject land during targeted surveys, however, the subject land offers potential foraging and roosting habitat.	Species credit species

Species	BC Act status*	EPBC Act status*	Occurrence in subject land	Type of credit
Grey-headed Flying-fox (*Pteropus poliocephalus*)	V	V	Known to occur in the subject land. This species was recorded by WSP (2018) flying over a number of locations within the subject land, during surveys carried out in 2017. A Grey-headed Flying-fox camp (Balgowlah Camp) was identified about 120 metres from the subject land.	Ecosystem/ species credit species
Powerful Owl (*Ninox strenua*)	V	-	High likelihood of occurrence in the subject land. This was recorded by WSP (2018) at Flat Rock Reserve, next to the subject land, during call play-back surveys in 2017. There are also recent Bionet records of the species at Manly Dam (2015 and 2017) and in Garigal National Park (2012 and 2013), near the northern extent of the subject land (DPIE (EES), 2020a).	Ecosystem/ species credit species
Rosenberg's Goanna (*Varanus rosenbergi*)	V	-	Known to occur in the subject land. This species was recorded by WSP (2018) in heath-woodland vegetation alongside Wakehurst Parkway in 2017.	Ecosystem/ species credit species
Glossy Black Cockatoo (*Calyptorhynchus lathami*)	V	-	High likelihood of occurrence in the subject land. This species was not recorded in the subject land during targeted surveys. However, it has been previously recorded in Willoughby (2013) (DPIE (EES), 2020a).	Ecosystem/ species credit species
Varied Sittella (*Daphoenositta chrysoptera*)	V	-	High likelihood of occurrence in the subject land. This species was not recorded in the subject land during targeted surveys. However, it has previously been recorded in the subject land by the Gore Hill Freeway (DPIE (EES), 2020a).	Ecosystem credit species
White-bellied Sea-Eagle (*Haliaeetus leucogaster*)	V	M	High likelihood of occurrence in the subject land. This species was not recorded in the subject land during targeted surveys. However, it has been previously recorded throughout Middle Harbour (DPIE (EES), 2020a).	Ecosystem/ species credit species
Large Bent-winged Bat (*Miniopterus orianae oceanensis*)	V	-	High likelihood of occurrence in the subject land. This species was recorded by Arcadis (2018) in vegetated habitat adjacent to Flat Rock Drive construction support site (BL2). This species has also been previously recorded in the Wakehurst Parkway east construction support site (BL13) (DPIE (EES), 2020a).	Ecosystem/ species credit species

Species	BC Act status*	EPBC Act status*	Occurrence in subject land	Type of credit
Little Bent-winged Bat (*Miniopterus australis*)	V	-	High likelihood of occurrence in the subject land. This species was recorded by Arcadis (2018) in vegetated habitat adjacent to Flat Rock Drive construction support site (BL2). This species has also been previously recorded in the northern extent of the subject land, near Wakehurst Parkway and in the Wakehurst Parkway east construction support site (BL13) (DPIE (EES), 2020a).	Ecosystem/ species credit species
Eastern Coastal Free-tailed Bat (*Micronomus norfolkensis*)	V	-	High likelihood of occurrence in the subject land. This species was not recorded in the subject land during targeted surveys.	Ecosystem/ species credit species
Little Penguin (*Eudyptula minor*) in the Manly Point Area	EP	-	High likelihood of occurrence in the subject land. This species was not recorded in the subject land during field surveys for this project. However, it has previously been recorded at several locations within the subject land and surrounding assessment area, including The Spit, Long Bay, Sailors Bay and in the main channel of Middle Harbour (DPIE (EES), 2020a).	Species credit species

*V=Vulnerable, EP=Endangered Population, M=Migratory

3.6.2.4.1 Red-crowned Toadlet (Pseudophryne australis)

The Red-crowned Toadlet is listed as a Vulnerable species under the BC Act.

This species was not identified in the subject land during targeted surveys. Recent surveys for Red-crowned Toadlet for the Northern Beaches Hospital road upgrade project (SMEC, 2015) recorded the species in the northern extent of the subject land. Accordingly, this species is assumed to be present in areas of suitable habitat adjoining the Wakehurst Parkway.

The *NSW Survey Guide for Threatened Frogs: A guide for the survey of threatened frogs and their habitats for the Biodiversity Assessment Method* (DPIE (EES), 2020f) outlines the methodology for the creation of species polygon for Red-crowned Toadlet as follows:

The species polygon boundary should align with aquatic habitats linked directly to the record and a buffer, incorporating the PCTs with which the species is associated, of 100 metres radius from the top of bank.

A species polygon was prepared for this species (Figure 3-8) applying this methodology. The species polygon includes potential habitat in two drainage lines adjacent to the Wakehurst Parkway which have connectivity to drainage lines with species records both for the Northern Beaches Hospital road upgrade project and Bionet (DPIE (EES), 2020a). The top of bank on the drainage lines were estimated to be five metres from the centre line of the drainage line. The 100 metre buffer was applied to the top of bank (five metre buffer on drainage lines). The area of the species polygon for Red-crowned Toadlet within the subject land is around 0.98 hectares.

Distribution of the Red-crowned Toadlet is confined to the Sydney Basin, from Pokolbin in the north, the Nowra area to the south, and west to Mount Victoria in the Blue Mountains. The species is found in open forests, mostly on Hawkesbury and Narrabeen Sandstones, where it periodically inhabits wet drainage lines below sandstone ridges that often have shale lenses or cappings. Breeding congregations occur in dense vegetation and debris beside ephemeral creeks and gutters, and eggs are laid in moist leaf litter. The Red-crowned Toadlet disperses outside the breeding period, when it is found under rocks and logs on sandstone ridges and forage among leaf-litter.

Several unnamed and unmapped ephemeral freshwater streams, which occur near Wakehurst Parkway between Frenchs Forest and Seaforth, flow in either an east–west direction into Manly Reservoir or in a west–east direction into Bantry Bay. Within the subject land, these streams comprise standing pools and riffles with substrate predominantly consists of Hawkesbury Sandstone bedrock and boulders. These streams are likely to provide sheltering, foraging and breeding habitat Red-crowned Toadlet. Rocks and logs within adjoining riparian vegetation (mainly open forest) offers sheltering habitat outside of the breeding period.

3.6.2.4.2 Eastern Pygmy-possum (*Cercartetus nanus*)

The Eastern Pygmy-possum is listed as a Vulnerable species under the BC Act.

The Eastern Pygmy-possum is found in south-eastern Australia, from southern Queensland to eastern South Australia and in Tasmania. In NSW, its distribution extends from the coast inland to the Pilliga, Dubbo, Parkes and Wagga Wagga. In these areas, the species is found in a broad range of habitats from rainforest through sclerophyll (including Box-Ironbark) forest and woodland to heath, but in most areas, woodlands and heath. The Eastern Pygmy-possum forages for nectar and pollen collected from banksias, eucalypts and bottlebrushes; insects and soft fruits are also eaten when flowers are unavailable. The Eastern Pygmy-possum shelters in tree hollows, rotten stumps, holes in the ground, abandoned bird-nests, Common Ringtail Possum (*Pseudocheirus peregrinus*) dreys or thickets of vegetation (eg *Xanthorrhoea* sp.). Each individual uses several nests within its home range; males have home-ranges averaging around 0.68 hectares, but they have been found with home ranges up to almost 20 hectares (Law, 2013). Females have smaller home ranges, averaging 0.35 hectares (DPIE (EES), 2020d).

This species was recorded on two occasions - 70 metres and 80 metres from the subject land - during spotlight surveys targeting Koalas in June/July 2021 in bushland east of Wakehurst Parkway. There are also recent Bionet records of the species in the Wakehurst Parkway east construction support site (BL13) (in 2018), around 800 metres east of the Wakehurst Parkway (in 2018) and in Manly Warringah War Memorial State Park (in 2017 and 2018), which adjoins the northern extent of the subject land (to the east) (DPIE (EES), 2020a). All PCTs mapped within the subject land next to Wakehurst Parkway offer potential foraging and sheltering habitat to this species. These vegetated habitats support preferred foraging resources due to the presence of a variety of banksia, eucalypt and bottlebrush species. A species polygon was prepared for this species which includes all the associated PCTs in the subject land next to the Wakehurst Parkway (Figure 3-8). The area of the species polygon for Eastern Pygmy-possum within the subject land is around 12.21 hectares.

3.6.2.4.3 Large-eared Pied Bat (*Chalinolobus dwyeri*)

The Large-eared Pied Bat is listed as a Vulnerable species under the BC Act and EPBC Act.

The Large-eared Pied Bat is found mainly in areas with extensive cliffs and caves, from Rockhampton in Queensland south to Bungonia in the NSW Southern Highlands. It is generally rare with a very patchy distribution in NSW. It roosts in caves (near their entrances), crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (*Petrochelidon ariel*), frequenting low to mid-elevation dry open forest and woodland close to these features (DPIE (EES), 2020d). Females have been recorded raising young in maternity roosts (c. 20-40 females) from November through to January in roof domes in sandstone caves and overhangs (DPIE (EES), 2020d), rock escarpments and collapsed cliff lines within small honeycombed holes in sandstone, the hollowed-out rooves of boulders and long slits in flaking sheets of sandstone (Lothian, 2019). They show roost fidelity to the same cave over many years. They are found in well-timbered areas containing gullies (DPIE (EES), 2020d).

The Threatened Biodiversity Data Collection (DPIE (EES), 2020c) defines potential habitat for the Large-eared Pied Bat as associated PCTs that are within two kilometres of rocky areas containing caves, overhangs, escarpments, outcrops, or crevices, or within two kilometres of old mines or tunnels. Rocky features are visible on aerial photography within two kilometres of the subject land at Wakehurst Parkway and Balgowlah.

Potential breeding habitat is defined as PCTs associated with the species within 100 metres of rocky areas containing caves, or overhangs or crevices, cliffs or escarpments, or old mines, tunnels, culverts, derelict concrete buildings where surveys carried out in accordance with the '*Species credit' threatened bats and their habitats – NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a) indicate presence of breeding individuals. This species was not recorded within the subject land during targeted surveys, but its echolocation call was recorded at a dam approximately 125 metres from the subject land (Figure 3-7). No microbats were caught in harp traps used to target breeding individuals in potential breeding habitat as defined above. There are recent Bionet records of the species foraging in the Wakehurst Parkway east construction support site (BL13) and around 800 metres east of the Wakehurst Parkway in 2018 (DPIE (EES), 2020a).

Rocky features of the subject land and within a 100 metre buffer comprise sandstone boulders, crevices and ledges. The rocky features of the subject land were inspected during field surveys carried out for this report and during previous surveys of the area (WSP, 2018) and no evidence of microbat use was found nor were any deemed suitable for breeding and/or roosting for the Large-eared Pied Bat.

However, rocky features suitable for breeding were identified within the 100 metre buffer around the subject land (excluding the subject land) at Wakehurst Parkway (southern end) during targeted surveys (Figure 3-9). However, no microbats, or signs of their habitation, were observed during diurnal roost searches. Not all suitable rocky features and the crevices within them could be accessed and inspected thoroughly. No microbats were recorded in potential roost sites during acoustic surveys nor were any caught in harp traps to confirm breeding. For the purposes of serious and irreversible impact assessment, breeding habitat for the Large-eared Pied Bat is considered present on the subject land if there is (OEH, 2018a):

- Potential breeding habitat, and
- Breeding individuals.

Where potential breeding habitat is defined as breeding habitat on or within 100 metres of the subject land and the area immediately surrounding the feature. Though there is potential breeding habitat within 100 metres of the subject land (Figure 3-9), surveys carried out in accordance with the guidelines failed to detect any breeding individuals. Therefore, breeding habitat is absent from the subject land, in accordance with the definition above.

A species polygon was prepared for this species (Figure 3-8) following the methods in Table 1 of '*Species credit' threatened bats and their habitats – NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a) which require the identification of foraging habitat.

Table 1 of the guidelines requires these features to be included in the species polygon:

- *"All habitat on the subject land where the subject land is within 2km of caves, scarps, cliffs, rock overhangs and disused mines."*

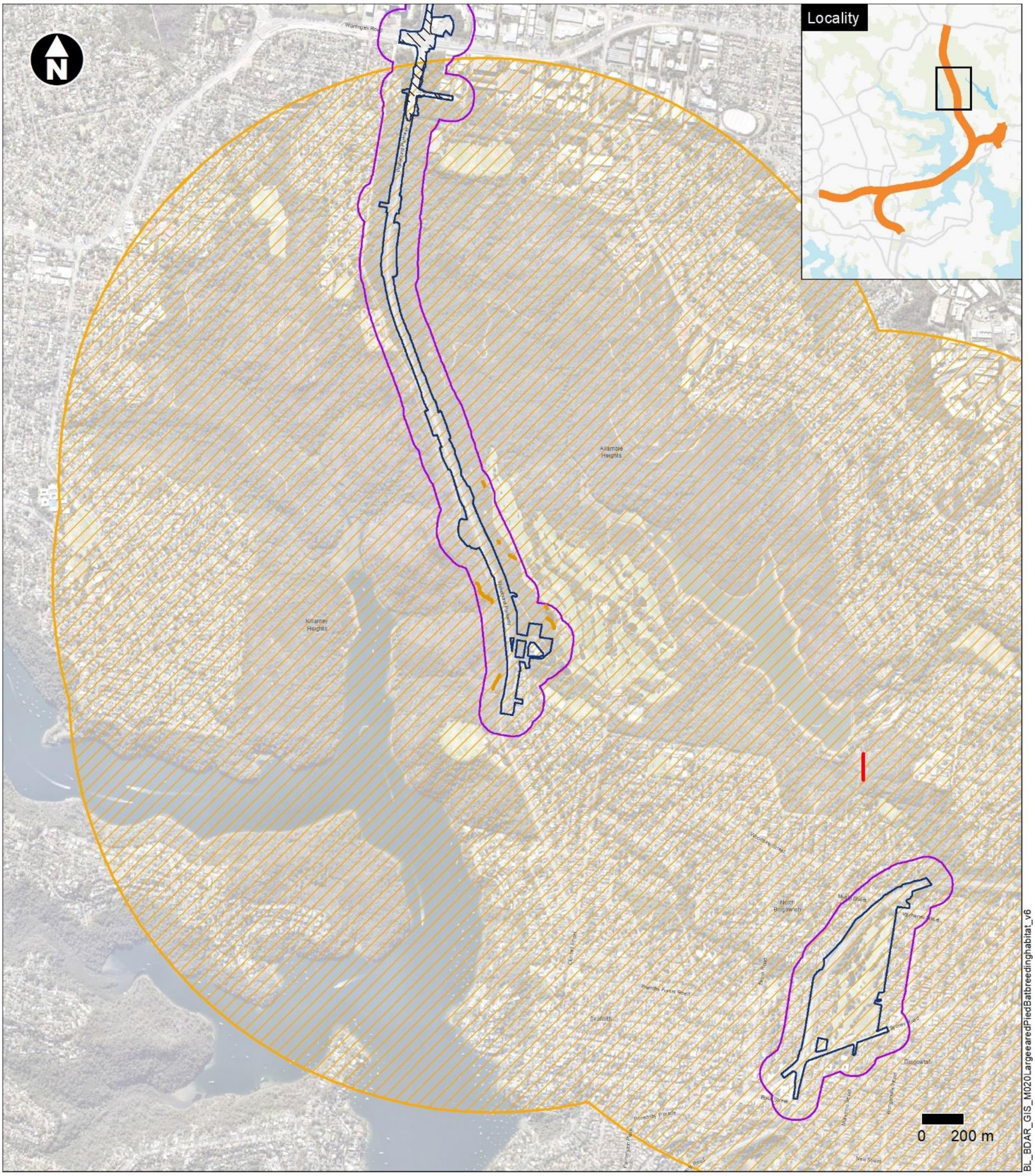
Where habitat is associated PCTs where the species is determined to be present.

In accordance with Table 1 of the guidelines, the approach to create the species polygon is to:

- *"Use high resolution aerial imagery and topographic maps to identify potential roost habitat features on the subject land when it is within 2km caves, scarps, cliffs etc. Species polygon boundary should align with PCTs on the subject land to which the species is associated (listed in the TBDC) that are within 2km of identified potential roost habitat features."*

All PCTs in the subject land are associated with the Large-eared Pied Bat as per the Threatened Biodiversity Data Collection (DPIE (EES), 2020c). Aerial imagery overlain with topographic contours within two kilometres of the subject land was investigated for presence of rocky features using GIS. Rocky features were identified within two kilometres of the PCTs along Wakehurst Parkway and Burnt Bridge Creek. The northernmost extent of PCTs at Burnt Bridge Creek

Deviation is about 650 metres from the closest potential roosting habitat in Manly Warringah War Memorial State Park and the southernmost extent of PCTs about one kilometre from the same features in Manly Warringah War Memorial State Park. The rocky feature in Manly Warringah War Memorial State Park is shown in Figure 3-9, though it should be noted that several other rocky features are within two kilometres of the subject land but are not mapped. The species recorded at Wakehurst Parkway is within two kilometres of PCTs at Burnt Bridge Creek. Therefore, the PCTs at this location in the subject land have been included in the species polygon as the species is assumed present at Burnt Bridge Creek. All PCTs mapped adjacent to Wakehurst Parkway are within two kilometres of potential roosting habitat, with the closest about 30 metres away as shown in Figure 3-9. As the species has been historically recorded in the Wakehurst Parkway east construction support site (BL13) and in connected bushland to the east, all the PCTs adjacent to the Wakehurst Parkway in the subject land are included in the species polygon. The area of the species polygon for Large-eared Pied Bat is around 13.51 hectares.



Legend

- Subject land
- Area not assessed by the updated biodiversity assessment
- Rocky features ground-truthed
- Rocky feature Manly Dam
- 100m buffer around subject land
- 2km buffer around rocky features

Figure 3-9 Large-eared Pied Bat rocky features and buffers

3.6.2.4.4 Southern Brown Bandicoot (*Isoodon obesulus obesulus*)

The Southern Brown Bandicoot is listed as an Endangered species under the BC Act and EPBC Act.

The Southern Brown Bandicoot is found in south-eastern NSW, east of the Great Dividing Range south from the Hawkesbury River, southern coastal Victoria and the Grampian Ranges, south-eastern South Australia, south-west Western Australia and the northern tip of Queensland. Southern Brown Bandicoots are generally only found in heath or open forest with a heathy understorey on sandy or friable soils. They nest during the day in a shallow depression in the ground covered by leaf litter, grass or other plant material. Nests may be located under Grass trees (*Xanthorrhoea* spp.), blackberry bushes and other shrubs, or in rabbit burrows. The upper surface of the nest may be mixed with earth to waterproof the inside of the nest (DPIE (EES), 2020d).

This species was not identified in the subject land during targeted surveys. However, there are Bionet records of the species approximately one kilometre north (in 2009) and two kilometres west (in 2011) of the subject land at Wakehurst Parkway (DPIE (EES), 2020a). The subject land supports potential habitat for the species in vegetation adjacent to the Wakehurst Parkway. Due to a lack of detection of the species during targeted surveys, no further assessment of the species is required and consequently a species polygon has not been prepared.

3.6.2.4.5 Southern Myotis (*Myotis macropus*)

Southern Myotis is listed as a Vulnerable species under the BC Act.

This species was not identified in the subject land during targeted surveys. However, there is a recent Bionet record of the species at Manly Dam (in 2018), which adjoins the northern extent of the subject land (to the east) (DPIE (EES), 2020a).

The Southern Myotis that occurs along the eastern coast of New South Wales and is rarely found more than 100 kilometres inland. This species is strongly associated with waterways, including streams, pools, dams and rivers. The Southern Myotis uses its large feet to trawl the surface of such waterways for aquatic invertebrates and small fish.

This species generally roosts in groups of 10 to 15 individuals close to water, and has been found roosting caves, mine shafts, hollow-bearing trees, storm water channels, buildings, under bridges and in dense foliage (DPIE (EES), 2020a). However, roosts have also been found in culverts more than one kilometre from the nearest permanent waterbody and this species is known to fly over land to forage at isolated farm dams (Anderson, Law and Tidemann, 2006).

The subject land supports potential marginal roosting habitat for the species, due to the presence of human made structures such as jetties, wharves along Middle Harbour foreshore, culverts and bridges. The subject land also contains potential foraging habitat, offered by freshwater watercourses (refer to Section 3.7.3) and sheltered bays of Middle Harbour. A scientific study carried out on the distribution and key foraging habitat of the Southern Myotis found the species to have a moderately high level of activity along small portions of Middle Harbour. Sheltered bays within and near the subject land (eg Sandy Bay, Shell Cove) that can provide calmer water surfaces are more suited to the trawling foraging strategy that the bats employ (Gonsalves and Law, 2017b). Due to a lack of detection of the species during targeted surveys, no further assessment of the species is required and consequently a species polygon has not been prepared.

3.6.2.4.6 Grey-headed Flying-fox (*Pteropus poliocephalus*)

The Grey-headed Flying-fox is listed as a Vulnerable species under the BC Act and EPBC Act.

This species was recorded by WSP (2018) flying over a number of locations within the subject land, during surveys carried out in 2017. In addition, there are a large number of recent Bionet records of this species throughout the subject land (DPIE (EES), 2020a).

The Grey-headed Flying-fox is generally found within 200 kilometres of the eastern coast of Australia, from Rockhampton to Melbourne. The species may be found in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps, while additional foraging is provided by urban gardens and cultivated fruit crops. The Grey-headed Flying-fox is a highly mobile species with a nightly feeding range of 20 to 50 kilometres from a roosting camp. Diet typically comprises a wide variety of flowering and fruiting plants (Tidemann, 1995; Churchill, 1998). Grey-headed Flying-foxes roost in large numbers, with up to tens of thousands of Flying-foxes using individual camps for mating, birth and rearing of young.

A Grey-headed Flying-fox camp (Balgowlah Camp) was identified in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation about 120 metres from the subject land, along Burnt Bridge Creek in Balgowlah (Figure 3-7). The camp occupies an area of around 0.59 hectares that comprises occupied and partially occupied roosting habitat (Ecosure, 2016). This camp is not identified as a nationally important Grey-headed Flying-fox camp (Flying-fox Camp I.D. 529) by *National Flying-fox monitoring viewer* (DAWE, 2020c). It has supported up to 10,000 Flying-foxes in recent years. Another camp (Flying-fox Camp I.D. 487) is located within Centennial Park, around eight kilometres south-east of the subject land. It has supported up to 50,000 Flying-foxes in recent years and is a nationally important Grey-headed Flying-fox camp.

It is likely that the individuals recorded flying over the subject land were from these camps (although a number of other camps are located within the species' foraging range) and were observed flying overhead during their nightly foraging activities. The subject land and wider assessment area provide foraging habitat for the Grey-headed Flying-fox, given the presence of preferred blossom and fruit tree species within parks, road verges, private land (eg residential gardens) and large tracts of contiguous vegetation in Garigal National Park and Manly Warringah War Memorial State Park. A number of PCTs within the subject land (refer to Section 3.3) support tree species that offer a foraging resource for the species, as listed by *Ranking the feeding habitats of Grey-headed Flying-foxes for conservation management* (Eby and Law, 2008). These tree species are listed in Table 3.30.

Table 3.30 Grey-headed Flying-fox feed trees recorded at sites within the subject land

Tree species recorded that are in the blossom diet of Grey-headed Flying-foxes	Tree species recorded that are in the fruit diet of Grey-headed Flying-foxes
• *Angophora costata* • *Corymbia gummifera* • *Corymbia maculata* • *Syncarpia glomulifera* • *Eucalyptus saligna* • *Eucalyptus resinifera* • *Eucalyptus robusta* • *Eucalyptus pilularis* • *Eucalyptus piperita* • *Eucalyptus paniculata* • *Eucalyptus punctata*	• *Elaeocarpus reticularis* • *Pittosporum undulatum*

3.6.2.4.7 Powerful Owl (Ninox strenua)

The Powerful Owl is listed as a Vulnerable species under the BC Act.

Powerful Owls were recorded at Hallstrom Park in Willoughby, next to the subject land and adjacent to the Flat Rock Drive construction support site (BL2) by WSP (2018). There are also recent Bionet records of the species at Manly Dam (from 2015 and 2017) and in Garigal National Park (from 2012 and 2013), near the northern extent of the subject land (DPIE (EES), 2020a).

The Powerful Owl is found in the coastal areas and adjacent ranges of eastern Australia from South Australia to around Rockhampton in Queensland, generally within 200 kilometres from the coast. Within NSW, Powerful Owls are distributed throughout the length of the Great Dividing Range and extend from the coast to the western slopes where they occur in much lower numbers.

The Powerful Owl inhabits a wide range of vegetation types including wet and dry forest, woodlands, sheltered gullies and particularly along watercourses. The Powerful Owl requires large areas of habitat but can occur in fragmented landscapes and has been recorded in exotic pine plantations and large trees in parks and gardens.

The Powerful Owl is the largest predator of nocturnal forest-dwelling animals in Australian forests; prey species in NSW forests are the Greater Glider *(Petauroides volans*), Common Ringtail Possum, Sugar Glider (*Petaurus breviceps*), Grey-headed Flying-fox and roosting birds, such as Pied Currawong (*Strepera graculina*), Australian Magpie (*Cracticus tibicen*) and Lorikeets. It roosts by day in dense vegetation such as *Syncarpia glomulifera*, *Allocasuarina littoralis*, *Acacia melanoxylon* (Blackwood), *Angophora floribunda* (Rough-barked Apple), *Exocarpos cupressiformis* (Cherry Ballart) and a number of eucalypt species.

Powerful Owls nest in a large vertical hollow in a large old tree (at least 150 years old), sometimes in excess of 25 metres above the ground. These trees are usually found growing on a hillside in heavy forest and may be used intermittently for several years.

No hollow-bearing trees that would offer potential nesting habitat to Powerful Owls were identified at Hallstrom Park in Willoughby or Flat Rock Reserve, where the species was recorded. One large hollow-bearing tree that contained a hollow greater than 20 centimetres in diameter was identified in the northern extent of the subject land, near Wakehurst Parkway.

This hollow offers potential nesting habitat. However, a stag watch and call play-back carried out at this location did not identify any owl activity (including indirect evidence such as the presence of white-wash on trees). Vegetated habitat within subject land, including Flat Rock Reserve where this species has been recorded, offers potential foraging habitat to the Powerful Owl, as preferred prey species including Common Ringtail possum, Common Brushtail possum (*Trichosurus vulpecula*), Sugar glider and a diversity of birds were recorded in such habitat within the subject land.

3.6.2.4.8 Rosenberg's Goanna (Varanus rosenbergi)

Rosenberg's Goanna is listed as a Vulnerable under the BC Act.

This species was recorded by WSP (2018) in heath-woodland vegetation alongside the Wakehurst Parkway. However, there is a Bionet records of the species in Manly Warringah War Memorial State Park, which adjoins the northern extent of the subject land (to the east) (DPIE (EES), 2020a).

Rosenberg's Goanna occurs in association with sandstone, from Wollemi National Park in the north to near Cooma in the south. The species is typically found in heath, open forest and woodland, where it forages for carrion, birds, eggs, reptiles and small mammals. Termite mounds are a critical nesting habitat component. The species shelters in hollow logs, rock crevices and in burrows, which they may dig for themselves, or they may use other species' burrows, such as rabbit warrens. Individuals require large areas of habitat (DPIE (EES), 2020c).

Tracts of native vegetation in the northern extent of the subject land offer potential foraging and nesting habitat to Rosenberg's Goanna. Heath, open forest and woodland PCTs mapped next to the Wakehurst Parkway comprise habitat for preferred prey including birds, reptiles and small mammals, while the presence of sandstone boulders, slabs and rock crevices offer potential sheltering habitat to the species. Termite mounds recorded near the Wakehurst Parkway offer preferred nesting habitat to the species. Rosenberg's Goanna may also forage for roadkill (carrion) along the margins of Wakehurst Parkway, where fauna mortality due to vehicle strike is high. Given that Rosenberg's Goanna requires a large area of habitat, it may range throughout habitat the subject land and adjoining vegetated areas, including Garigal National Park and Manly Warringah War Memorial State Park.

3.6.2.4.9 Glossy Black-Cockatoo (Calyptorhynchus lathami)

The Glossy Black-Cockatoo is listed as a Vulnerable species under the BC Act.

This species was not recorded in the subject land during targeted surveys. However, there are Bionet records of the species in Willoughby (2013), near the subject land (DPIE (EES), 2020a).

Distribution of the Glossy Black-Cockatoo is sparse but widespread across the east coast of Australia, occurring in suitable habitat from central Queensland to East Gippsland in Victoria. In NSW, the species occurs from the coast inland to the southern tablelands and central western plains. An isolated population is known from the Riverina (DPIE (EES), 2020d). Movement of the species is not well understood. Populations or individuals may be sedentary or locally or partly nomadic (Higgins, 1999). Glossy Black-Cockatoos occur in coastal woodland or dry eucalypt forests dominated by *Allocasuarina* and *Casuarina* species and are rarely observed away from *Allocasuarina* species. The species may also occur in open inland woodlands, forested watercourses where *Allocasuarina* species occur or on stony ridges (Higgins, 1999; OEH, 2012).

The Glossy Black-Cockatoo feeds almost exclusively on seeds extracted from the wooden cones of Allocasuarinas (Higgins, 1999). In coastal areas, *Allocasuarina torulosa* (Forest Oak) and *Allocasuarina littoralis* (DEC, 2004) are preferred. The species primarily forages among the branches of trees with a preference for mature trees two to ten metres tall. Rarely, the species may forage in other shrubs or trees, including Acacia, Casuarina, Hakea, Angophora or Eucalyptus (Higgins, 1999). The species most commonly breeds in a hollow of a tall, living or dead Eucalypt within woodland. Eucalypts are also preferred roosting trees, typically located less than one kilometre from feed trees (Higgins, 1999).

Areas of native vegetation within the subject land offer potential foraging habitat to the species, where preferred foraging trees species (*Allocasuarina* and *Casuarina* species) occur. One large hollow-bearing tree that contained a hollow greater than 20 centimetres in diameter was identified in the northern extent of the subject land, near the Wakehurst Parkway. This hollow comprised potential nesting habitat for Glossy Black-Cockatoo. However, no individuals were recorded using this hollow.

3.6.2.4.10 Varied Sittella (Daphoenositta chrysoptera)

Varied Sittella is listed as a Vulnerable species under the BC Act.

The species was not identified during field surveys however, it has previously been recorded in the subject land by the Gore Hill Freeway (DPIE (EES), 2020a). The Varied Sittella inhabits most of mainland Australia except the treeless deserts and open grasslands. It inhabits eucalypt forests and woodlands, especially rough-barked species and mature smooth-barked gum with dead branches, mallee and Acacia woodland (DPIE (EES), 2020d). Vegetated habitats, particularly in the northern extent of the subject land, and within Flat Rock Drive construction support site (BL2), offer potential foraging habitat to the species.

3.6.2.4.11 White-bellied Sea-Eagle (Haliaeetus leucogaster)

White-bellied Sea-Eagle is listed as a Vulnerable species under the BC Act and a Migratory species under the EPBC Act.

This species was not recorded in the subject land during targeted surveys. However, there are Bionet records of the species throughout Middle Harbour, near the subject land and a record from 2013 at the northern end of the Wakehurst Parkway, within the subject land (DPIE (EES), 2020a).

The White-bellied Sea-Eagle is a large eagle that is distributed along the east coast of NSW (around bays and inlets, beaches, reefs, lagoons, estuaries and mangroves), and along all major inland rivers, swamps, freshwater lakes and reservoirs. This species hunts above large areas of open water for fish, freshwater turtles, waterbirds, reptiles, mammals and carrion. White-bellied Sea-Eagles typically construct a large stick nest in a large emergent eucalypt, within mature tall open forest, open forest, tall woodland, and swamp sclerophyll forest close to foraging habitat. However, nests may be built in a variety of sites including bushes, mangroves, cliffs, rocky outcrops, caves, crevices, on the ground or on artificial structures (DAWE, 2020b). White-bellied Sea-Eagles may be solitary or live in pairs or small family groups consisting of a pair of adults and dependent young. Resident pairs are territorial and occupy nesting territories of hundreds of hectares.

The subject land is not known to support a White-bellied Sea-Eagle nest. The closest known nesting site is located in Newington Nature Reserve, next to the Parramatta River, about 13 kilometres west of the subject land. A pair of White-bellied Sea-Eagles currently occupies this nest (Birdlife, 2018).

The subject land offers foraging habitat to the species, due to the presence of preferred prey species that inhabit Middle Harbour. The subject land also offers potential perching habitat in the trees that occur along the foreshore at The Spit, Seaforth and Clontarf.

3.6.2.4.12 Large Bent-winged Bat **(*Miniopterus orianae oceanensis*)**

Large Bent-winged Bat is listed as a Vulnerable species under the BC Act.

The Large Bent-winged Bat is a microbat that occurs along the east and north-west coasts of Australia (DPIE (EES), 2020d) where it is known from a variety of habitats including rainforest, dry and wet sclerophyll forest, open woodland, paperbark forest and open grassland. The species hunts for moths and other flying insects above trees canopies or in open areas (DPIE (EES), 2020d).

Large Bent-winged Bats are known to use a number of roost sites throughout the year (Churchill, 1998). Caves are the primary roosting habitat for this species; however, Large Bent-winged Bats also use derelict mines, storm-water tunnels, buildings and other human made structures (DPIE (EES), 2020d). The most significant of these roosts are maternity roosts and those roosts used over winter for hibernation (DEC, 2004).

Female Large Bent-winged Bats inhabit and congregate in specific caves that provide constant high temperate and humidity to give birth and raise young (Dwyer, 2009). Maternity caves are used annually in spring and summer for the birth and rearing of young. At other times of the year, populations disperse within a territorial range of about 300 kilometres from the maternity cave (Churchill, 2008).

This species was recorded adjacent to Flat Rock Drive construction support site (BL2) during Anabat surveys. In addition, there are Bionet records of this species along the Wakehurst Parkway, in the northern extent of the subject land and in the Wakehurst Parkway east construction support site (BL13) (DPIE (EES), 2020a).

Vegetated habitats, particularly in the northern extent of the subject land and within Flat Rock Drive construction support site (BL2), offer potential foraging habitat to the species. The subject land does not support a maternity cave. Culverts and bridges within the subject land offer potential artificial roosting habitat; however, targeted surveys at concrete culvert at Balgowlah, Artarmon and a concrete underground walkway at Willoughby did not detect the presence of any roosting Large Bent-winged Bats.

3.6.2.4.13 Little Bent-winged Bat (Miniopterus australis)

Little Bent-winged Bat is listed as Vulnerable species under the BC Act.

The Little Bent-winged Bat occurs along the east coast and ranges of Australia from Cape York in Queensland to Wollongong in NSW, where it inhabits moist eucalypt forest, rainforest, vine thicket, wet and dry sclerophyll forest, *Melaleuca* swamps, dense coastal forests and banksia scrub. This species is generally found in well-timbered areas, where it hunts for flying insects (predominantly beetles, moths and flies) between the shrub and canopy layer (OEH, 2013; Churchill, 2008).

The Little Bent-winged Bat roost in caves, tunnels, tree hollows, abandoned mines, stormwater drains, culverts, bridges and sometimes buildings during the day. During winter, the species enters a shallow hibernation, emerging frequently from these roosts to hunt for food. The Little Bent-winged Bat moves to maternity caves in spring, often with the Large Bent-winged Bat; Little Bent-winged Bats appear to depend on the congregation of the larger-bodied bats like the Large Bent-winged Bat to provide the high temperatures needed to rear its young. Males and juveniles disperse from maternity roosts in summer (OEH, 2013; Churchill, 2008).

This species was recorded adjacent to Flat Rock Drive construction support site (BL2) during Anabat surveys. In addition, there are Bionet records of this species along Wakehurst Parkway, in the northern extent of the subject land and in the Wakehurst Parkway east construction support site (BL13) (DPIE (EES), 2020a).

Vegetated habitats, particularly in the northern extent of the subject land, and within Flat Rock Drive construction support site (BL2), offer potential foraging habitat to the species. Culverts and bridges within the subject land offer potential artificial roosting habitat; however, targeted surveys at a concrete underground walkway at Willoughby and at concrete culverts at Balgowlah and Artarmon did not detect the presence of any roosting Little Bent-winged Bats.

3.6.2.4.14 Eastern Coastal Free-tailed Bat (Micronomus norfolkensis)

The Eastern Coastal Free-tailed Bat is listed as a Vulnerable species under the BC Act.

The Eastern Coastal Free-tailed Bat is found east of the Great Dividing Range, from Brisbane in south-east Queensland to Sydney in NSW, where it is most commonly recorded in dry eucalypt forest and woodland and shows a preference for open spaces in woodland or forest. The species has also been recorded in swamp forests and mangrove forests. The Eastern Coastal Free-tailed Bat forages in openings and gaps in the forest including over larger waterways (Churchill, 2008). The diet of this species has not been studied but is most probably insectivorous (DPIE (EES), 2020d). The Eastern Coastal Free-tailed Bat roost mainly in tree hollows, usually in hollow spouts of large mature trees, but will also roost under exfoliating bark or in human made structures and buildings (DPIE (EES), 2020d; Churchill, 2008).

This species was not recorded in the subject land during targeted surveys. Three hollow-bearing trees identified near the Wakehurst Parkway and culverts and bridges within the subject land offer potential roosting habitat to the species. However, targeted Anabat surveys and stag watches at the large hollow-bearing tree near the Wakehurst Parkway, at concrete culverts at Balgowlah, Artarmon and a concrete underground walkway at Willoughby did not detect the presence of any roosting Eastern Coastal Free-tailed Bat. Native vegetation throughout the subject land, particularly larger continuous tracts of native vegetation in the northern extent of the subject land, offers potential foraging habitat to the species.

3.6.2.4.15 Little Penguin in the Manly Point Area

Little Penguins in the Manly Point Area (from just north of Smedley's Point to Cannae Point), are listed as an Endangered Population under the BC Act. Little Penguin was not recorded in the subject land during targeted surveys. However, there are Bionet records of the species in and near the subject land, including The Spit, Long Bay, Sailors Bay and in the main channel of Middle Harbour (DPIE (EES), 2020a).

This population at Manly is the only known breeding population of Little Penguins on the mainland in NSW, where nesting habitat at Manly includes burrows under rocks on the foreshore, under seaside houses and structures (such as stairs or in wood piles), and under overhanging vegetation including *Lantana camara* and under coral tree roots (NPWS, 2000).

From May, male penguins start establishing or reconstructing a suitable burrow for nesting and to attract females. Egg-laying at Manly has been recorded as early as the first week of June. However, the peak breeding season is generally from July to December. After the chicks have hatched (Little Penguins usually lay a clutch of two eggs), adults alternate between remaining in the nest and foraging, until the chicks have developed enough to be left unguarded during the day, while both adults forage. The adults return to the nest to feed their chicks at night, until the chicks leave the nest after seven to nine weeks to mature at sea. It is common for the Little Penguins at Manly to produce a second clutch of eggs later in the season, after the chicks from the first clutch have fledged (NPWS, 2000).

Little Penguins forage in shallow waters throughout Sydney Harbour (including Middle Harbour) for small shoaling fish, cephalopods, and to a lesser extent, crustaceans (NPWS, 2000). Adult penguins may travel 14 to 20 kilometres a day when foraging and have been recorded at several locations within the subject land and surrounding assessment area. While the subject land offers foraging habitat to Little Penguins (marine habitat), nesting habitat at Manly is located about six kilometres to the east, outside of the assessment area.

3.7 Fauna habitat

3.7.1 Vegetated habitats

Land use within the subject land is dominated by residential development, and to a lesser extent, commercial and industrial development. Throughout much of the subject land, native vegetation has also been removed for infrastructure development such as roads and rail corridors. As a result, vegetation occurring in developed areas of the subject land is highly modified, commonly consisting of trees and shrubs in landscaped parks and reserves, private residential gardens and road verges. Some parks and public open spaces support areas of native bushland. Within the subject land, small, fragmented areas of vegetated habitats are present at the following locations as shown in Figure 3-11:

- Within and next to the Gore Hill Freeway
- Balgowlah Golf Course construction support site (BL10)
- Kitchener Street construction support site (BL11).

Fauna species that would inhabit these smaller fragments of habitat would generally be limited to those highly mobile species which are capable of using small, isolated patches of habitat in a landscape otherwise cleared of native vegetation, and tolerant of disturbances typical of the urban environment (such as light and noise pollution). These fragments, containing flowering and fruiting trees and shrubs, may offer foraging, nesting and roosting habitat to bats, birds and arboreal mammals, such as Grey-headed Flying-fox, Australian Magpie, Noisy Minor (*Manorina melanocephala*), Rainbow Lorikeet (*Trichoglossus haematodus*), Grey Butcherbird (*Cracticus torquatus*), Common Brushtail Possum and Common Ringtail Possum.

Larger tracts of native vegetation occur at Flat Rock Reserve, within and near Flat Rock Drive construction support site (BL2), and in the northern extent of the subject land, on either side of the Wakehurst Parkway. Open forest, woodland and heath plant communities are mapped next to the Wakehurst Parkway (refer to Section 3.3), although woody weeds and other exotic flora species commonly occur in association with ephemeral watercourses. Vegetation occurring alongside the western margin of the Wakehurst Parkway is continuous with large areas of native vegetation within Garigal National Park, while vegetation occurring alongside the eastern margin of the Wakehurst Parkway is continuous with large areas of native vegetation within Manly Warringah War Memorial State Park.

Larger tracts of vegetation within and near Flat Rock Drive construction support site (BL2) and on either side of the Wakehurst Parkway, offer a range of fauna habitat resources, including:

- Flowering plants (including a diversity of Eucalypts, Banksias, Melaleucas, Leptospermums and Acacias) that offer nectar, pollen, sap and gum to mammals such as Grey-headed Flying-fox, Sugar Gliders and Common Ringtail Possums; nectivorous birds such as Red Wattlebird (*Anthochaera carunculata),* Noisy Miner and Rainbow Lorikeet
- The presence of Common Ringtail possum, Common Brushtail possum, Sugar glider and a diversity of birds offer foraging resources to Powerful Owl
- Intact native vegetation offers foraging habitat to a diversity of microbat species, that may forage above or below the tree canopy for invertebrates
- Groundlayer microhabitats such as well-developed leaf litter, logs and ground timber and a diversity of groundlayer plants that offer sheltering and foraging habitat to reptiles, small mammals, birds and some amphibians such as Brown Antechinus (*Antechinus stuartii*)*,* Bush Rat (*Rattus fuscipes*), Australian Brush Turkey (*Alectura lathami)*, Rosenberg's Goanna and Bibron's Toadlet (*Pseudophryne bibronii*) (known to occur in Flat Rock Gully)
- Sandstone boulders, crevices and ledges that provide sheltering and foraging habitat for reptiles, small mammals and some amphibians such as Brown Antechinus, Bush Rat, Rosenberg's Goanna and Glebe Gully Skink (*Saproscincus spectabilis)* (known to occur in Flat Rock Gully)
- Three hollow-bearing trees located near Wakehurst Parkway (two in the subject land and one outside) that offer potential nesting, roosting and sheltering habitat to hollow-dependent birds,

arboreal mammals such as Rainbow Lorikeet and Common Brushtail Possum and hollow-roosting microbats.

Plate 8 Vegetation occurring on slopes adjoining the Wakehurst Parkway

Plate 9 Vegetation occurring at Flat Rock Reserve

Riparian vegetation also offers a diversity of fauna habitat features. Riparian habitat that occurs in association with watercourses that transect (or are located downstream of) the subject land is described in Table 3.31 of Section 3.7.3.

3.7.2 Human made structures

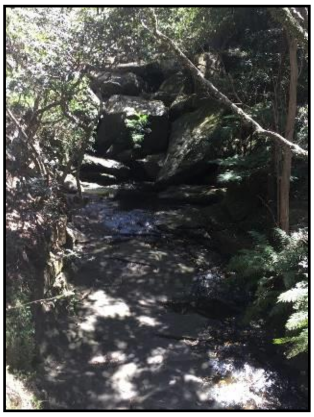
A number of built structures, including concrete culverts at Balgowlah, Artarmon and a concrete underground walkway at Naremburn occur within the subject land. These structures provide potential habitat for microbats that prefer to roost in human made structures, such as the Little Bent-winged Bat, Large Bent-winged Bat, Eastern Coastal Free-tailed Bat, Yellow-bellied Sheathtail-bat and Greater Broad-nosed Bat.

3.7.3 Freshwater habitats

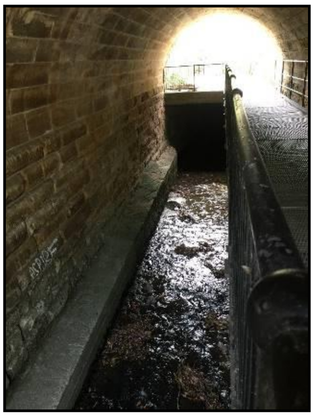
The project transects several waterways: Flat Rock Creek and associated unnamed tributary (Artarmon and Naremburn), Burnt Bridge Creek (North Balgowlah) and a number of unnamed watercourses near the Wakehurst Parkway (Killarney Heights to Frenchs Forest). The catchments of four other waterways fall within the subject land: Willoughby Creek, Manly Creek (also known as Curl Creek), Manly Dam and Trefoil Creek. These waterways are considered in this updated biodiversity assessment as they are located downstream of the project and may be indirectly impacted by the project (refer to Section 5).

These waterways and the freshwater habitat features they support are summarised in Table 3.31. A detailed description of each waterway is provided in *Beaches Link and Gore Hill Freeway Connection Freshwater Ecology Impact Assessment* (Cardno, 2020a) (Annexure D). Attachment A of Annexure G also provides further detail on the freshwater ecology at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, with information included in Table 3.31 as required.

Table 3.31 Freshwater habitat, within and downstream of the subject land

Feature	Description
Willoughby Creek	
Description	Located downstream and to the north-east of Cammeray Golf Course construction support site (BL1), outside of the subject land. Flows in a general easterly direction from Cammeray Golf Course to Primrose Park, before discharging into Willoughby Bay at Cammeray (Middle Harbour). Parts of the project would be located within the Willoughby Creek catchment, which is characterised by residential development, parkland and a network of local roads. Willoughby Creek receives stormwater from the greater residential area of Cremorne (North Sydney Council, 2003).
Stream order	First order waterway.
Key Fish Habitat Type and Class	Type 3 – minimally sensitive Key Fish Habitat Class 3 – minimal Key Fish Habitat for fish passage.
Sensitive receiving environment	No.
Geomorphology	Entrenched bedrock in the upstream reaches of the survey site, that has been modified to form a stormwater channel Concrete-lined channel around 10 metres downstream of the survey point.
General water quality	• Freshwater • Periodically elevated heavy metal concentrations • Elevated nitrogen concentrations • Low dissolved oxygen.
Condition of riparian vegetation	Commonly occurring native tree species within remnant riparian vegetation include *Callicoma serratifolia*, *Ceratopetalum apetalum* (Coachwood), *Elaeocarpus reticulatus* and *Glochidion ferdinandi*. Localised infestations of *Ligustrum lucidum* and *Lantana camara* occur within riparian vegetation (North Sydney Council, 2003). The riparian corridor is wider on the northern bank (around 70 metres wide), and narrower on southern bank where it is next to grass playing fields within Primrose Park.
Instream habitat	No instream (aquatic of emergent) vegetation or woody debris. Some rocky features are present. The waterway is substantially shaded by adjacent riparian vegetation.
Photo	  Willoughby Creek looking downstream (left) and upstream (right).

Feature	Description
Flat Rock Creek	
Description	Located directly east of, and within Flat Rock Drive construction support site (BL2) and above the ramp tunnel alignment at Artarmon (from Gore Hill Freeway Connection). Flows in a generally east direction from Artarmon, through Willoughby and towards Cammeray where it discharges into Long Bay, on the southern side of Middle Harbour. 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. 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. The Flat Rock Creek catchment is characterised by residential development, recreational areas and a network of local and arterial roads.
Stream order	First order waterway upstream of the Quarry Creek confluence and a second order waterway downstream.
Key Fish Habitat Type and Class	Not at upper reaches (Artarmon) Lower reach (where the creek is quasi natural and estuarine) is classified as Type 1 – highly sensitive Key Fish Habitat and Class 1 – major Key Fish Habitat for fish passage.
Sensitive receiving environment	Not at upper reaches in Artarmon Lower reaches in Willoughby are considered sensitive receiving environments.
Geomorphology	Variable. At Artarmon, Flat Rock Creek occurs as an artificially reconstructed concrete lined waterway which flows under the Gore Hill Freeway in Artarmon. In Willoughby and Northbridge (and downstream of the subject land), Flat Rock Creek occurs as a natural ephemeral creek consisting of small standing pools and riffles varying in width (less than one to 10 metres) and depth (zero to greater than 0.5 metres). The substrate predominantly consists of Hawkesbury Sandstone bedrock and boulders, mud, detritus and logs. Stormwater flows appear to have had a large influence along this waterway, generally scouring the bedrock base and removing coarse and fine sediments.
General water quality	• Freshwater at upper reaches • Estuarine at lower reaches, due to influx of saltwater of Middle Harbour • Elevated heavy metal concentrations • Elevated nutrient concentrations • Microbiological contamination evident.
Condition of riparian vegetation	At Artarmon, riparian vegetation consists of mixed native plantings in the canopy shrub and ground layers, characteristic of locally occurring native riparian communities. At Northbridge, riparian vegetation occurs along the majority of Flat Rock Creek and varies in width (zero to greater than 50 metres) and condition. Vegetation consists predominantly of Urban Exotic/Native vegetation, native revegetation, PCT 1841 Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region, and infestations of weeds and exotics in areas which are significantly disturbed. Within the subject land Flat Rock Creek is likely to only to provide marginal quality habitat suitable for disturbance tolerant species of amphibian, reptile, mammal, invertebrate and bird. There is a lack of substantial fauna habitat present (ie logs, leaf litter, rock etc) and water quality is poor as a result of the creeks catchment area. These are limiting factors which are likely to prevent threatened aquatic species from occurring.

Feature	Description
Instream habitat	Absent from Artarmon, where Flat Rock Creek consists of an open concrete channel. In Northbridge (downstream of the subject land), large snags and dense instream, emergent vegetation is present in some areas. No instream macrophytes were recorded in the creek however, moss was observed in some reaches.
Photo	  Flat Rock Creek at the upstream site looking upstream (5a) (left) and along the underground channel (right)   Flat Rock Creek at the downstream site looking upstream (5b) (left) and at the estuarine site (5c) looking at the right bank (right)
Existing aboveground watercourse within the northern extent of Flat Rock Reserve	
Description	An existing aboveground watercourse flows from the northern end of Flat Rock Reserve in the Flat Rock Drive construction support site (BL2), parallel to Wilksch Walk and joins Flat Rock Creek at a rock cascade about 50 metres south-west from the Calbina Road cul de sac. This watercourse drains through a 0.4 metre underground pipe at the Small Street roundabout (northern extent of the subject land) but also receives catchment runoff from the escarpment which forms the north-eastern bank. This escarpment bank is steep, ranging between three and 10 metres along the tributary and is generally comprised of sandstone. The Wilksch Walk intersects the watercourse in a number of locations as the following features: • Boardwalk • Pipe culverts • Stepping stones across a spillway.
Stream order	Second order waterway.
Key Fish Habitat Type and Class	Not Key Fish Habitat.
Sensitive receiving environment	No.

Feature	Description
Geomorphology	The natural channel bed is generally bedrock with a layer of sediment and detritus colonised by exotic grasses and forbs. Concrete or rock is laid on the channel bed in sections exposed to higher flow velocities. Channel banks are steep. Watercourse width ranged between two and 10 metres albeit only some sections were flowing. Riffles and pools were observed and where there is no flow, the channel bed is soft and damp.
General water quality	• Freshwater • Elevated heavy metal concentrations • Elevated nutrient concentrations.
Condition of riparian vegetation	Dense native and exotic riparian vegetation occurs along both banks. The escarpment is well vegetated with a mix of native and exotic woody trees, ferns with a dense midstorey and groundcover. The south-western banks that plateau to the Wilksch Walk track, range between two and four metres and are substantially lower. These banks are also densely vegetated with a similar vegetation assemblage as the escarpment. However, the riparian corridor along the south-western side is narrower due to the constraints of walking track and open space clearings.
Instream habitat	Moss, rocks and loose snags occur in some sections. No instream macrophytes were recorded in the tributary. Where there is no flow, the channel bed is mostly colonised by exotic grasses and forbs, typically found in riparian corridors in Sydney metropolitan areas (eg *Tradescantia fluminensis*, *Ehrharta erecta*).
Photo	 Existing aboveground watercourse within the northern extent of Flat Rock Reserve looking downstream from the Small Street roundabout culvert   Pool along the Existing aboveground watercourse within the northern extent of Flat Rock Reserve (left) and Wilksch Walk crossing along the unnamed tributary (right)

Feature	Description
Quarry Creek	
Description	Quarry Creek is a small natural 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 and is densely vegetated by weeds and has limited accessibility. It generally flows in a north-easterly direction from Bridgeview Avenue, Cammeray into Tunks Park, Cammeray. It is estuarine downstream of its confluence with Flat Rock Creek. Quarry Creek is shorter than the other two creeks, has no stormwater outlets along its length and apart from the top section generally flows down a steep gradient. Quarry Creek is located outside of the subject land and project would not be located within its catchment.
Stream order	Second order waterway.
Key Fish Habitat Type and Class	Not Key Fish Habitat. Class 3 – Minimal Key Fish Habitat for fish passage
Sensitive receiving environment	Yes.
Geomorphology	Quarry Creek generally consists of cascade/riffle zones with few shallow or deep pools. Stormwater flows appear to have had a large influence along this waterway, generally scouring the bedrock base and removing coarse and fine sediments apart from one large deep pool.
General water quality	• Freshwater at upper reaches • Estuarine downstream of its confluence with Flat Rock Creek • Elevated heavy metal concentrations • Microbiological contamination evident.
Condition of riparian vegetation	Most of Quarry Creek is among natural bushland with the riparian condition of much of the creek being either quasi natural or only partly modified.
Instream habitat	No instream macrophytes were recorded in the creek, however moss was observed in some reaches.
Photo	  Quarry Creek cascades and boulder instream features (left). Quarry Creek large deep pools upstream of the confluence of Quarry Creek and Flat Rock Creek (right)

Feature	Description
Burnt Bridge Creek	
Description	Transects the project at North Balgowlah and is located next to Balgowlah Golf Course and Kitchener Street construction support sites (BL10 and BL11). Flows to the east, originating from Seaforth, through bushland and under Burnt Bridge Creek Deviation. It then flows north-east through Balgowlah Golf Course and a linear tract of bushland (that supports a Grey-headed Flying-fox camp, as described in Section 3.6.2.4.6), before it is channelled below Balgowlah Industrial estate via a series of culverts to Manly Golf Course and ultimately, Manly Lagoon. The Burnt Bridge Creek catchment supports residential development, Balgowlah Industrial Estate, Balgowlah and Manly Golf Courses and a network of local and arterial roads such as Burnt Bridge Creek Deviation.
Stream order	First order waterway.
Key Fish Habitat Type and Class	Upper and middle reaches are not classified as Key Fish Habitat and have been assigned a waterway Class 3 – Minimal Key Fish Habitat for fish passage. Lower reach (where the creek is estuarine) is classified as Type 1 – highly sensitive Key Fish Habitat and Class 1 – major Key Fish Habitat for fish passage. For the purposes of considering offsets, the area of waterway impacted by the culvert extension works and scour protection has been assigned Type 2 – moderately sensitive Key Fish Habitat (refer to Section 7.2).
Sensitive receiving environment	No.
Geomorphology	The upstream reach of Burnt Bridge Creek (3a) comprises a mostly natural channel with rocky outcrops and low levels of sedimentation (sandy silt) over bedrock. Modified stormwater inflows and culvert crossings are present along this reach. Stormwater flows appear to have had a large influence along the upstream reach, generally scouring the bedrock base and removing coarse and fine sediments. The gradient of the creek lessens at the middle reach of Burnt Bridge Creek (immediately south of Burnt Bridge Creek Deviation) and here it has been modified and realigned in the past and the upper extent of this reach was defined by one large continuous deep pool behind a weir, with cobble/gravel, silt and detritus substratum. Downstream of the weir there are pools connected with cascades before Burnt Bridge Creek traverses north-east underneath the Burnt Bridge Creek Deviation. Further downstream in the Balgowlah industrial area the creek becomes an artificial channel form with no riffle/pool sequence.
General water quality	• Freshwater with stormwater inflows from multiple locations • Low dissolved oxygen • Elevated heavy metal concentrations • Elevated nutrient concentrations.
Condition of riparian vegetation	Riparian vegetation which occurs along the majority of Burnt Bridge Creek varies in width (zero to 30 metres) and condition. Riparian vegetation consists of PCT 1250 Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion, urban exotic/natives and is infested with weeds and exotics in areas which are significantly disturbed. Bush regeneration practices along its length within the subject land have resulted in large areas of exposed ground which often lacks vegetation cover. Leaf litter within riparian vegetation is variable.

<table>
<tr><th>Feature</th><th>Description</th></tr>
<tr><td>Instream habitat</td><td>The upstream reach consists of partially connected pools with some exotic instream vegetation, isolated occurrences of emergent snags and substantial shading from riparian vegetation. The mid-reach of Burnt Bridge Creek supports disconnected pools with minimal connectivity with moderate shading from riparian vegetation and small snags instream at middle reaches. Established exotic macrophytes also lined much of the banks. At lower reaches, pools and runs of varying depth occur, with some instream macrophytes, overhanging native riparian vegetation and instream shading.
Burnt Bridge Creek is likely to only provide marginal quality habitat suitable for disturbance tolerant species of amphibian, reptile, mammal, invertebrate and bird. There is a lack of substantial fauna habitat present (ie logs, leaf litter, rock etc) and water quality is poor as a result of the catchment area. These are limiting factors which mean this waterway does not support preferred habitat for threatened aquatic species such as the Red-crowned Toadlet and Giant Burrowing Frog.</td></tr>
<tr><td>Photo</td><td> 
Site 3a looking upstream (left) and at site 3b looking upstream (right)
 
Site 3c looking upstream (left) and at site 3d looking upstream (right)</td></tr>
</table>

Feature	Description
Manly Creek	
Description	The headwaters of Manly Creek are located about 300 metres east of the northern extent of the subject land. Flows in a south easterly direction from the northern end of Manly Warringah War Memorial State Park (east of Wakehurst Parkway, in Allambie Heights) to Manly Dam. From the eastern extent of Manly Dam, Manly Creek flows east through bushland contained within David Thomas Reserve and through Warringah Golf Club, in a general eastward direction to Manly Lagoon. The Manly Creek catchment is characterised by large tracts of bushland contained within Manly Warringah War Memorial State Park, residential development, Warringah Golf Club and a network of local and arterial roads.
Stream order	First order waterway.
Key Fish Habitat Type and Class	Type 1 – highly sensitive Key Fish Habitat Class 1 – major Key Fish Habitat for fish passage waterway.
Sensitive receiving environment	Yes.
Geomorphology	Substratum of mostly sandstone bedrock, boulders and cobbles. Channel of connected pools, runs and riffles. Pools appeared to hold some sediment.
General water quality	• Freshwater • Low dissolved oxygen • Elevated heavy metal concentrations • Elevated nutrient concentrations.
Condition of riparian vegetation	Upstream of Manly Dam, Manly Creek flows through a large area of intact native bushland, contained within Manly Warringah War Memorial State Park. Sydney Sandstone Gully Forest (specifically, Peppermint-Angophora Forest) is mapped as occurring along the banks of Manly Creek (Warringah Council, 2013). Weeds occur in places along the creek.
Instream habitat	At 7b, this waterway is characterised by a series of connected pools, runs and riffles. The banks were low and large snags and boulders provided potential fish habitat throughout the surveyed reach.
Photo	  Manly Creek(7b) looking upstream (left) and downstream (right)

Feature	Description
Manly Dam	
Description	Manly Dam is located about one kilometre east and downstream of the subject land. Manly Dam was constructed in 1982, by building a dam wall across Manly Creek, to provide water to Manly, and over time, neighbouring suburbs of Balgowlah and Seaforth. Manly Dam is one of the largest artificial freshwater dams in the Sydney metropolitan area, with a capacity of about 2,000 megalitres. The water level behind Manly Dam Wall is maintained at 34.1 metres. An artificial wetland is located in the upper reaches of the dam (Warringah Council, 2013).
Stream order	Not applicable, Manly Dam is not a stream. Manly Creek, which flows into and from the dam, is a first order stream.
Key Fish Habitat Type and Class	Type 1 – highly sensitive major Key Fish Habitat Class 1 – sensitive Key Fish Habitat for fish passage.
Sensitive receiving environment	Yes.
Geomorphology	Lagoon bound by sandstone slopes, rock platforms and gullies.
General water quality	• Freshwater • Seasonally fluctuating dissolved oxygen conditions • Elevated nutrient concentrations. • Periodically experience elevated heavy metal concentrations.
Condition of riparian vegetation	Vegetation mapped along the shores of Manly Dam is dominated by Bloodwood-Scribbly Gum Woodland and Sandstone Heath, with small patches of highly disturbed vegetation occurring on the southern shore (Warringah Council, 2013).
Instream habitat	Shallow wetland areas scattered around the dam foreshore support native and exotic emergent macrophytes, that offer potential habitat for Common Eastern Froglet (*Crinia signifera)*, Eastern Dwarf Tree Frog (*Litoria fallax*) and Eastern Banjo Frog (*Limnodynastes dumerilii*). Deeper parts of the dam support Eastern Long-necked Turtle (*Chelodina longicollis*), Australian Bass (*Macquaria novemaculeata*) and Silver Perch (*Bidyanus bidyanus*) (Warringah Council, 2013).
Photo	  Many Dam mid-dam (6b) (left) and at the dam wall (6c) (right).

Feature	Description
Trefoil Creek	
Description	The headwaters of Trefoil Creek are located about 300 metres north of the northern extent of the subject land. This watercourse flows north from Frenchs Forest Road at Frenchs Forest, crosses underneath the Wakehurst Parkway and discharges into Middle Creek, which flows into Narrabeen Lagoon to the north-east. The Trefoil Creek catchment is characterised by residential development and large tracts of bushland.
Stream order	First order.
Key Fish Habitat Type and Class	Type 2 – moderately sensitive Key Fish Habitat Class 3 – minimal Key Fish Habitat for fish passage.
Sensitive receiving environment	Yes.
Geomorphology	Narrow, natural channel located within a steep gully Sandy silt substratum overlaying bedrock with occasional rocky outcrops.
General water quality	• Freshwater • Elevated heavy metal concentrations during wet weather • Elevated nutrient concentrations during wet weather.
Condition of riparian vegetation	Riparian vegetation comprises dense, overhanging native and exotic vegetation.
Instream habitat	Substantial riparian shading over ephemeral and disconnected pools (at the time of survey).
Photo	 Trefoil Creek along the survey reach (8b).
Unnamed watercourses along the Wakehurst Parkway	
Description	The headwaters of a number of small, ephemeral watercourses are located within the subject land, near the Wakehurst Parkway in the northern extent of the subject land. These watercourses flow in either a west-east direction into Manly Dam or in an east-west direction into Bantry Bay. Each of these streams before entering Manly Dam or Bantry Bay flow through high quality remnant native vegetation, contained in Manly Warringah War Memorial State Park or Garigal National Park, respectively. The catchments of these watercourses are characterised by large tracts of bushland and a small number of local and arterial roads.
Stream order	First order.

Feature	Description
Key Fish Habitat Type and Class	Type 3 – minimally sensitive Key Fish Habitat Class 3 – minimal Key Fish Habitat for fish passage.
Sensitive receiving environment	No.
Geomorphology	Substrate predominantly consists of Hawkesbury Sandstone bedrock and boulders, mud, detritus and logs.
General water quality	Freshwater. During periods of heavy rainfall, the streams would flow readily and collect stormwater runoff from the surrounding area. Stormwater runoff is likely to contain fewer pollutants than the other creeks within the subject land given the surrounding high quality vegetation.
Condition of riparian vegetation	Riparian vegetation which occurs in association with these streams includes Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies. This riparian vegetation offers habitat to locally occurring amphibian, reptile and mammal species, due to the diversity of fauna habitat features available, including rocks and logs, well-developed leaf litter and intact native vegetation.
Instream habitat	Standing pools and riffles with an ephemeral flow varying in width (0.5 to two metres) and depth (0 to 0.5 metres). These watercourses are likely to provide sheltering, foraging and breeding habitat for numerous species of amphibian, reptile, mammal, invertebrate and bird including threatened species such as Red-crowned Toadlet and Giant Burrowing Frog (though low likelihood for this species to occur) given the presence of substantial fauna habitat (ie logs, leaf litter, rock etc).
Wakehurst Golf Course dam	
Description	Wakehurst Golf Course dam is a freshwater lagoon on the western boundary of the Wakehurst Golf Club. It is nested within the bushland reserve between Wakehurst Parkway and Wakehurst Golf Club and is about 100 metres north-east of Wakehurst Parkway east construction support site (BL13). The Wakehurst Golf Course dam is about 50 by 20 metres with a two metre levee/bank on the golf course side and an eight to 10 metre natural escarpment on the reserve side. The dam does not appear to spill/discharge into any aboveground waterways. It appears to receive water from the escarpment to the west. Wakehurst Parkway forms a ridge where runoff from the road is likely to drain to the west to Bantry Bay and to the east to Wakehurst Golf Club. A vegetated drainage line originates from a 0.4 metre pipe, flowing into the dam down the escarpment on the western side of the dam. This drainage line is about one metre wide at the pipe becomes wider towards its approach to the dam. There was little flow from the pipe and no water reached the dam at the time of inspection.
Stream order	Not relevant - dam is not a waterway.
Key Fish Habitat Type and Class	Not Key Fish Habitat.
Sensitive receiving environment	No.

Feature	Description
Geomorphology	Dam bound by sandstone escarpment to west and levee banks to its north, east and south. The bed and the banks of the dam were mostly comprised of unconsolidated sediment and detritus albeit there were little suspended particles in the water column at the time of survey. Sand and small boulders were observed at the discharge location of the drainage line.
General water quality	Freshwater.
Condition of riparian vegetation	Riparian vegetation comprises dense, native vegetation with some exotic understorey.
Instream habitat	The northern and southern areas of the dam are fringed with native emergent macrophytes (*Eleocharis* spp.). Filamentous green algae were recorded on the sediment close to the banks. The drainage channel bed along the upstream sections are vegetated with shrubs, ferns, grasses and forbs or layered with detritus. No instream macrophytes albeit moss was observed in some channel sections.
Photo	  Instream condition of the dam looking south-west from the northern end (left) and vegetation drainage line originating from a 40 centimetre pipe on the escarpment (right).
Balgowlah Golf Course dam	
Description	Within the eastern side of the Burnt Bridge Creek catchment is the Balgowlah Golf Course stormwater harvesting dam which was completed in 2013. The dam is a four megalitre pond/dam with a maximum nominal water depth of 2.5 metres and it is used irrigate the Balgowlah Golf Course. A key outcome of the Balgowlah Golf Course stormwater harvesting project was that the golf course no longer needed to extract water from Burnt Bridge Creek for irrigation that would have affected environmental flows. This allowed for a return to the natural conditions of flow in the creek.
Stream order	Not relevant - dam is not a waterway.
Key Fish Habitat Type and Class	Not Key Fish Habitat.
Sensitive receiving environment	No.

Feature	Description
Geomorphology	It was noted that the dam includes rubber matting base overlain with soft sediment and rock. Rocks, exotic grasses, and exotic herbs and forbs occur on the dam banks.
General water quality	Freshwater.
Condition of riparian vegetation	Nil. The dam is surrounded by mown grassland and landscaped vegetation of the golf course.
Instream habitat	Sparsely emergent aquatic vegetation (eg *Persicaria* sp. and *Juncus* sp.) occurs near the dam banks and filamentous green algae were recorded within the dam. The dam provides habitat for common aquatic fauna adapted to highly modified aquatic environments such as eels, Mosquitofish (*Gambusia holbrooki*) and turtles. Aquatic birds (eg ducks) could forage in the dam though there is minimal habitat for nesting. The dam could also provide foraging habitat for microbats. Given its recent construction and disconnection from natural watercourses it is unlikely to provide potential habitat for native fish or threatened fauna species. The stormwater harvesting dam at Balgowlah Golf Course could provide a water source for terrestrial fauna.
Photo	  View of dam showing instram and adjacent vegetation of the golf course (left) and instream emergent vegetation (right).

3.7.4 Marine and intertidal habitats

The subject land encompasses a portion of Middle Harbour and its foreshores, between Northbridge on the southern shore and Seaforth on the northern shore. A number of shallow bays that fringe the main channel of Middle Harbour fall within the subject land and wider assessment area, including Sailors Bay, Pearl Bay, Peach Tree Bay and Bantry Bay.

Middle Harbour extends from about the Roseville Bridge in the west to its confluence with Port Jackson in the east, between Middle Head and Grotto Point. Middle Harbour is a tidal estuary that is deeply incised in Hawkesbury Sandstone, and supports five broad marine habitats (Cardno, 2020a):

- Intertidal rocky shores
- Shallow soft sediments, including seagrass, saltmarsh, mangroves and intertidal sandflats and mudflats
- Subtidal rocky reefs
- Deep soft sediments

- Open water.

While some of these habitats have been modified and disturbed by the construction of artificial structures such as seawalls, jetties, pontoons and marinas, much of the natural foreshore has been retained within the subject land. In addition, much of the foreshore within the subject land supports native vegetation, predominantly woodland and forest communities associated with sandstone-derived soils.

The marine and intertidal habitats identified in the subject land, and the resources they offer to marine mammals, reptiles and fish species are described and mapped in *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b). Some of these habitats offer resources to wandering seabirds, shorebirds, Little Penguin and White-bellied Sea-Eagle, and these are summarised below.

3.7.4.1 Intertidal sand and mudflats

Intertidal sandflats and mudflats occur where alluvial and marine sediment depositions accumulate, typically in shallow bays. Within the subject land, intertidal sand and mudflats were identified along the foreshore of Clive Park (Northbridge), Beauty Point (The Spit) and Peach Tree Bay (Seaforth).

These small areas of sand and mudflats within the subject land provide marginal foraging habitat to threatened shorebird species, where worms, bivalves, crustaceans and other invertebrates occur within soft substrate tidal areas that are exposed during low tide. However, no threatened shorebird species were recorded during targeted surveys, nor were determined to have a high likelihood of occurrence in the subject land. Sand and mudflats do not offer nesting or roosting habitat, as they are inundated at high tide.

Plate 10 Sand flats near Clive Park, near Middle Harbour south cofferdam (BL7)

Plate 11 Sand flats near Clive Park, near Middle Harbour south cofferdam (BL7)

3.7.4.2 Intertidal rocky shores

Rocky intertidal shores occur between the low- and high-water tidemarks. Within the subject land, intertidal rocky shores typically consist of natural, sandstone rocky shores along much of the foreshore of the bays and headlands within the subject land, including Peach Tree Bay, Seaforth Bluff, Beauty Point, Quakers Hat, Fig Tree Point, Fig Tree Cove, Clive Park and Sailors Bay (Figure 3-11).

Vertical walls and intertidal rocky areas in the subject land support a high abundance of Sydney Rock Oysters (*Saccostrea glomerata*), which offer limited foraging resources to threatened shorebirds. Intertidal rocky areas within the subject land do not offer nesting or roosting opportunities to threatened shorebird species, as these areas are inundated at high tide. No threatened shorebird species identified during database searches were determined to have a high likelihood of occurrence in the subject land.

Plate 12 Rocky shores on the southern shore of Middle Harbour, near Middle Harbour south cofferdam (BL7)

Plate 13 Rocky shores on the southern shore of Middle Harbour, near Middle Harbour south cofferdam (BL7)

3.7.4.3 Open water

Open water habitat within Middle Harbour (Plate 14, Plate 15) supports a diversity of marine fauna species, including plankton, invertebrates, fish, sharks, turtles and occasionally mammals such as seals and whales. These species and how they use open water habitat within the subject land are described in *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b), which is included as Appendix T of the environmental impact statement.

Open water habitat provides foraging habitat for a number of threatened bird species that forage for fish other marine prey species. As described in Section 3.6.2.4.10, White-bellied Sea-Eagle has been previously recorded at several locations throughout Middle Harbour, including within the subject land (DPIE (EES), 2020a), where the species may forage for fish, turtles and sea snakes.

As described in Section 3.6.2.4.15, Little Penguins have been recorded at several locations within the subject land, including The Spit, Long Bay, Sailors Bay, and in the main channel of Middle Harbour (DPIE (EES), 2020a), where the species likely forages in shallow waters for small shoaling fish, cephalopods, and to a lesser extent, crustaceans (NPWS, 2000).

Open water within Middle Harbour does not support preferred habitat for wandering seabirds such as Albatross and Petrels. No wandering seabird species that were identified during database searches were determined to have a high likelihood of occurrence in the subject land.

Plate 14 Open water of Middle Harbour, looking north towards Middle Harbour north cofferdam (BL8)

Plate 15 Open water of Middle Harbour, looking north-west towards Seaforth and Bantry Bay

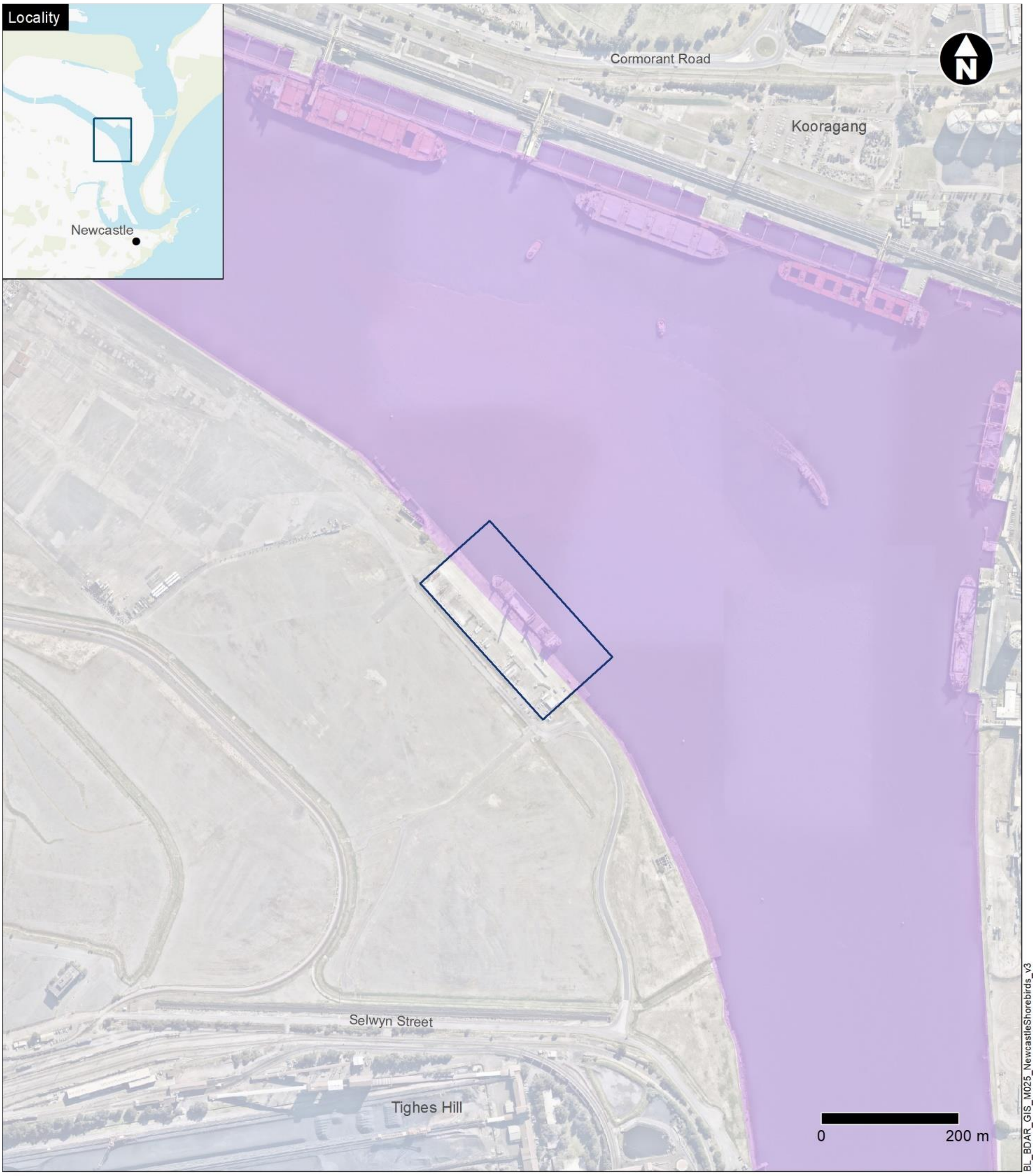
3.7.5 Threatened shorebirds

The Port of Newcastle construction support site (BL15) is partially located within the Hunter Estuary important area shorebird mapping as shown in Figure 3-10.

This important area mapping indicates the approximate boundaries of the Hunter Estuary, parts of which contain known important habitat for the BC Act listed Curlew Sandpiper, Terek Sandpiper and Black-tailed Godwit, and the EPBC Act listed Eastern Curlew, Bar-tailed Godwit and Red Knot.

The Port of Newcastle construction support site (BL15) comprises entirely of a constructed hardstand area and open water of the Hunter River. It does not contain any native vegetation, such as mangroves or saltmarsh that would constitute foraging or roosting habitat for these six migratory shorebird species. Additionally, the Hunter River shoreline within the Port of Newcastle construction support site (BL15) consists of an active port used by docking ships, and therefore there is no mud, sand or intertidal areas that may provide habitat for migratory shorebirds. As such, no threatened shorebirds are considered likely to occur on the Port of Newcastle construction support site (BL15).

However, the importance of the Hunter River estuary to migratory shorebirds is well known (DEC, 2006). The primary habitat for these species is located within defined areas around Stockton and Kooragang Island. Although the Port of Newcastle construction support site (BL15) does not contain any suitable habitat for these six migratory shorebird species, the Hunter River itself may at times be used as a flight path. The Port of Newcastle construction support site (BL15) is not located between known habitat areas, therefore the surrounding section of the Hunter River is not likely to be commonly traversed by the Curlew Sandpiper, Terek Sandpiper, Black-tailed Godwit, Eastern Curlew, Bar-tailed Godwit or Red Knot.



Legend

- Port of Newcastle construction support site (BL15)
- Migratory Shorebird Important Area - Hunter Estuary (digitised from Biodiversity Offsets and Agreement Management System, October 2021)

Figure 3-10 Port of Newcastle construction support site (BL15) and important area shorebird mapping

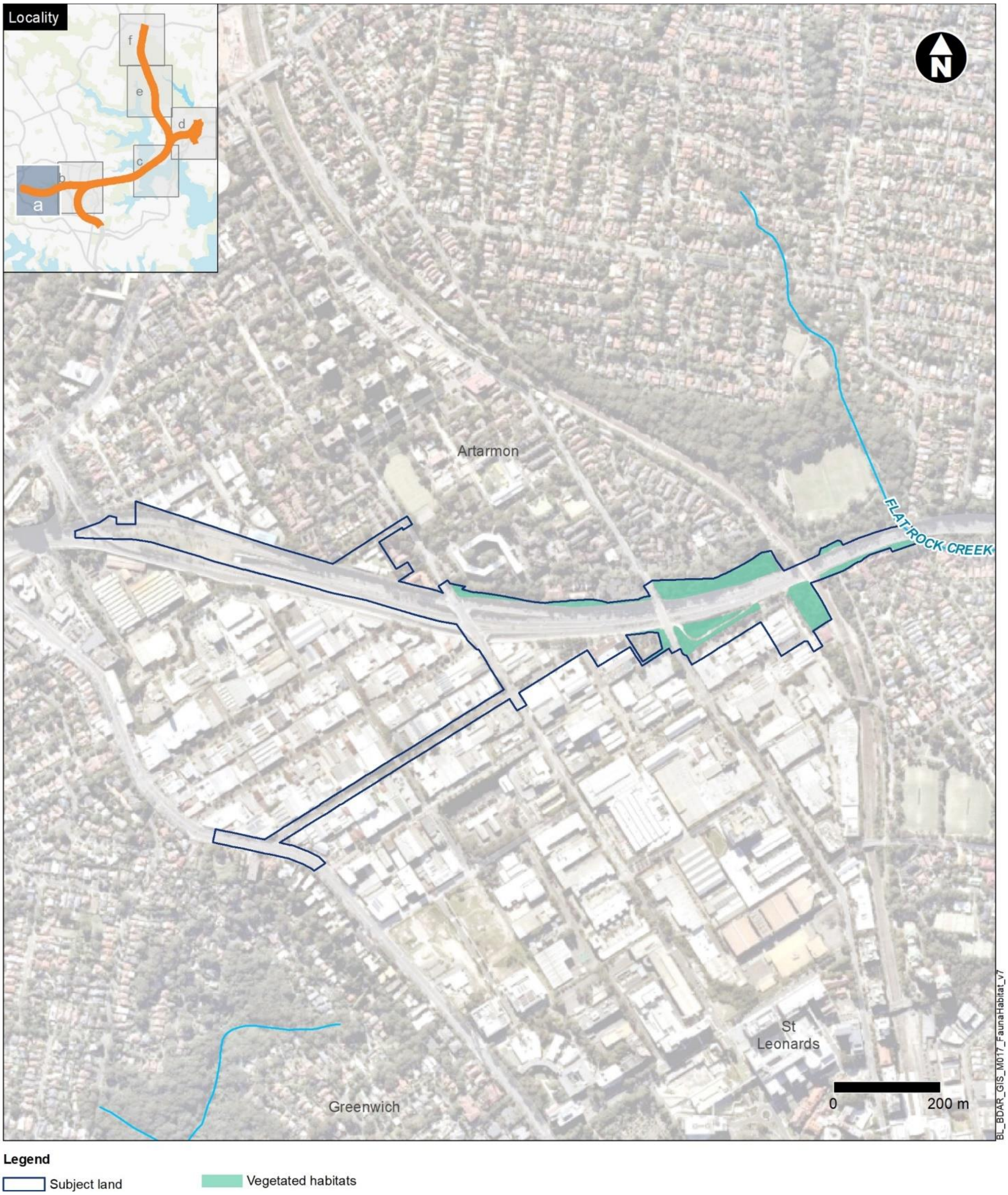


Figure 3-11 Distribution of fauna habitats within the subject land (map a)

Legend

Subject land

Vegetated habitats

Figure 3-11 Distribution of fauna habitats within the subject land (map b)

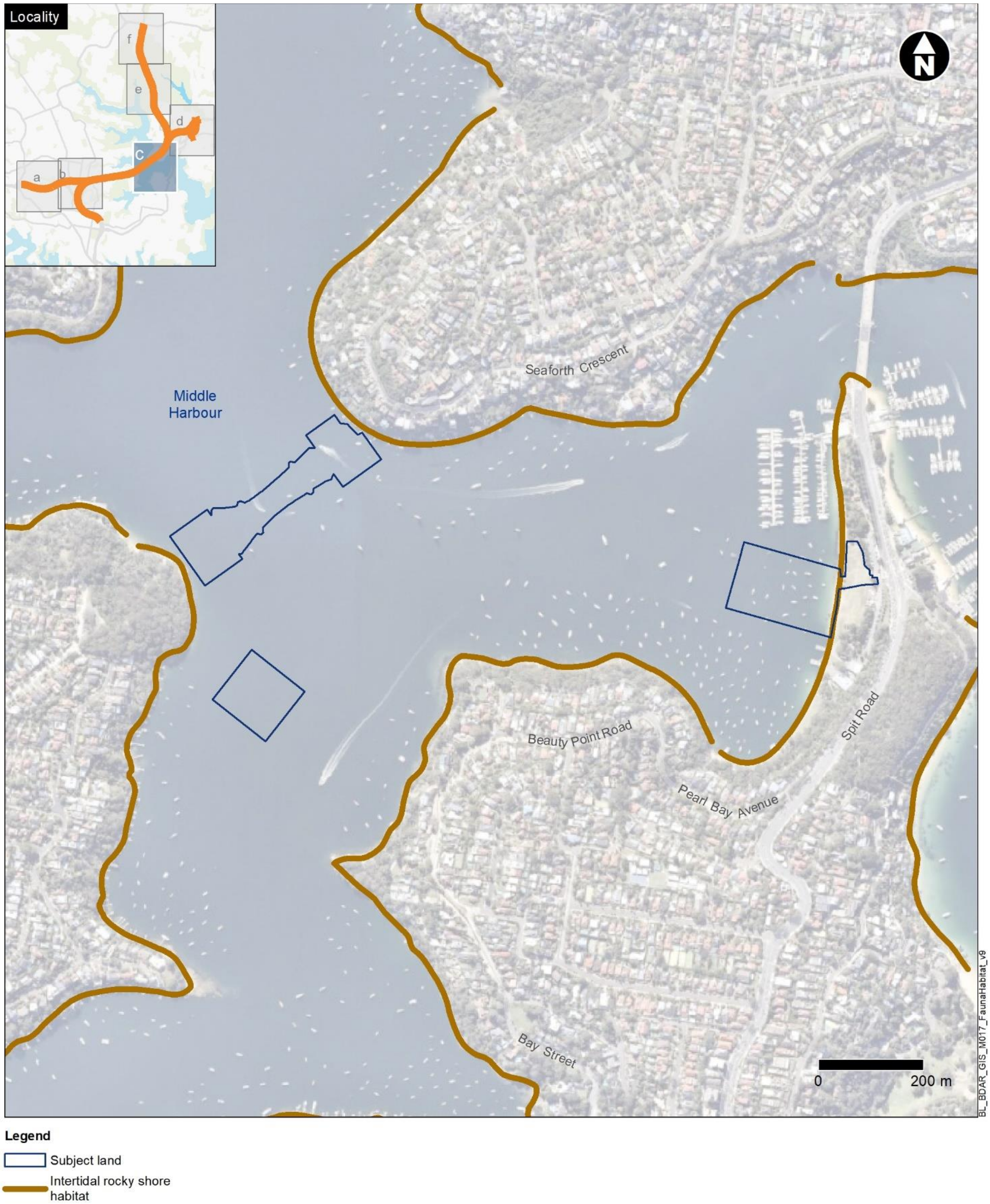


Figure 3-11 Distribution of fauna habitats within the subject land (map c)

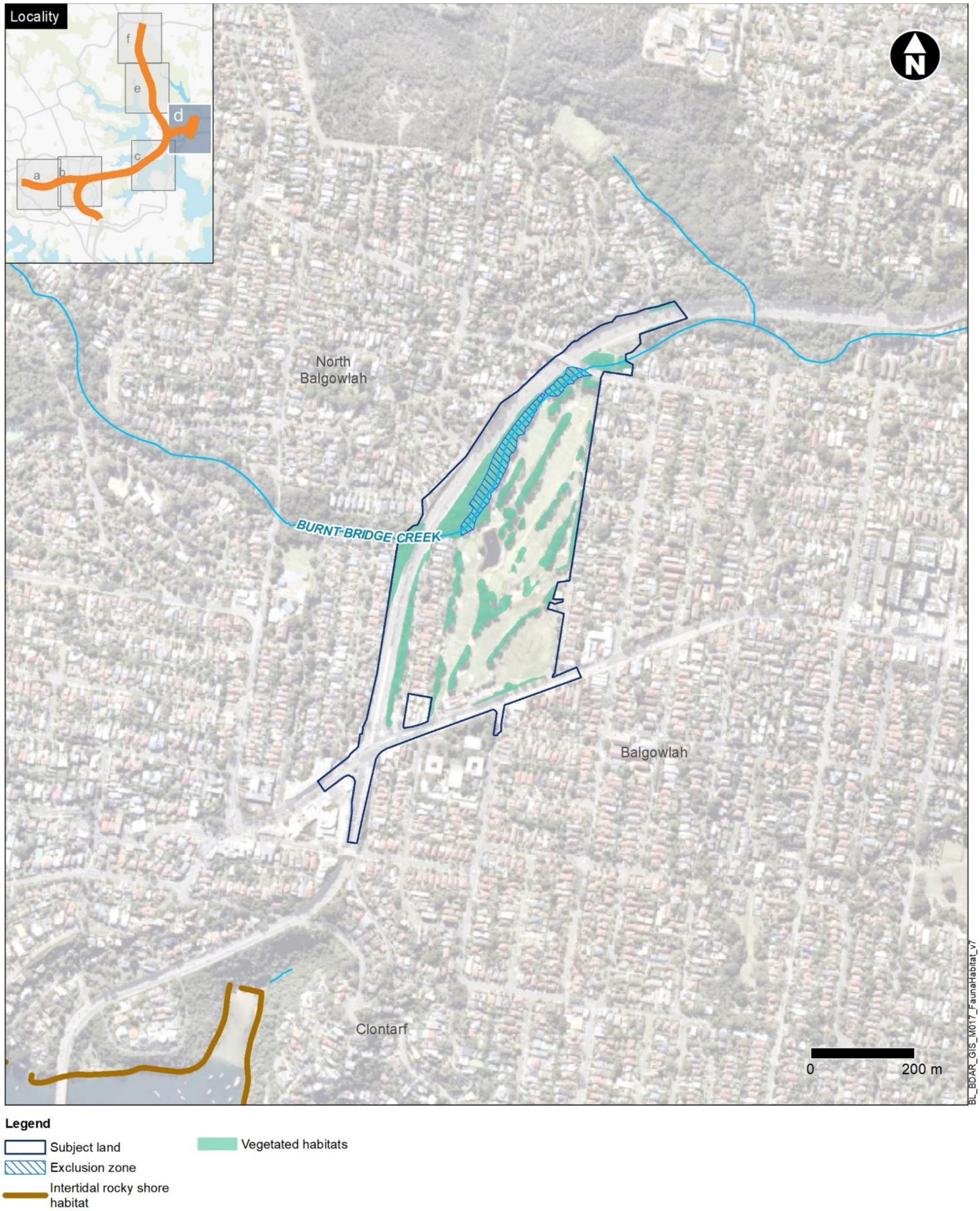


Figure 3-11 Distribution of fauna habitats within the subject land (map d)

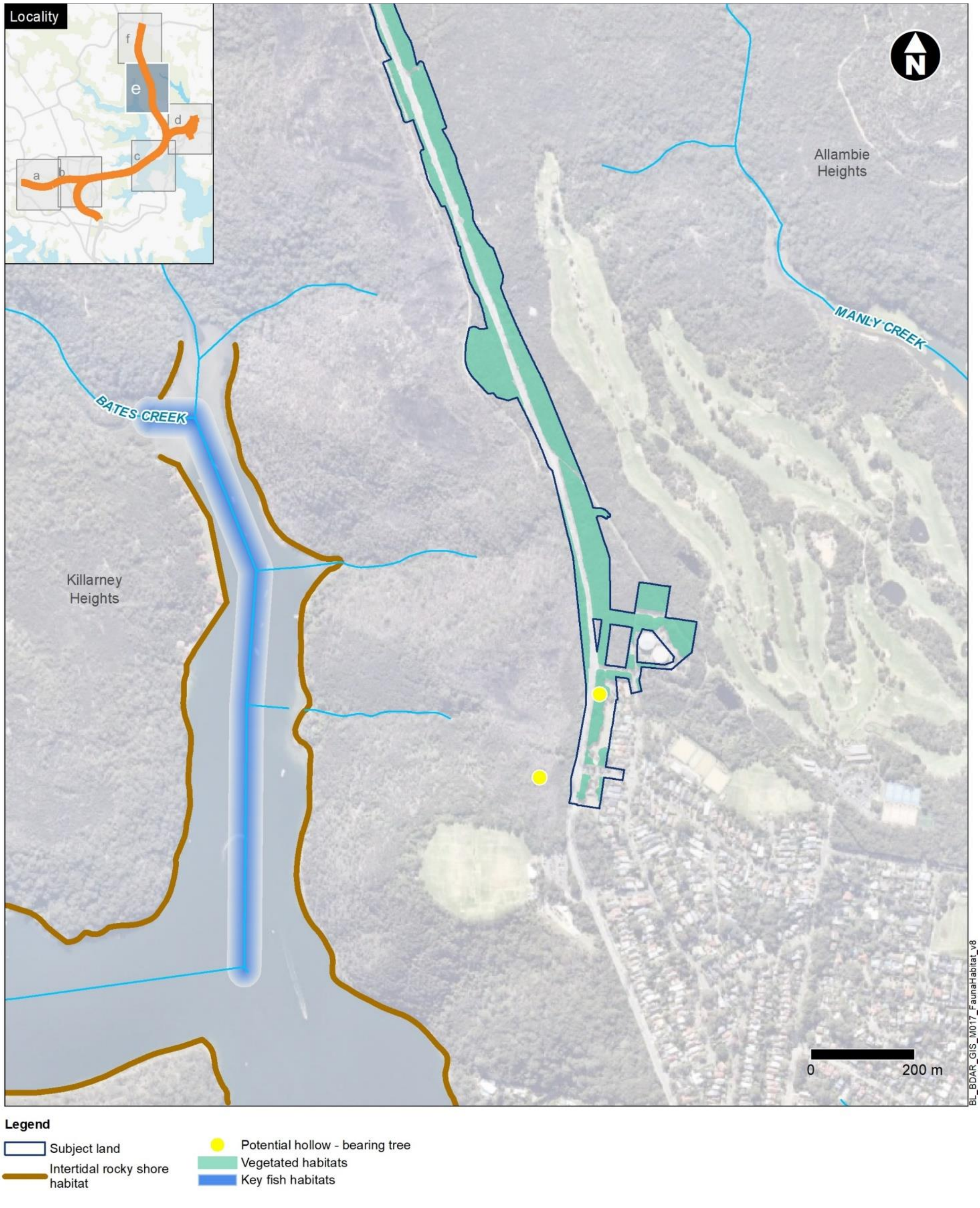


Figure 3-11 Distribution of fauna habitats within the subject land (map e)

Figure 3-11 Distribution of fauna habitats within the subject land (map f)

3.8 Groundwater dependent ecosystems

A search of the *National Atlas of Groundwater Dependent Ecosystems* (BOM, 2018) did not identify any groundwater dependent ecosystems within the subject land. However, several groundwater dependent ecosystems with potential reliance on subsurface groundwater were identified in the locality by the Bureau of Meteorology (BOM) (2018) (refer to Table 3.32 and Figure 3-12). For the purpose of identifying groundwater dependent ecosystems, the locality is defined as all areas within 500 metres of the subject land, plus any additional areas potentially impacted by water table drawdown, as shown on Figure 3-12.

Table 3.32 Groundwater dependent ecosystems mapped by BOM (2018) in the locality of the subject land

Location of mapped groundwater dependent ecosystems	Distance from subject land	Ecosystems mapped
Upper reaches of Flat Rock Creek at Munro Park – moderate to high potential for groundwater interaction	Around 280 metres south east of the subject land	Coastal Sandstone Gully Forest Sandstone Riparian Scrub Coastal Sand Forest Coastal Sandstone Plateau Heath Estuarine Fringe Forest Illawarra Gully Wet Forest.
Bates Creek – moderate to high potential for groundwater interaction	Around 550 metres west of the subject land	Estuarine Mangrove Forest Seagrass Meadow Coastal Sandstone Gully Forest.
Manly Warringah War Memorial State Park – moderate potential for groundwater interaction	Around 650 metres east of the subject land	Coastal Sandstone Gully Forest Coastal Sandstone Plateau Heath.

Ground truthing of the vegetation mapped as groundwater dependent ecosystems around Flat Rock Creek and Quarry Creek (carried out June 2021) found that the vegetation on the slopes and on top of sandstone cliffs is consistent with PCT 1778: Coastal Sandstone Foreshores Forest, with trees of *Eucalyptus pilularis* (Blackbutt), *Angophora costata* (Smooth-barked Apple) and a midstorey of *Allocasuarina littoralis* (Forest She-oak). There are signs of active bush regeneration in most areas of PCT 1778 inspected. The vegetation adjoining Quarry Creek is consistent with PCT 1841 Coastal enriched sandstone moist forest, with a canopy of *Eucalyptus pilularis* and a midlayer of *Ceratopetalum apetalum* (Coachwood) and *Callicoma serratifolia* (Blackwattle) with a ferny and mossy ground layer.

The vegetation adjoining Flat Rock Creek at the northern extent of the area mapped as groundwater dependent ecosystems by BOM (2018) is consistent with PCT 1828 Coastal Sandstone Gallery Rainforest, with a canopy of *Ceratopetalum apetalum*, *Elaeocarpus reticulatus* (Blueberry Ash), Acmena smithii (Lilly Pilly) and the exotic species *Ligustrum lucidum* (Broad-leaved Privet). The flats adjoining much of the length of Flat Rock Creek are dominated by exotic species, with *Ligustrum* spp., *Solanum mauritianum* (Wild Tobacco Bush), Cardiospermum grandiflorum (Balloon Vine), *Ehrharta erecta* (Panic Veldt Grass) and *Megathyrsus maximus* (Guinea Grass) all observed to be abundant.

The vegetation types mapped by BOM (2018) around Flat Rock Creek and Quarry Creek are not representative of the plant community types observed within the area. The OEH (2016) vegetation mapping of the Sydney Metropolitan Catchment Management Authority provides a more accurate representation of the vegetation communities and the extent of disturbance around the mapped groundwater dependent ecosystems; this mapping also corresponds to PCTs in the BioNet Vegetation Information System database.

Appendix 4 of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources – Background Document* (NSW Office of Water, 2011) identifies high priority groundwater dependent ecosystems in the Greater Metropolitan Region, as defined under Schedule 4 of the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*. None of the high priority groundwater dependent ecosystems listed are located in the subject land. The closest high priority groundwater dependent ecosystem to the subject land is Coastal Saltmarsh, mapped around 540 metres to the west of the Wakehurst Parkway section of the subject lands by OEH (2016).

Coastal Upland Swamp in the Sydney Basin Bioregion, listed as Endangered under the BC Act and EPBC Act, is mapped near the subject land. This TEC primarily occurs on impermeable sandstone plateaux with shallow groundwater aquifers, in the headwaters and impeded drainage lines of streams, and on sandstone benches with abundant seepage moisture. The closest mapped area of Coastal Upland Swamp is 30 metres to the east of the subject land; however, ground truthing of this location in May 2018 did not identify this community. The next closest mapped patch of Coastal Upland Swamp is 95 metres west of the Wakehurst Parkway in Garigal National Park; Coastal Upland Swamp has been confirmed in this location following site inspection in June 2021, but with some minor differences in the boundaries of the mapped patches (see Figure 3-6).

Another small (around 0.07 hectares) area of Coastal Upland Swamp was identified north of Bantry Bay Oval, about 135 metres south-east of the subject land. The extent of groundwater dependence of this small patch is not known; the hydrology of this patch and surrounding areas has been substantially modified, with a large dam constructed to the north and a cleared sports ground located on elevated, possibly filled land to the south.

Details regarding the further investigations of groundwater dependent ecosystems carried out following the exhibition of the environmental impact statement is provided in Attachment B of Annexure G. This includes investigations of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek. While there were no identified groundwater dependent ecosystems mapped by BOM (2018) at Burnt Bridge Creek, the creek and surrounding vegetation does receive some of its contribution from groundwater. However, given the poor water quality and disturbed vegetation, it is only considered to be a low ecological value groundwater dependent ecosystem (refer to Attachment B of Annexure G for further discussion).

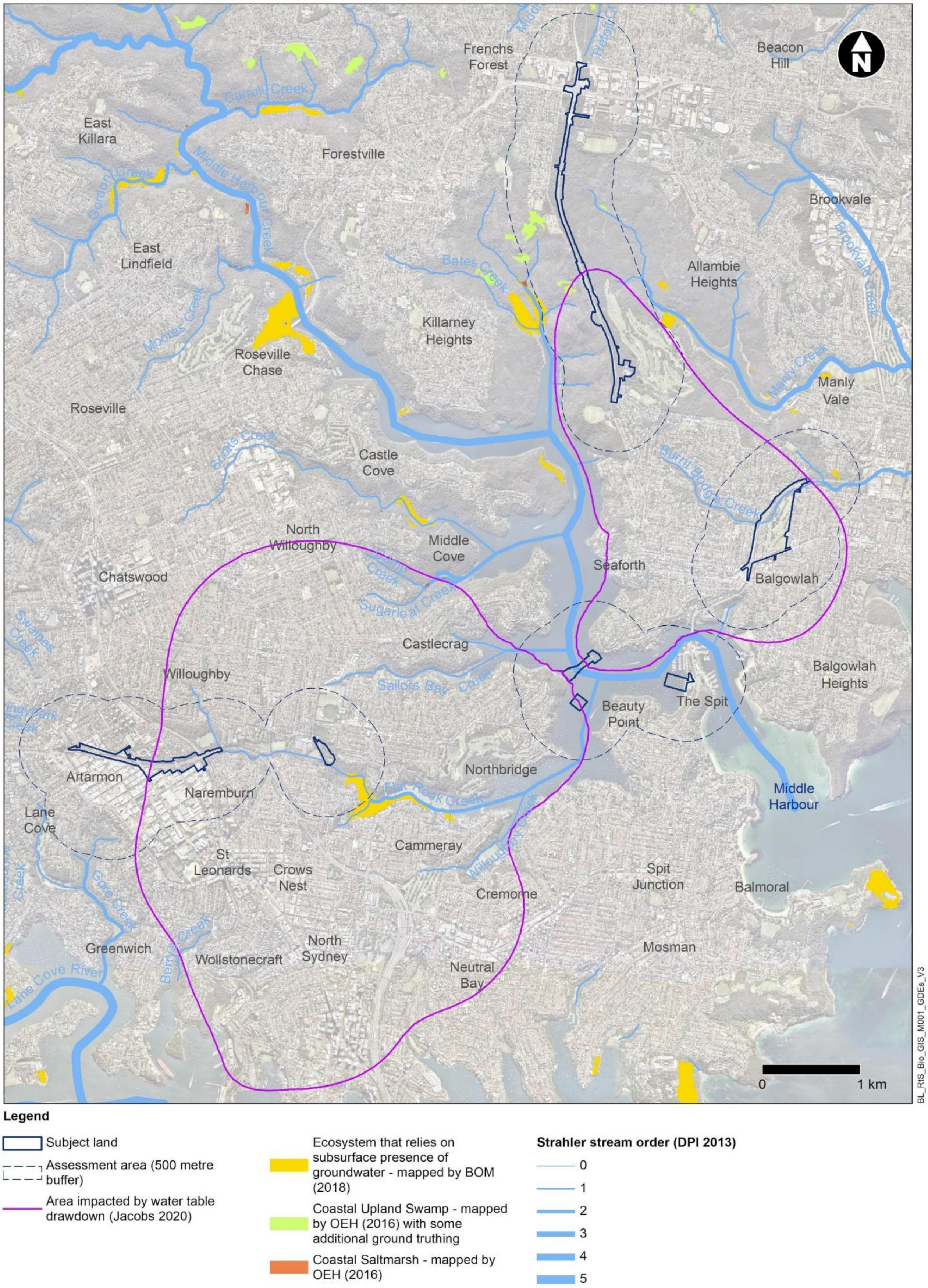


Figure 3-12 Distribution of groundwater dependent ecosystems

3.9 Matters of National Environmental Significance

The Secretary's environmental assessment requirements require that MNES listed under the EPBC Act are considered by this updated biodiversity assessment.

A search of the EPBC Protected Matters Search Tool was completed for an area within 10 kilometres of the subject land. The results of this search are provided in Annexure B of this report and discussed below.

3.9.1 Wetlands of international importance

A search of the EPBC Protected Matters Search Tool found no wetlands of international importance within 10 kilometres of the subject land. The closest wetland of international importance is Towra Point nature reserve, located over 20 kilometres south of the subject land on the southern shores of Botany Bay, on the Kurnell Peninsula.

3.9.2 Terrestrial threatened species and communities

A search of the EPBC Protected Matters Search Tool found 13 TECs, 34 threatened flora species, 36 threatened bird species, three threatened frog species, eight threatened terrestrial mammal species, one threatened snail and one threatened terrestrial reptile species listed under the EPBC Act that are likely to occur within 10 kilometres of the subject land. Annexure A assesses the likelihood of these TECs and threatened species to occur in the subject land.

One TEC listed under the EPBC Act, Coastal Upland Swamps in the Sydney Basin Bioregion, has been identified near the subject land, although not within it. This TEC has been mapped about 95 metres to the west of the subject land in Garigal National Park, and a smaller, modified patch has been identified north of Bantry Bay Oval, about 135 metres south-east of the subject land.

Two threatened species listed under the EPBC Act were identified in the subject land during field surveys: *Syzygium paniculatum* and Grey-headed Flying-fox. One individual of *Syzygium paniculatum* was recorded next to Wakehurst Parkway in PCT 1250. The species is not known to be associated with this vegetation type and it is considered unlikely to occur naturally at this location. However, there is no evidence that this specimen has been planted, and it may be of wild provenance, therefore it is considered to be remnant at this location.

A Grey-headed Flying-Fox camp (Balgowlah Camp) occurs at a location in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the subject land. Grey-headed Flying-fox was also recorded by WSP flying over a number of locations within the subject land, during surveys carried out in 2017. This species and its habitat within the subject land is described in Section 3.6.2.4.6.

Additionally, there are recent Bionet records of the Large-eared Pied Bat at the Wakehurst Parkway east construction support site (BL13) and around 800 metres east of the Wakehurst Parkway from 2018 (DPIE (EES), 2020a). This species was not recorded in the subject land during targeted surveys. No Large-eared Pied Bat were caught in the harp traps placed outside the subject land. However, the Large-eared Pied Bat was acoustically recorded 125 metres south-east of the Wakehurst Parkway east construction support site (BL13), during passive Anabat surveys. The species roosts in caves (near their entrances), crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (*Petrochelidon ariel*), frequenting low to mid-elevation dry open forest and woodland close to these features. Rocky features that could provide suitable roosting habitat are in close proximity to the Wakehurst Parkway (Figure 3-9). All PCTs on the subject land in proximity to the Wakehurst Parkway offer potential foraging habitat for the species.

No other MNES were recorded or considered highly likely to occur in the subject land.

3.9.3 Migratory birds

A search of the EPBC Protected Matters Search Tool found 54 migratory bird species listed under the EPBC Act that are known or are likely to occur within 10 kilometres of the subject land (Annexure B). The likelihood of these migratory species to occur in the subject is assessed in Annexure A. One migratory bird species was considered to have a high likelihood of occurrence in the subject land; White-bellied Sea-Eagle. A detailed description of this species and its habitat in the subject land is provided in Section 3.6.2.4.10.

Intertidal sand and mud flats within the subject land, as described in Section 3.7.4, do not comprise preferred foraging habitat for migratory shorebirds or waders. The marine waters of Middle Harbour, as described in Section 3.7.4, do not comprise preferred foraging habitat for wandering seabirds such as albatrosses or petrels.

Other migratory marine species listed under the EPBC Act are assessed in *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b).

3.9.4 Marine species

The likelihood of threatened marine species listed under the EPBC Act to occur in the subject land is assessed in *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b).

4 Avoid and minimise impacts

Chapter 4 (Project development and alternatives) of the environmental impact statement describes the alternatives that were considered as part of the project development process and explains the selection of the preferred corridor and design.

Five corridor alternatives were considered for the project; four of these included upgrade of the Wakehurst Parkway, where most biodiversity impacts occur. The five corridors were evaluated to identify the most technically, socially and environmentally acceptable alternative with the most efficient transport connections. Environmental evaluation criteria included to minimise environmental impact and minimise long-term loss of public open space and recreational areas. The five corridor alternatives are shown in Chapter 4 of the environmental impact statement.

The principles in Section 8.1 of the BAM (OEH, 2017a) have been considered to avoid and minimise impacts on native vegetation and habitat, where possible, through the project development process as described in Table 4.1.

Table 4.1 Project consistency with the principles of the BAM to avoid and minimise impacts on biodiversity

Principles	Project consistency
Corridor selection	
Locating the project in areas where there are no biodiversity values.	Areas of biodiversity value could not be entirely avoided but impacts to these areas have been minimised.
Locating the project in areas where the native vegetation or threatened species habitat is in the poorest condition (ie areas that have a lower vegetation integrity score).	Although the native vegetation in the subject land is largely in moderate to good condition, the areas of native vegetation that would be impacted by the project generally consist of existing roadside vegetation that is currently subject to edge effects and fragmentation.
Locating the project in areas that avoid habitat for species that have a high biodiversity risk weighting or native vegetation that is a CEEC or an EEC.	There are three threatened fauna species with a high biodiversity risk weighting that are considered to have a high likelihood of occurrence in the subject land: Large-eared Pied Bat, Large Bent-winged Bat and Little Bent-winged Bat. No breeding habitat for these species was identified in the subject land during targeted surveys, and the foraging habitat that would be impacted does not comprise a significant proportion of foraging habitat for these species in the surrounding locality or wider bioregion. Impacts to Duffys Forest TEC have been avoided as far as possible through minimisation of the area of the subject land in these patches by optimising the location of the tunnel portals and permanent tunnel support facilities (Figure 4-1).
Locating the project such that connectivity enabling movement of species and genetic material between areas of adjacent or nearby habitat is maintained.	The project includes the provision of a number of dedicated fauna crossings spanning the Wakehurst Parkway that would provide fauna connectivity between Garigal National Park to the west and Manly Warringah War Memorial State Park to the east (refer to Section 5.4.4). Fauna fencing would be provided for the length of Wakehurst Parkway to reduce the risk of vehicle strike and fauna mortality, and guide fauna towards fauna-crossing structures.

Principles	Project consistency
Consideration of alternatives	
An analysis of alternative modes or technologies that would avoid or minimise impacts on biodiversity values and justification for selecting the proposed mode or technology.	The majority of the project avoids surface impacts to terrestrial biodiversity values by tunnelling. The project design and construction works have been developed to avoid direct impacts to seagrass and other areas of marine habitat value in Middle Harbour. The construction methodology for the crossing of Middle Harbour has been designed to avoid dredging of the sand bank at the entrance to Middle Harbour or dredging in the vicinity of the Spit West Reserve construction support site (BL9).
An analysis of alternative routes that would avoid or minimise impacts on biodiversity values and justification for selecting the proposed route.	Five corridor alternatives were considered for the project; four of these included upgrade of the Wakehurst Parkway, where most biodiversity impacts occur. A summary of the alternative routes considered is provided in Chapter 4 of the environmental impact statement. The selected route avoids impacts associated with other options to the areas around Parriwi Park and Fisher Bay Bushland Reserve, where threatened species have been recorded.
An analysis of alternative locations that would avoid or minimise impacts on biodiversity values and justification for selecting the proposed location.	
An analysis of alternative sites within a property on which the project is proposed that would avoid or minimise impacts on biodiversity values and justification for selecting the proposed site.	Three alternative locations were considered for the location of the tunnel portals and ventilation facility along the Wakehurst Parkway (portal location A, B and C). The selected location (portal location B) minimises impacts to Duffys Forest TEC compared with other portal location A and required less tunnelling than portal location C (Figure 4-1). Refer to Chapter 4 (Project development and alternatives) of the environmental impact statement for information.
Design refinement	
Reducing the clearing footprint of the project.	The project minimises impact to sensitive areas around the Wakehurst Parkway, including Duffys Forest TEC, by optimising the location of tunnel portals and permanent tunnel support facilities. In addition, since the exhibition of the environmental impact statement Transport for NSW has refined the design of the ramps for the new shared user bridge at the northern end of the upgraded and realigned Wakehurst Parkway as outlined in Section A4.3 of the submissions report. The
Locating ancillary facilities in areas where there are no biodiversity values.	
Locating ancillary facilities in areas where the native vegetation or threatened species habitat is in the poorest condition (ie areas that have a lower vegetation integrity score).	

Principles	Project consistency
Locating ancillary facilities in areas that avoid habitat for species and vegetation in high threat status categories (eg an EEC or CEEC).	design refinement has reduced the area of Duffys Forest TEC that would be impacted by the project from 1.38 hectares to 1.21 hectares (Figure 4-2). The riparian zone of Flat Rock Creek has been avoided, and impacts in Flat Rock Reserve are mostly limited to revegetated areas Direct vegetation impacts around Burnt Bridge Creek have been reduced by establishing an exclusion zone around riparian native vegetation adjoining the creek. Noise and vibration impacts at the Grey-headed Flying-fox camp at Burnt Bridge Creek have been reduced during design refinement. The Kitchener Street bridge was originally proposed for demolition would instead be retained, substantially reducing the duration of potential noise and vibration impacts at the camp during construction.
Providing structures to enable species and genetic material to move across barriers or hostile gaps.	The project includes the provision of a number of dedicated fauna crossings spanning Wakehurst Parkway that would provide fauna connectivity between Garigal National Park to the west and Manly Warringah War Memorial State Park to the east. Three new rope bridges and three underpasses to facilitate fauna crossings are proposed (Figure 5-5). Fauna fencing would be provided for the length of Wakehurst Parkway to reduce the risk of vehicle strike and fauna mortality, and guide fauna towards fauna-crossing structures.
Making provision for the demarcation, ecological restoration, rehabilitation and/or ongoing maintenance of retained native vegetation habitat on the development site*.	Native vegetation within and adjoining the subject land would be managed in accordance with *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011). The costs of on-site biodiversity management would be determined during management plan preparation. The costs of offsets would be determined by the BAM calculator based on the final offset value. The cost of offsetting via payment to the fund is likely to change over time, as credit prices are market driven and updated in the BAM calculator on a quarterly basis.

* note – the term ‘development site’ is a term used by the BAM, which for the purposes of this assessment, is analogous with the terms ‘subject land’ and ‘development footprint’

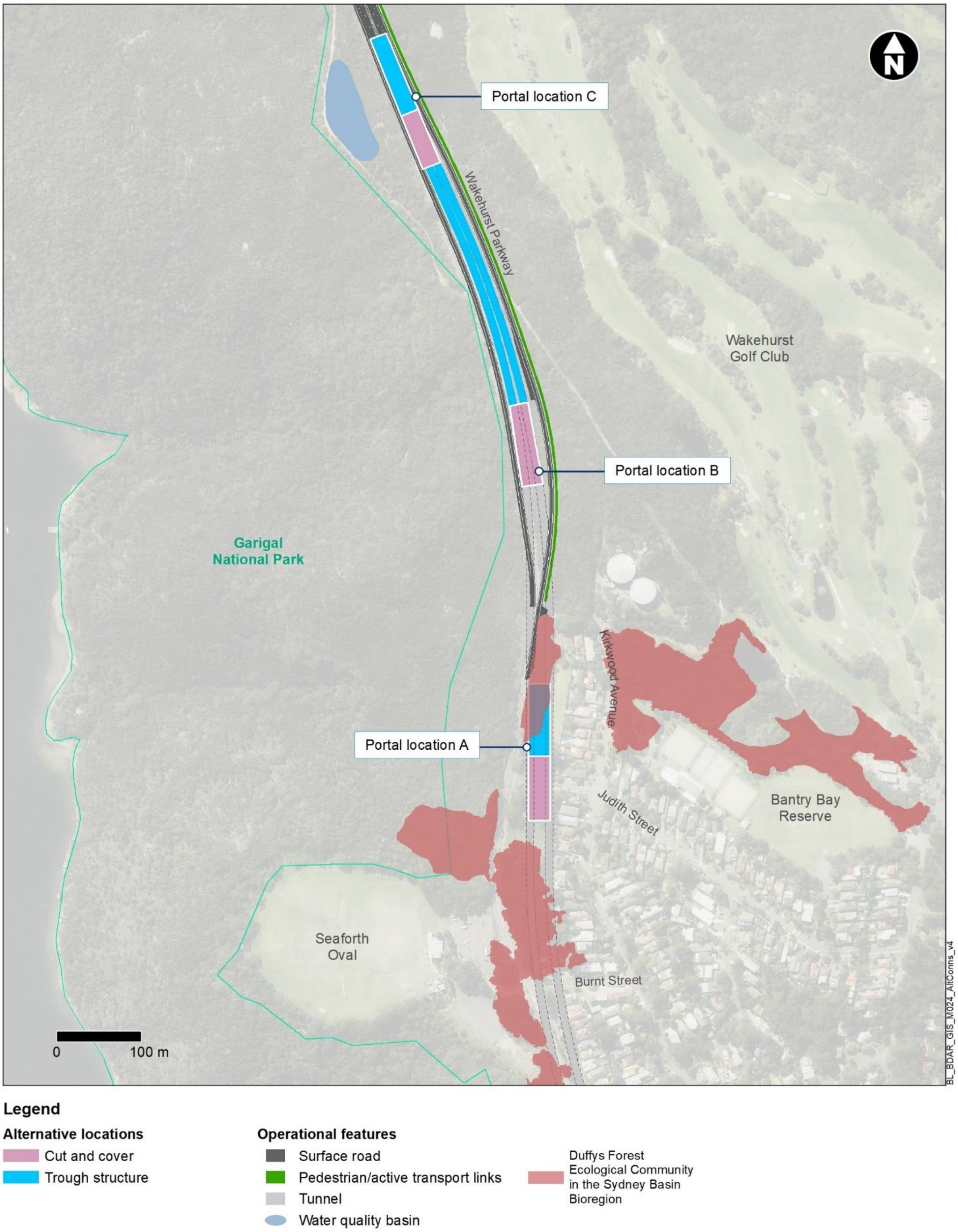


Figure 4-1 Connection location alternatives at the southern extent of Wakehurst Parkway

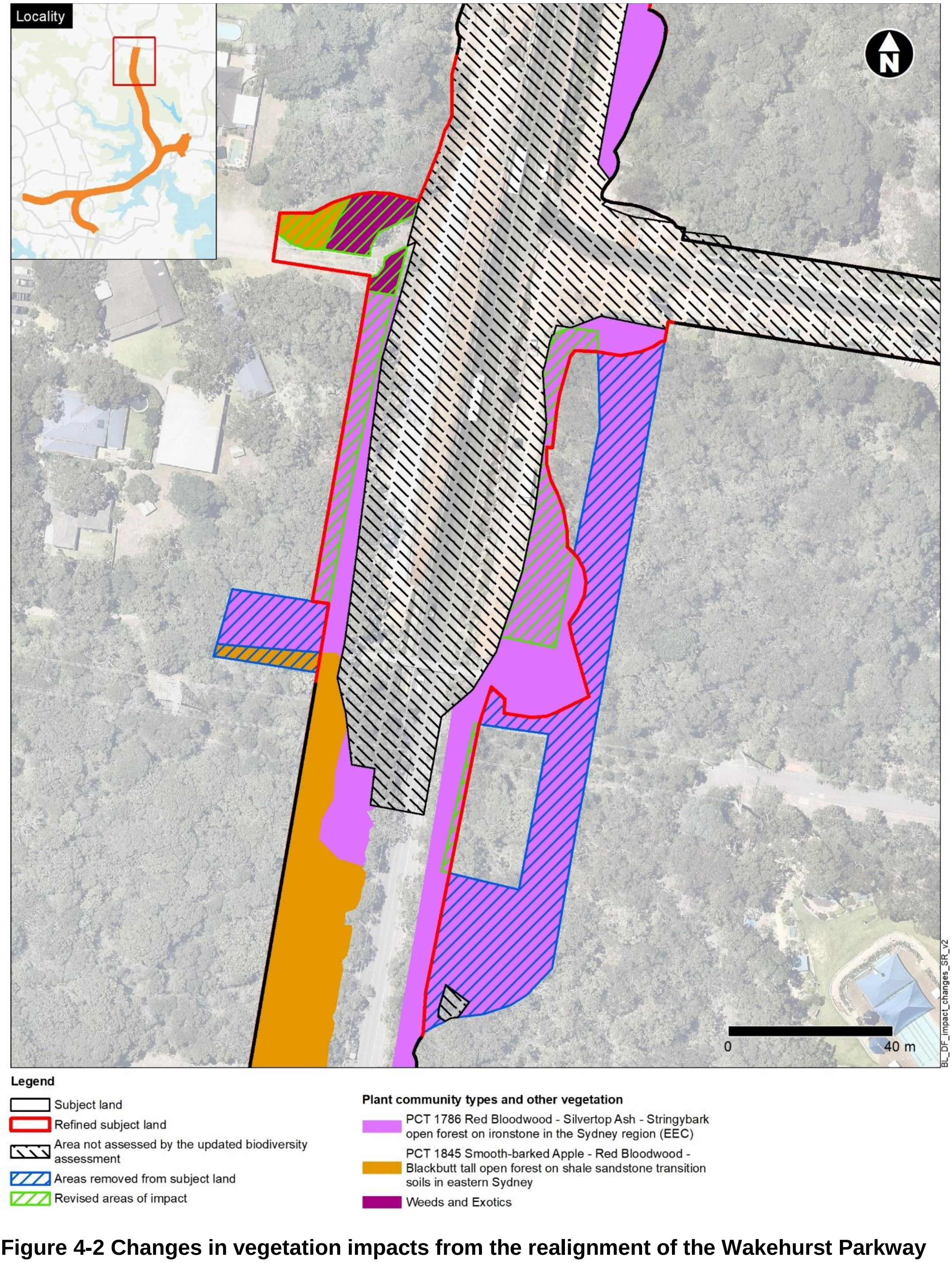


Figure 4-2 Changes in vegetation impacts from the realignment of the Wakehurst Parkway shared user bridge ramps

Section 8.2 of the BAM (OEH, 2017a) identifies principles for avoiding and minimising prescribed biodiversity impacts. Prescribed biodiversity impacts are discussed in Section 5.4 of this updated biodiversity assessment. Prescribed biodiversity impacts that are relevant to the project include:

- Impacts of development on the habitat of threatened species or ecological communities associated with rocks
- Impacts of development on the habitat of threatened species or ecological communities associated with human made structures
- Impacts of development on the habitat of threatened species or ecological communities associated with non-native vegetation
- Impacts of development on the connectivity of different areas of habitat of threatened species that facilitates the movement of those species across their range
- Impacts of the development on movement of threatened species that maintains their life cycle
- Impacts of development on water quality, water bodies and hydrological processes that sustain threatened species and TECs
- Impacts of vehicle strikes on threatened species of animals or on animals that are part of a TEC.

The principles for avoiding and minimising prescribed biodiversity impacts are considered in Table 4.2.

Table 4.2 Project consistency with the principles of the BAM to avoid and minimise prescribed biodiversity impacts

Principles	Project consistency
Project location	
Locating the envelope of surface works to avoid direct impacts on the habitat features identified as subject to prescribed biodiversity impacts.	Generally, areas of native vegetation were prioritised for avoidance over areas of non-native vegetation and human made structures, as they provide greater habitat value for threatened species.
Locating the envelope of sub-surface works, both in the horizontal and vertical plane, to avoid and minimise operations beneath the habitat features identified as subject to prescribed biodiversity impacts eg locating longwall panels away from geological features of significance or water dependent plant communities and their supporting aquifers.	Tunnelling has largely avoided impacts to areas supporting groundwater dependent ecosystems, with the exception of some vegetation at Flat Rock Creek/Quarry Creek that would be subject to potential water table drawdown impacts.
Locating the project to avoid severing or interfering with corridors connecting different areas of habitat, migratory flight paths to important habitat or local movement pathways.	The project includes realignment and upgrade of the Wakehurst Parkway, which would result in an increase in the gap between areas of habitat to the west and east. This impact could not be avoided; however, the project includes the provision of a number of dedicated fauna crossings spanning Wakehurst Parkway that would provide fauna connectivity between Garigal National Park to the west and Manly Warringah War Memorial State Park to the east. Fauna fencing would be provided for the length of Wakehurst Parkway to reduce the risk of vehicle strike and fauna mortality, and guide fauna towards fauna-crossing structures.

Principles	Project consistency
Optimising project layout to minimise interactions with threatened species and ecological communities, eg designing turbine layout to allow buffers around features that attract and support aerial species, such as forest edges, riparian corridors and wetlands, ridgetops and gullies.	Impact to sensitive areas have been minimised by optimising the location and layout of temporary construction support sites and permanent tunnel support facilities.
Locating the project to avoid direct impacts on water bodies.	Alternative crossing methodologies for Middle Harbour were explored during design development. As summarised in Chapter 4 (Project development and alternatives) of the environmental impact statement, the preferred methodology of the immersed tube tunnel was selected as it provides a shallow alignment and enables better grades and journey experience (eg safety and long-term emissions). In order to minimise water quality impacts on Middle Harbour, the selected methodology for the project has considered dredging methods and controls to limit the potential for turbidity impacts and mobilisation of sediment. The preferred design at Balgowlah would have direct impacts on a short section of Burnt Bridge Creek to facilitate an extension of the existing box culvert crossing of Burnt Bridge Creek Deviation further into the existing Balgowlah Golf Course. The section of creek located within the golf course has been realigned in the past. The preferred design at this location was selected as it provided constructability benefits, reduced private property impacts and reduced environmental impacts. In particular, it reduced impacts to Burnt Bridge Creek to the east and west of Burnt Bridge Creek Deviation compared to other options.
An analysis of alternative modes or technologies that would avoid or minimise prescribed biodiversity impacts and justification for selecting the proposed mode or technology.	The majority of the project avoids surface impacts to terrestrial biodiversity values by tunnelling. Design and construction works have been developed to avoid direct impacts to seagrass and other areas of marine habitat value in Middle Harbour. Offshore cofferdams have avoided a physical impact on the sensitive foreshores of Clive Park and Seaforth Bluff. Traditional immersed tube construction would involve land-based coffer dams to construct interface structures. The construction methodology for the crossing of Middle Harbour has been designed to avoid dredging of the sand bank at the entrance to Middle Harbour and in the vicinity of Spit West Reserve construction support site (BL9).
An analysis of alternative routes that would avoid or minimise prescribed biodiversity impacts and justification for selecting the proposed route.	Five corridor alternatives were considered for the project; four of these included realignment and upgrade of the Wakehurst Parkway, where most biodiversity impacts occur. A summary of the alternative routes considered is provided in Chapter 4 (Project development and alternatives) of the environmental impact statement. The selected route avoids impacts associated with other options to the areas around Parriwi Park and Fisher Bay Bushland Reserve, where threatened species have been recorded.
An analysis of alternative locations that would avoid or minimise prescribed biodiversity impacts and justification for selecting the proposed location.	

Principles	Project consistency
An analysis of alternative sites within a property on which the project is proposed that would avoid or minimise prescribed biodiversity impacts and justification for selecting the proposed site.	Three alternative locations were considered for the location of the tunnel portals and ventilation facility along the Wakehurst Parkway. The selected location minimises impacts to Duffys Forest TEC compared with other locations.
Justifications for project location decisions should identify any other site constraints that the proponent has considered in determining the location and design of the project, eg bushfire protection requirements including clearing for asset protection zones, flood planning levels, servicing constraints.	Site constraints have been minimised by optimising the location and layout of temporary construction support sites and permanent tunnel support facilities.
Project design	
Engineering solutions, eg proven techniques to minimise fracturing of bedrock underlying features of geological significance, water dependent communities and their supporting aquifers, proven engineering solutions to restore connectivity and favoured movement pathways.	The project includes the provision of a number of dedicated fauna crossings spanning Wakehurst Parkway that would provide fauna connectivity between Garigal National Park to the west and Manly Warringah War Memorial State Park to the east. Fauna fencing would be provided for the length of Wakehurst Parkway to reduce the risk of vehicle strike and fauna mortality, and guide fauna towards fauna-crossing structures.
Design of project elements to minimise interactions with threatened and protected species and ecological communities, eg designing turbines to dissuade perching and minimise the diameter of the rotor swept area, designing fencing to prevent animal entry to transport corridors.	Fauna fencing would be provided for the length of Wakehurst Parkway to reduce the risk of vehicle strike and fauna mortality, and guide fauna towards fauna-crossing structures. In addition, removal of the existing fauna fencing installed as part of the Northern Beaches Hospital road upgrade project will be avoided where possible in overlapping construction areas. Where this is not possible, temporary fauna fencing will be installed during construction to ensure fauna are guided to existing underpasses and away from construction areas and/or live traffic. As discussed in Table 4.1, Transport for NSW has refined the design of the ramps for the new shared user bridge at the northern end of the upgraded and realigned Wakehurst Parkway as outlined in Section A4.3 of the submissions report. The design refinement has reduced the area of Duffys Forest TEC that would be impacted by the project from 1.38 hectares to 1.21 hectares (Figure 4-2).
Design of the project to maintain environmental processes critical to the formation and persistence of habitat features not associated with native vegetation.	The project is not expected to adversely impact environmental processes critical to the formation and persistence of habitat features not associated with native vegetation, due to an absence of karst, caves, crevices, cliffs or other features of geological significance. Where rocky features are required to be removed (as part of vegetation clearing), these would be salvaged and translocated to areas of vegetation to be retained in the subject land.

Principles	Project consistency
Design of the project to maintain hydrological processes that sustain threatened species and TECs.	The drainage and stormwater design maintains pre-existing hydrological flows. Discharges from the wastewater treatment plants would be designed to not worsen water quality in the receiving environment during construction and operation. This includes Flat Rock Creek, Willoughby Creek and Burnt Bridge Creek. During construction, discharges to Flat Rock Creek, Willoughby Creek and Burnt Bridge Creek would be treated to comply with the following discharge criteria: • The relevant physical and chemical stressors, the guideline values set out in Table 3.3.2 and 3.3.3 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000) • The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 95 per cent species protection levels • The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water). Where the ANZG (2018) does not provide a default guideline value for a particular pollutant, the approaches set out in the ANZG (2018) for deriving guideline values, using interim guideline values and/or using other lines of evidence such as international scientific literature or water quality guidelines from other countries, will be used. During operation, discharges to Flat Rock Creek would be treated to comply with the following discharge criteria: • The relevant physical and chemical stressors, the guideline values set out in Tables 3.3.2 and 3.3.3 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000) • The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels • The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water). Where the ANZG (2018) does not provide a default guideline value for a particular pollutant, the approaches set out in the ANZG (2018) for deriving guideline values, using interim guideline values and/or using other lines of evidence such as international scientific literature or water quality guidelines from other countries, will be used. The project would also include the provision of water quality control measures along the Wakehurst Parkway, including new or modified drainage and water quality basins. Modelling concluded that the operation of the project at the Wakehurst Parkway would not decrease the water quality of nearby ephemeral and unnamed freshwater waterways, nor Garigal National Park drainage lines, Bantry Bay, Manly Dam or Manly Creek. Works at Burnt Bridge Creek have been modified to reduce the need to realign a section of creek and instead extend an existing culvert which has a smaller impact on aquatic habitat and hydrology of Burnt Bridge Creek.

Principles	Project consistency
Design of the project to avoid and minimise downstream impacts on rivers, wetlands and estuaries by control of the quality of water released from the site.	Temporary construction erosion and sediment control measures, including water quality basins 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 to minimise impacts to watercourses downstream of the subject land. 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 Punch Street, Artarmon is proposed to treat discharge and manage potential adverse impacts on Flat Rock Creek.

5 Impact assessment

For the purpose of this updated biodiversity assessment, it is assumed that all biodiversity values occurring within the subject land would be removed (with the exception of identified exclusion zones), due to the construction and operation of temporary and permanent features of the project. The term 'subject land' is analogous with the term 'construction footprint' that is used in the environmental impact statement, and with the term 'development footprint' that is prescribed by the BAM.

Refer to sections 1.4 and 1.5 for a description of the key features of the project. Further detail is provided in Chapter 5 (Project description) and Chapter 6 (Construction work) of the environmental impact statement, and should be read in conjunction with the refinements and clarifications provided in Section A4 and A5 of the submissions report.

Vegetation removal including the clearing of native vegetation and fauna habitat would be further minimised during further design development and detailed construction planning, where feasible and reasonable.

The final layout of the new and improved open space and recreation facilities at Balgowlah, including the retention and/or removal of trees, would be subject to the outcome of the dedicated community consultation process. The dedicated consultation process jointly led by Transport for NSW and Northern Beaches Council would take place to give the community an opportunity to provide input on the final layout of the new and improved open space and recreation facilities at Balgowlah. This consultation would be separate to the consultation for the Beaches Link environmental impact statement. This process is expected to commence after planning approval and well in advance of construction starting. As part of this consultation process, a community reference group would be established, with representative stakeholder groups and the community, to support Transport for NSW and Northern Beaches Council with the development of this important public space. An expression of interest for participation in the consultation process is expected to be issued later in 2021. The project would return an area, equivalent to around 90 per cent of the current open space, to the community as new and improved public open space and recreation facilities.

5.1 Direct impacts on native vegetation and habitat

5.1.1 Removal of native vegetation

Construction of the project would require the removal of native vegetation within the subject land. Vegetation from six ground-truthed PCTs would be removed as detailed in Table 5.1, resulting in the complete loss of vegetation integrity for each PCT. Of these, PCT 1786 (Red Bloodwood – Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast) falls within the definition of a TEC. PCT 1786 is consistent with the definition of Duffys Forest Ecological Community in the Sydney Basin Bioregion, which is listed as an EEC under the BC Act. This TEC adjoins Wakehurst Parkway at Seaforth and Frenchs Forest (Figure 3-6), and 1.21 hectares would be removed for the realignment and upgrade of the Wakehurst Parkway. No TECs listed under the EPBC Act would be removed for the project.

In order to reduce impacts on native vegetation, an exclusion zone is proposed to be established around riparian vegetation adjoining Burnt Bridge Creek adjacent to the surface road works at Balgowlah. The exclusion zone would be about 0.90 hectares in area and would contain 0.48 hectares of PCT 1250 and 0.42 hectares of PCT 1841. The exclusion zone boundary would be formalised during further construction planning and design development prior to construction commencement.

Ecosystem credits are required to offset the direct impacts of the project (ie the removal of native vegetation). Additional information about the offsetting requirements is provided in Section 7.

Table 5.1 Direct impacts to native vegetation

Vegetation zone	Status (BC Act)	Area to be impacted (ha)	Future value	Change (loss) in vegetation integrity score	Number of hollow bearing trees impacted
PCT 1250: Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion (Moderate/Good – Good)	Not listed	0.20	0	82.5	1
PCT 1250: Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion (Moderate/Good – Moderate)		0.40	0	54	0
PCT 1783: Red Bloodwood – Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast (Moderate/Good)	Not listed	4.23	0	62.9	0
PCT 1786: Red Bloodwood - Silvertop Ash – Stringybark open forest on ironstone in the Sydney region (Moderate/Good – Good)	EEC (Duffys Forest Ecological Community in the Sydney Basin Bioregion)	0.84	0	69.1	0
PCT 1786: Red Bloodwood - Silvertop Ash – Stringybark open forest on ironstone in the Sydney region (Moderate/Good – moderate)		0.37	0	40.5	0
PCT 1824: Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin (Moderate/Good)	Not listed	6.18	0	66.4	0
PCT 1841: Smooth-barked Apple – Turpentine – Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region (Moderate/Good)	Not listed	1.37	0	65.3	0
PCT 1845: Smooth-barked Apple – Red Bloodwood – Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney (Moderate/Good)	Not listed	0.39	0	78.1	1
Native revegetation	Not listed	1.29	0	37.7	0
Total		**15.27**			**2**

5.1.2 Removal of threatened flora species

Construction of the project would have direct impacts on two threatened flora species listed under the BC Act and EPBC Act. Table 5.2 summarises the impacts to these species.

Species credits are required to offset the impacts to one possibly remnant individual of *Syzygium paniculatum.* The credit requirements are provided in Section 7. No other threatened plant species listed under the BC Act and/or EPBC Act are anticipated to be directly impacted by the project.

Table 5.2 Summary of impacts on threatened flora species

Threatened species	BC Act Status*	EPBC Act Status*	Number of individuals to be removed	Offsets required?
Callistemon linearifolius (Netted Bottle Brush)	V	-	Up to 4 planted individuals – these plants are located on the north-western edge of the exclusion zone to be established along Burnt Bridge Creek.	No. Planted individuals to be impacted by the project are not considered to be of conservation significance and are not assessed further under the BAM.
Syzygium paniculatum (Magenta Lilly Pilly)	E	V	1 remnant individual located at the edge of the eastern boundary of the subject land adjoining the Wakehurst Parkway. The individual is mapped just outside the boundary of the subject land but due to GPS error, may be located within it. It is assumed for the purpose of assessment that this individual would be removed. Up to 4 planted individuals - these plants are located on the north-western edge of the exclusion zone to be established along Burnt Bridge Creek.	Yes (for 1 possibly remnant individual). No (for planted individuals). Planted individuals to be impacted by the project are not considered to be of conservation significance and are not assessed further under the BAM.

*V=Vulnerable, E=Endangered

5.1.3 Removal of threatened fauna species habitat

Around 20.78 hectares of vegetation would be removed for the project. This vegetation consists of:

- 13.98 hectares of native vegetation that meets the definition of a PCT
- 1.29 hectares of native revegetation (assigned to PCT 1841)
- 0.36 hectares of native plantings
- 4.89 hectares of urban exotic/native plantings
- 0.26 hectares of weeds and exotics.

Vegetation that would be removed is primarily located adjacent to the Wakehurst Parkway, within the Flat Rock Drive construction support site (BL2), Balgowlah Golf Course construction support site

(BL10), Wakehurst Parkway south construction support site (BL12) and Wakehurst Parkway east construction support site (BL13).

The removal of native flowering and fruiting trees, shrubs and ground layer vegetation from the subject land would result in the loss of potential foraging and sheltering habitat to a number of threatened fauna species known or considered likely to occur in the subject land. Clearing of vegetation would also result in the loss of two hollow-bearing trees that were identified in the subject land at:

- The northern part of Wakehurst Parkway on the western side (tree contains hollows greater than 20 centimetre diameter)
- The southern end of Wakehurst Parkway within the Wakehurst Parkway south construction support site (BL12).

Ecosystem credits are required to offset the impacts to the threatened fauna ecosystem credit species known or likely to occur in the subject land (Table 5.3); the credit requirements are provided in Section 7.

No threatened species credit fauna species were recorded in the subject land during targeted seasonal surveys. Although fauna species which are listed as both species credit and ecosystem credit species were recorded (Grey-headed Flying-fox, Powerful Owl, Glossy Black-Cockatoo, White-bellied Sea-Eagle, Little Bent-winged Bat and Large Bent-winged Bat), no suitable breeding habitat for these species to which species credits would apply was recorded in the subject land. A Grey-headed Flying-fox camp known at a location in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, about 120 metres from the subject land. Potential impacts from construction noise on the Grey-headed Flying-fox camp are discussed below.

Two threatened species credit fauna species, Eastern Pygmy-possum and Large-eared Pied Bat were previously recorded on the Wakehurst Parkway east construction support site (BL13) in 2018 (DPIE (EES), 2020a). The Large-eared Pied Bat was acoustically recorded 125 metres southeast of the Wakehurst Parkway east construction support site (BL13), during passive Anabat surveys on a single night and the Eastern Pygmy-possum was recorded twice during spotlight surveys targeting Koalas near the subject land east of Wakehurst Parkway in June/July 2021. These species are associated with all PCTs in the subject land adjoining the Wakehurst Parkway. Large-eared Pied Bat is also associated with the PCTs adjoining the Burnt Bridge Creek Deviation. Species polygons were prepared for these species (Figure 3-8). The area of the species polygon for the Eastern Pygmy-possum is around 12.21 hectares and the area of the species polygon for the Large-eared Pied Bat is around 13.51 hectares.

One threatened species credit fauna species, Red-crowned Toadlet, is assumed to occur in the subject land, as the species was previously recorded nearby in similar habitat for the Northern Beaches Hospital road upgrade project (SMEC, 2015). This species is assumed to be present in areas of suitable habitat adjoining the Wakehurst Parkway. Species credit habitat for the Red-crowned Toadlet consists of areas adjoining unnamed and unmapped freshwater watercourses in the north of the subject land. A species polygon was prepared for this species (Figure 3-8). The area of the species polygon for Red-crowned Toadlet within the subject land is around 0.98 hectares.

An additional two threatened species credit fauna species, Southern Brown Bandicoot and Southern Myotis, were not recorded in the subject land, however were considered candidate species due to potential habitat within the subject land. Due to a lack of detection of both species during targeted surveys, they were considered absent from the subject land. Accordingly, species credits are not required to offset impacts on these species.

Table 5.3 Threatened ecosystem credit species with a moderate to high likelihood of occurrence in the subject land

Common name	Scientific Name	BC Act status*	EPBC Act status*	Ecosystem or species credit species	Likelihood of occurrence in subject land	If ecosystem credit, which vegetation zones (PCTs) provide habitat and require offsets
Glossy Black-Cockatoo	*Calyptorhynchus lathami*	V		Ecosystem (foraging) Species (breeding)	High	1250, 1783, 1786, 1824, 1841, 1845
Varied Sittella	*Daphoenositta chrysoptera*	V		Ecosystem	High	1250, 1783, 1786, 1824, 1841, 1845
Spotted-tailed Quoll	*Dasyurus maculatus*	V	E	Ecosystem	Moderate	1250, 1783, 1786 1824, 1841, 1845
Little Lorikeet	*Glossopsitta pusilla*	V		Ecosystem	Moderate	1250, 1783, 1786, 1824, 1841, 1845
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	V		Ecosystem (foraging) Species (breeding)	High	1250, 1783, 1786, 1824
Little Eagle	*Hieraaetus morphnoides*	V		Ecosystem (foraging) Species (breeding)	Low-Moderate	1250, 1783, 1786, 1824, 1841, 1845
Swift Parrot	*Lathamus discolor*	E	CE	Ecosystem (foraging) Species (breeding)	Moderate	1250, 1783, 1786, 1824, 1841, 1845
Square-tailed Kite	*Lophoictinia isura*	V		Ecosystem (foraging) Species (breeding)	Moderate	1250, 1783, 1786, 1824, 1845
Little Bent-winged Bat	*Miniopterus australis*	V		Ecosystem (foraging) Species (breeding)	High	1250, 1783, 1786, 1824, 1841, 1845
Large Bent-winged Bat	*Miniopterus orianae oceanensis*	V		Ecosystem (foraging) Species (breeding)	High	1250, 1783, 1786, 1824, 1841, 1845
Eastern Coastal Free-tailed Bat	*Micronomus norfolkensis*	V		Ecosystem	High	1250, 1783, 1786, 1824, 1841, 1845

Common name	Scientific Name	BC Act status*	EPBC Act status*	Ecosystem or species credit species	Likelihood of occurrence in subject land	If ecosystem credit, which vegetation zones (PCTs) provide habitat and require offsets
Barking Owl	*Ninox connivens*	V		Ecosystem (foraging) Species (breeding)	Moderate	1250, 1783, 1786, 1841, 1845
Powerful Owl	*Ninox strenua*	V		Ecosystem (foraging) Species (breeding)	High	1250, 1783, 1786, 1841, 1845
Eastern Osprey	*Pandion cristatus*	V	M	Ecosystem (foraging) Species (breeding)	Moderate	1250, 1783, 1841
Grey-headed Flying-fox	*Pteropus poliocephalus*	V	V	Ecosystem	Known	1250, 1783, 1786, 1824, 1841, 1845
Yellow-bellied Sheathtail-bat	*Saccolaimus flaviventris*	V		Ecosystem	Low-moderate	1250, 1841, 1845
Masked Owl	*Tyto novaehollandiae*	V		Ecosystem (foraging) Species (breeding)	Moderate	1250, 1783, 1786, 1824, 1841, 1845
Sooty Owl	*Tyto tenebricosa*	V		Ecosystem (foraging) Species (breeding)	Low-moderate	1250, 1824
Rosenberg's Goanna	*Varanus rosenbergi*	V		Ecosystem	Known	1250, 1783, 1786, 1824, 1841

*V=Vulnerable, E=Endangered, CE=Critically Endangered, M=Migratory

5.1.4 Fauna injury and mortality

Terrestrial fauna injury or mortality would occur during vegetation clearing activities (particularly during the felling of trees) or may result from collisions with work vehicles or plant, or accidental entrapment in plant, trenches or other works. Vehicle strike, particularly where construction vehicles would be in operation near tracts of fauna habitat along the Wakehurst Parkway, would not only directly impact the fauna species injured or killed, but would potentially impact predatory species likely to feed on the roadkill. For example, Rosenberg's Goanna has been known to feed on roadkill, and was recorded along the Wakehurst Parkway during field surveys carried out by WSP in 2017. Threatened fauna species with a high likelihood or known occurrence in the subject land could be subject to injury and mortality.

The majority of fauna species recorded within the subject land are highly mobile bird and mammal species and these species are likely to be able to move away from vegetation clearing and other construction activities quite readily. Fauna species susceptible to injury or mortality include less mobile species such as amphibians, reptiles, invertebrates and juvenile/nesting birds/mammals and small mammals. Threatened fauna species that are at highest risk of injury or mortality include:

- Red-crowned Toadlet
- Eastern Pygmy-possum
- Rosenberg's Goanna.

Marine fauna injury or mortality may occur during construction of the crossing of Middle Harbour, or could result from collisions with watercraft or barges carrying out construction within Middle Harbour. This could include the threatened Little Penguin; however, this species typically forages in shallow waters at the shoreline, which the project largely avoids. Middle Harbour is subject to high levels of water traffic and the species may be adapted to avoiding water vessels.

Measures to avoid fauna injury and mortality are described in Section 6.

5.2 Indirect impacts on native vegetation and habitat

Indirect impacts occur when the project or activities relating to the construction or operation of the project affect native vegetation, TECs and threatened species habitat adjoining or outside the subject land. Impacts may also result from changes to land-use patterns, such as an increase in vehicular access and human activity on native vegetation, TECs and threatened species habitat.

Section 9.1.4.2 of the BAM identifies the types of indirect impacts on native vegetation and habitat beyond the subject land that must be considered. The relevance of these types of impacts to the project are provided in Table 5.4. Matters that have been determined to be relevant are considered further in this section.

Table 5.4 Indirect impacts on native vegetation and habitat specified by the BAM

Indirect impact	Relevance to the project
Inadvertent impacts on adjacent habitat or vegetation	Vegetation occurring along the margins of the Wakehurst Parkway could be inadvertently impacted by the realignment and upgrade of Wakehurst Parkway. This impact has been considered further in this section.
Reduced viability of adjacent habitat due to edge effects	All vegetation to be impacted is already subject to edge effects. New edges would be created in native vegetation adjacent to the widened Wakehurst Parkway expanding edge effects into new areas. This impact has been considered further in this section.
Reduced viability of adjacent habitat due to noise, dust or light spill	Noise, vibration, dust and light spill could affect fauna inhabiting vegetation in nearby terrestrial habitats. This impact has been considered further in this section.

Indirect impact	Relevance to the project
Transport of weeds and pathogens from the site to adjacent vegetation	An increase in movements of people and machinery may facilitate the introduction or spread of weeds. This impact has been considered further in this section.
Increased risk of starvation, exposure and loss of shade or shelter	Not relevant. Fauna species using modified habitats within the subject land are highly mobile bird and mammal species and are likely to be able to move away from vegetation clearing and other construction activities quite readily. Fauna habitat to be removed along the less disturbed Wakehurst Parkway is adjacent to intact native vegetation that could be used by less mobile species for relocation during clearing activities.
Loss of breeding habitats	Not relevant. Adjacent vegetated habitats could be used for breeding. However, the project would not result activities/disturbances that could result in a loss of breeding habitat. Potential breeding habitat could be impacted or degraded as a result of edge effects and increased noise, light and dust.
Trampling of threatened flora species	Not relevant. One threatened flora species, *Syzygium paniculatum,* was recorded immediately adjacent to the subject land at Wakehurst Parkway, as a single mature tree. If retained, this tree is unlikely to be trampled. There is some potential habitat for threatened flora in areas adjacent to the project to the east and west of the Wakehurst Parkway; any potential impacts from trampling are likely to be minor and contained to the edge of subject land, where targeted threatened flora surveys by WSP (2018) did not detect any threatened flora species.
Inhibition of nitrogen fixation and increased soil salinity	Not relevant. The project would not inhibit nitrogen fixation in adjacent vegetation communities and the risk of increased soil salinity as a result of the project is low to negligible.
Fertiliser drift	Not relevant. The project would not include use of fertiliser.
Rubbish dumping	Not relevant. The project would not result in increased public access to areas of habitat that could be impacted by rubbish dumping and therefore would not increase the existing likelihood of rubbish dumping. Fauna fencing would be provided along both sides of the Wakehurst Parkway restricting access to native vegetation in this area.
Wood collection	Not relevant. The project would not result in increased public access to areas of native vegetation and therefore would not increase the existing likelihood of wood collection. Fauna fencing would be provided along both sides of the Wakehurst Parkway restricting access to native vegetation in this area.
Bush rock removal and disturbance	Not relevant. The project would not result in increased public access to areas of native vegetation and therefore would not increase the existing likelihood of bush rock removal and disturbance. Fauna fencing would be provided along both sides of the Wakehurst Parkway restricting access to native vegetation in this area.
Increase in predatory species populations	Not relevant. Predatory species in the locality of the project are most likely to be domesticated pets and foxes, and the project would not result in increase to these populations.
Increase in pest animal populations	Low but not considered to be relevant. The subject land is in a highly urbanised area, and the project is unlikely to increase the population of any pest animals.
Increased risk of fire	Not relevant.

Indirect impact	Relevance to the project
Disturbance to specialist breeding and foraging habitat, eg beach nesting for shorebirds.	Not relevant. No areas of specialist breeding and foraging habitat have been identified within the subject land.

5.2.1 Inadvertent impacts on adjacent native vegetation and habitat

Native vegetation occurring along the margins of the Wakehurst Parkway could be inadvertently impacted by the widening of the Wakehurst Parkway. Indirect impacts to this vegetation could include the introduction and spread of weeds, soil disturbance and trampling, though impacts are likely to be minor and contained to the edge of subject land.

5.2.2 Reduced viability of adjacent habitat due to edge effects

The project would result in indirect impacts to some areas of native vegetation adjoining the subject land, mainly due to fragmentation of vegetation and creation of new edges, which may result in edge effects.

Most of the subject land adjoins small, fragmented areas of vegetation within urban areas. This vegetation is often already situated adjacent to an existing cleared edge, such as a road, and is subject to ongoing disturbance and edge effects.

Larger areas of native vegetation occur to the east and west of the Wakehurst Parkway, in Manly Warringah War Memorial State Park and Garigal National Park, respectively. The vegetation occurring along the margins of the Wakehurst Parkway is currently subject to edge effects, including weed incursion at the road margin and fragmentation by bicycle and walking tracks on both sides of the road. The realignment and upgrade of Wakehurst Parkway would result in additional edge effects in some areas through the creation of new edges in previously undisturbed vegetation.

The extent of the existing edge effects in native vegetation adjoining the Wakehurst Parkway was assessed based on site inspection of areas within 50 metres of the subject land and supported by collection of data from 10 vegetation condition transects (Figure 5-1, Figure 5-2). This assessment found that edge impacts such as increased weed cover and reduced native ground and shrub cover are largely limited to the area within 20 metres of the road edge.

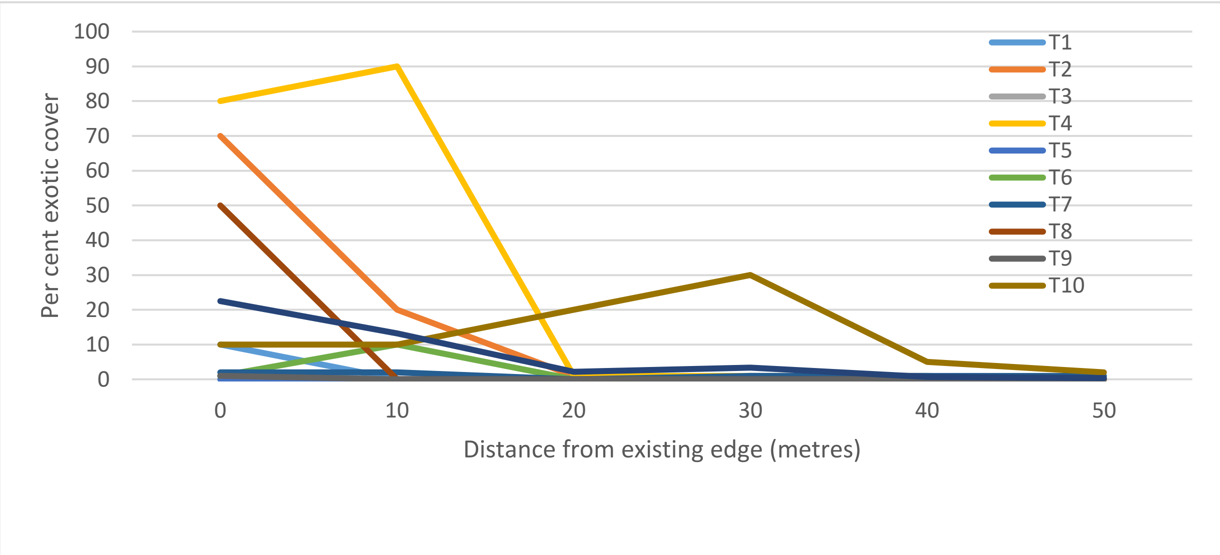


Figure 5-1 Per cent exotic vegetation cover recorded over distance from existing edge in vegetation condition transects

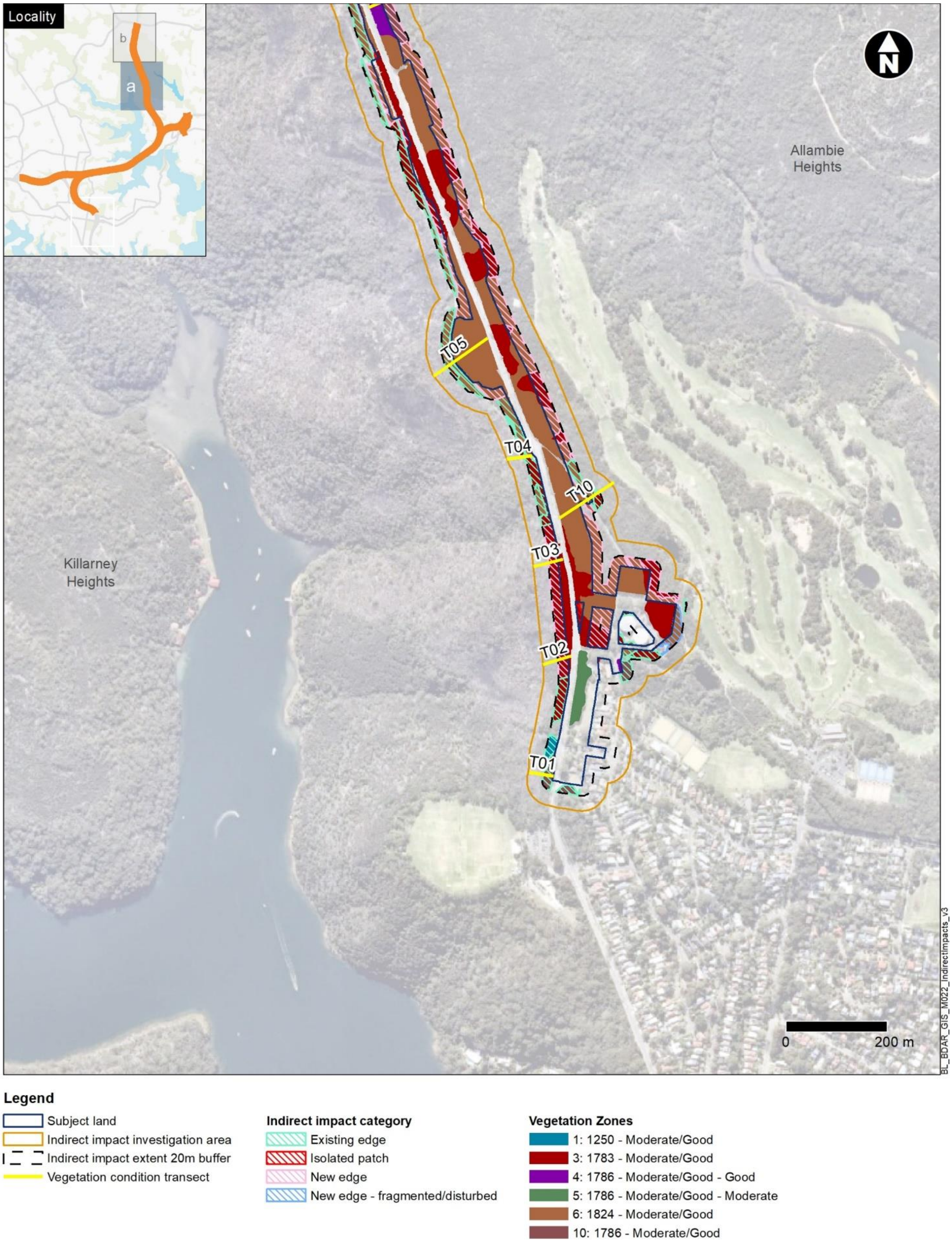


Figure 5-2 Indirect impacts to native vegetation adjoining the Wakehurst Parkway (map a)

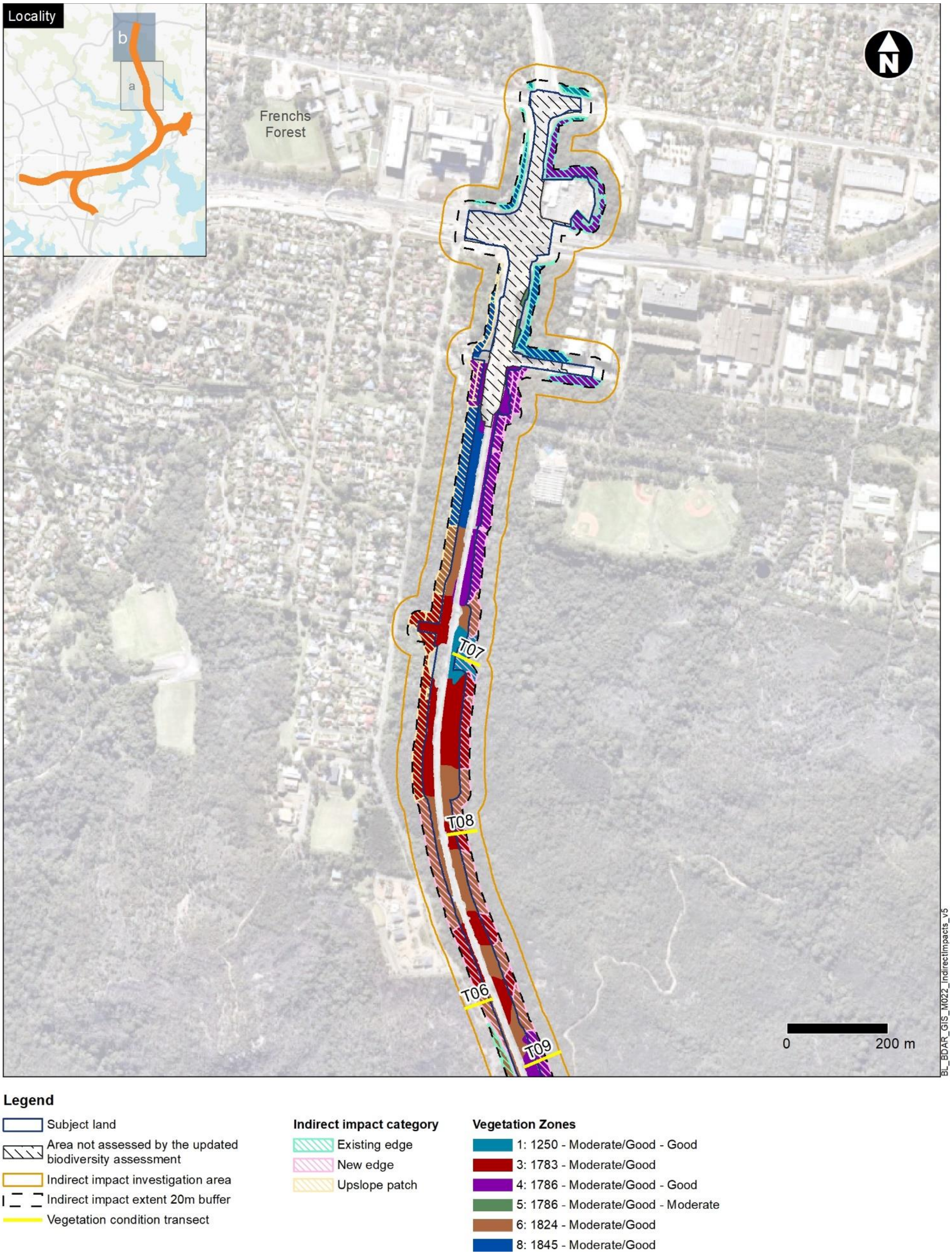


Figure 5-2 Indirect impacts to native vegetation adjoining the Wakehurst Parkway (map b)

Based on the assessment of existing edge effects, the project could result in impacts from the formation of new edges extending up to 20 metres from the subject land.

A 20 metre buffer was applied from the edge of the subject land and an analysis of native vegetation mapped within the buffer zone was conducted. The analysis focused on the potential for edge effects such as changes to vegetation structure, increase in exotic species cover and alteration of microhabitats to occur within the buffer zone as a result of the project. Five categories for potential edge effects were determined, as listed in Table 5.5 and mapped in Figure 5-2.

Table 5.5 Potential for edge effects in vegetation within 20 metres of the subject land adjoining the Wakehurst Parkway

Category	Description	Area of native vegetation within 20 m buffer (ha)	Potential for indirect impacts
Isolated patches	Small fragments of vegetation (<0.25 ha) within the buffer, previously part of larger patches, left between gaps in the construction footprint or adjacent to other permanent disturbance. These vegetation fragments are considered no longer likely to be viable in the long term.	0.06	Likely
Existing edge	Vegetation edge adjoins, only slightly overlaps (ie 1-2 metres of overlap) or is set back from the construction footprint; the existing edge effects within these patches are unlikely to increase.	3.62	Unlikely
New edge in fragmented and/or disturbed vegetation	Vegetation in any condition within the patch is less than 50 metres wide and/or is currently fragmented and disturbed with modified structure and high exotic cover, therefore new edges are unlikely to result in substantial alteration to these areas of vegetation.	0.15	Unlikely
New edge in un-fragmented and undisturbed vegetation	Vegetation patch in moderate to good condition that will be fragmented by the construction footprint to form one or more new edges within previously unfragmented vegetation that extends over 50 metres from the edge of the construction footprint.	8.26	Likely
New edge in upslope vegetation	Vegetation patch in moderate to good condition lies upslope of the construction footprint (adjoining areas of cut).	1.99	Unlikely

The analysis of potential for edge effects found:

- A total of 0.06 hectares of native vegetation would be subject to increased edge effects to the extent they would become unviable due to the small size and isolation of the remaining patches
- A total of 8.26 hectares of native vegetation would be subject to increased edge effects as a result of the project due to the creation of one or more new edges within previously unfragmented vegetation. These new edges could be subject to degradation by the establishment and spread of weeds, enriched runoff from road pavement and dumping of rubbish. However, the project would include the provision of drainage infrastructure that would appropriately manage surface water flows. Fauna fencing to be installed along the Wakehurst Parkway would likely prevent the dumping of rubbish along the roadside.

Of the 8.32 hectares of vegetation subject to edge effects, about 1.26 hectares meet the criteria for the BC Act listed Duffys Forest TEC. There are no areas of indirect impact that meet the criteria for any the EPBC Act listed TEC. The indirect impacts of the project on native vegetation are detailed in Table 5.6. Offsets for these impacts are considered in Section 7.

Table 5.6 Native vegetation subject to indirect impacts (potential edge effects)

Impact category	PCT name	Vegetation zone	Area of indirect impacts (ha)
Isolated patches	PCT 1783: Red Bloodwood – Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	1783 Moderate/Good	0.05
	PCT 1824: Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	1824 Moderate/Good	0.01
Total isolated patches			**0.06**
New edge in un-fragmented and undisturbed vegetation	PCT 1250: Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	1250 Moderate/Good	0.22
	PCT 1783: Red Bloodwood – Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	1783 Moderate/Good	2.59
	PCT 1786: Red Bloodwood - Silvertop Ash – Stringybark open forest on ironstone in the Sydney region (Duffys Forest TEC)	1786 Moderate/Good	1.26
	PCT 1824: Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	1824 Moderate/Good	4.20
Total new edges			**8.26**
Grand total			**8.32**

5.2.3 Reduced viability of adjacent habitat due to noise, dust or light spill

Construction activities would result in localised and temporary noise and vibration impacts, however as most construction areas occur in highly urbanised areas that are subject to ambient noise, this increase in noise and vibration is not expected to have a significant impact on native fauna.

Construction activities (specifically, modifications to surface roads) may impact the viability of adjacent habitat at two locations within the subject land; along the Wakehurst Parkway and at Balgowlah. These locations are discussed in further detail below.

5.2.3.1 Wakehurst Parkway surface road works

The realignment and upgrade of the Wakehurst Parkway may indirectly affect threatened fauna species that have been previously recorded in adjacent native vegetation, including:

- Red-crowned Toadlet
- Eastern Pygmy-possum
- Large Bent-winged Bat
- Little Bent-winged Bat
- Large-eared Pied Bat
- Grey-headed Flying-fox
- Powerful Owl

- Eastern Coastal Free-tailed Bat
- Southern Myotis
- Rosenberg's Goanna
- Glossy Black-Cockatoo.

Construction activities including the realignment and upgrade of the Wakehurst Parkway around the cut and cover and trough structures of the ramp tunnels and widening of the Wakehurst Parkway, and establishment and operation of construction support sites, could result in noise, vibration, light spill and dust impacts on adjacent habitat throughout the duration of construction. Excavation along the Wakehurst Parkway is required (eg at cuttings) and would require the use of rock-hammers. Controlled blasting has also been identified as an opportunity in a few selected locations as an alternative to rock-hammers to minimise the duration of excavation. This alternative methodology would be investigated during further design development.

Both methods would produce high levels of noise and vibration. The typical sound power level of rock hammering is 118 dB(A) (Renzo Tonin and Associates, 2020). This is about 90 dB(A) at a distance of 10 metres (noisetools.net/noisecalculator2). For reference, human perception of various sound levels be can be found at www.yourhome.gov.au/housing/noise-control.

Blasting would be carried out such that it conforms with noise criteria in *AS 2187.2-2006 Explosives—Storage and use* (Standards Australia, 2006) at nearby sensitive receivers as shown in Table 5.7 and Table 5.8. Test blasts would be conducted to determine the explosive charge needed to stay within this criteria. Any blasting in proximity to nearby sensitive receivers is likely to be of a lower charge and impact.

Table 5.7 Recommended airblast limits for human comfort (Australian Standard, 2006)

Category	Type of blasting operations	Peak sound pressure level (dBL)
Sensitive site*	Operations lasting longer than 12 months or more than 20 blasts	115 dBL for 95 per cent blasts per year 120 dBL maximum unless agreement is reached with occupier that a higher limit may apply
Sensitive site*	Operations lasting for less than 12 months or less than 20 blasts	120 dBL for 95 per cent blasts 125 dBL maximum unless agreement is reached with occupier that a higher limit may apply
Occupied non-sensitive sites, such as factories and commercial premises	All blasting	125 dBL maximum unless agreement is reached with the occupier that a higher limit may apply. For sites containing equipment sensitive to vibration, the vibration should be kept below manufacturer's specifications or levels that can be shown to adversely affect the equipment operation

*A sensitive site includes houses and low rise residential buildings, theatres, schools, and other similar buildings occupied by people

Table 5.8 Recommended airblast limits for damage control (Australian Standard, 2006)

Category	Type of blasting operations	Peak sound pressure level (dBL)
Structures that include masonry, plaster and plasterboard in their construction and also unoccupied structures of reinforced concrete or steel construction	All blasting	133 dBL maximum unless agreement is reached with the owner that a higher limit may apply
Service structures, such as pipelines, powerlines and cables located above the ground	All blasting	Limit to be determined by structural design methodology

Fauna can be sensitive to elevated noise, altering their behaviour and impacting their physiology (Cumberland Ecology, 2013). Rock hammering and blasting have potential to impact fauna inhabiting vegetation and rocky habitat adjacent to the Wakehurst Parkway.

Noise from rock hammering and blasting may affect fauna differently due to nature of each activity and associated acoustic characteristics (ie amplitude and frequency). However, the use of blasting as an alternative methodology would minimise the duration of excavation, reducing noise and vibration exposure periods for fauna and shorten the overall duration of works in the area.

Fauna may initially desert the immediate area at the start of excavation activities due to increased noise and vibration levels. Native vegetation and rocky habitats in the adjacent Garigal National Park and Manly Warringah War Memorial State Park would provide refuge for any displaced individuals with mobility. Fauna could then gradually reinhabit, potentially developing a tolerance to the high noise levels during construction. Folchi (2003) suggests the time for reoccupation following blasting is weeks to months. However, due to the extent of adjoining habitat, the initial displacement from the immediate area could become permanent. For less mobile species or breeding individuals, the effects of the high noise levels may be more acute.

Measures have been included in Section 6 to manage potential noise and vibration impacts including the development of activity-specific management measures for Large-eared Pied Bat due to the proximity of potential roost habitat. Noise and vibration-intensive works such as rock hammering and blasting would be managed by the implementation of standard management and environmental management measures as outlined in Beaches Link and Gore Hill Freeway Connection Technical working paper: Noise and vibration (Renzo Tonin and Associates, 2020).

5.2.3.2 Balgowlah surface road works

Upgrade and integration works at Balgowlah may indirectly impact the Grey-headed Flying-fox camp located 120 metres from the subject land, as Grey-headed Flying-foxes roosting in the camp during the day may be affected by construction noise. Surface road works at Balgowlah that may impact biodiversity includes:

- Construction of portals within the Burnt Bridge Creek Deviation, realignment and widening to the east of the Burnt Bridge Creek Deviation
- Construction of a new access road between Burnt Bridge Creek Deviation and Sydney Road
- A localised adjustment of the Burnt Bridge Creek
- Retaining walls to support cut rock faces and retain fill embankments
- Relocation of existing utilities impacted by the project at various locations where surface works are required
- Establishment and operation of Kitchener Street (BL11) construction support site.

Grey-headed Flying-foxes would be most sensitive to construction noise during daytime hours (ie during standard construction hours) when they are roosting in the camp, and particularly during the months of August to February:

- During August, females are reaching the end of their gestation period and have been known to abort young when stressed

- During September to November, the females have given birth and are lactating. Stressed females have been known to drop young during this period. Stressed young are also at risk of falling to the ground which could result in starvation, predation and death
- In December, juveniles are easily stressed which could result in falling to the ground
- During January to February, Grey-headed Flying-foxes are prone to heat stress. During this time, additional potential stressors such as noise can increase the likelihood of an individual falling from a tree due to heat stress.

Grey-headed Flying-foxes may not be so sensitive to construction noise at night time (ie related to construction activities proposed to occur outside of standard construction hours), as most individuals would be engaging in nocturnal foraging activities throughout the surrounding locality.

An assessment of airborne noise impacts from the surface road works and construction supports site related activities at Balgowlah has been carried out in Beaches Link and Gore Hill Freeway Connection Technical working paper: Noise and vibration (Renzo Tonin and Associates, 2020). Based on the results in this technical working paper, Renzo Tonin and Associates provided predicted construction airborne noise levels at the Grey-headed Flying-fox camp (Table 5.9).

Noise monitoring was carried out about 300 metres east of Grey-headed Flying-fox camp, at a location adjacent to the Burnt Bridge Creek Deviation road corridor, to determine existing noise levels (ie without construction). Road traffic noise dominated the existing environment, with ambient day time noise levels of 54 dB(A) on a representative weekday and 52 dB(A) on a representative weekend being recorded.

A summary of construction activities that would occur near the camp and their predicted noise levels at the camp is provided in Table 5.9.

Table 5.9 Construction activities that would occur near the Grey-headed Flying-fox camp and their predicted noise levels

Location	Key noise-generating construction activities	$L_{Aeq\ 15\ minute}$ dB(A) construction noise level during standard construction hours	
		Typical*	Worst case#
Burnt Bridge Creek Deviation surface works (northbound)	Demolition (rock hammering)	55	67
Burnt Bridge Creek Deviation surface works (southbound)	Demolition (rock hammering)	56	68
Trough works	Paving/asphalting/road works (including road saws)	33	42
Cut and cover portal works	Paving/asphalting/road works (including road saws)	32	41
Access road within Balgowlah Golf Course	Paving/asphalting/road works (including road saws)	<30	38
Access road intersection works at Burnt Bridge Creek Deviation	Utilities modification works	<30	38
Sydney Road roadworks	Mobilisation/demobilisation and site setup	<30	37

Location	Key noise-generating construction activities	$L_{Aeq\ 15\ minute}$ dB(A) construction noise level during standard construction hours	
		Typical*	Worst case#
Kitchener Street construction support site	Deliveries (oversized)	57	57

***Typical** is during the typical loud activities (eg vacuum truck operating)
#**Worst case** is during the worst case loud activities (eg rock hammering or road saws in use)

Best practice guidelines for the Grey-headed Flying-fox (DECC, 2008a) state that absolutely no work activities should be conducted (loud or quiet) in 'close proximity' to a camp between the months of September to February. What distance comprises 'close proximity to a camp' is not defined by the guidelines. The *Balgowlah Grey-headed Flying-fox Camp Management Plan* (Ecosure, 2016) states that bushland restoration activities within the camp (including the use of power tools such a chainsaws) can be carried out between September and February in the evening, after the Grey-headed Flying-foxes fly out of the camp to forage for the night, or during the day with a 'suitably qualified person' monitoring Grey-headed Flying-fox behaviour, who has the authority to stop works (if required).

Construction noise levels associated with the surface road works at Balgowlah would exceed typical noise levels of bushland restoration activities described by Ecosure (2016), but no construction activities for the project would be carried out within or immediately adjacent the camp itself. The assessment of airborne noise impacts at Balgowlah determined that typical noise levels of key noise-generating construction activities during the day would be similar to, or less than, noise levels generated by existing day time road traffic noise on the Burnt Bridge Creek Deviation. That is, typical noise levels of key noise-generating construction activities listed in Table 5.9 are less than, or similar to, the ambient day time noise levels of 53.6 dB(A) (on a representative weekday) and 52.4 dB(A) (on a representative weekend) that were recorded near the camp.

Construction noise levels from the establishment and operation of the construction support site at Balgowlah Golf Course (BL10), including the construction of the new open space and recreation facilities, are predicted to be less than the existing ambient day time noise levels in the vicinity of the camp, which is dominated by road traffic noise from Burnt Bridge Creek Deviation. The highest predicted construction noise level is 49 dB(A) $L_{Aeq\ 15\ minute}$, predicted to occur during the establishment of the site.

Grey-headed Flying-foxes occupying the Balgowlah camp appear to be accustomed to background traffic noise and have persisted at the camp despite regular maintenance of the gross pollutant trap (GPT) directly near core roosting habitat (Ecosure, 2016). Accordingly, typical noise levels of key noise-generating construction activities during the day are not anticipated to adversely impact the Grey-headed Flying-fox camp.

Some noise-generating construction activities are predicted in worst case to exceed existing day time road traffic noise levels on the Burnt Bridge Creek Deviation, as identified in Table 5.9. These activities include:

- Burnt Bridge Creek Deviation surface works (northbound)
- Burnt Bridge Creek Deviation surface works (southbound)
- Kitchener Street construction support site (BL11).

However, reasonable and feasible noise management measures would be implemented when construction activities are occurring near the Grey-headed Flying-fox camp, as outlined in Section 6.

5.2.4 Transport of weeds and pathogens from the site to adjacent vegetation

An increase in the movement of people, vehicles, machinery, vegetation waste and soil during and following construction activities may facilitate the introduction or spread of weeds. Disturbed areas, such as those in which earthworks are to be carried out, including the realignment and upgrade of the Wakehurst Parkway would be particularly susceptible to weed establishment due to earthworks carried out in widening the road. Temporary construction areas around Flat Rock Reserve would also be highly susceptible to weed establishment. Other areas such as the Gore Hill Freeway would also be susceptible, however as these areas are highly urbanised, with little to no native vegetation, the spread of weeds is of lower risk. Even so, management measures would be required to minimise the risk of introduction and spread of weeds.

The project has the potential to increase the spread of pathogens that threaten native biodiversity values, such as the soil-borne pathogen Phytophthora (*Phytophthora cinnamomi*). Phytophthora infects roots and is associated with damage and death to native plants. It may be dispersed over large distances in flowing water, such as storm runoff, or may be spread within a site via mycelial growth from infected roots to roots of healthy plants. Propagules of Phytophthora may also be dispersed by vehicles (eg cars and earth moving equipment), animals, walkers and movement of soil. It is listed as a Key Threatening Process (defined as a process which threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community) under BC Act. There may be an increased risk of dispersal of Phytophthora as a result of the construction activities that involve soil disturbance.

5.3 Serious and Irreversible Impacts

The OEH (2017c) *Guidance to assist a decision-maker to determine a serious and irreversible impact* identifies threatened species and ecological communities most at risk of serious and irreversible impacts.

5.3.1 Duffys Forest Ecological Community in the Sydney Basin Bioregion

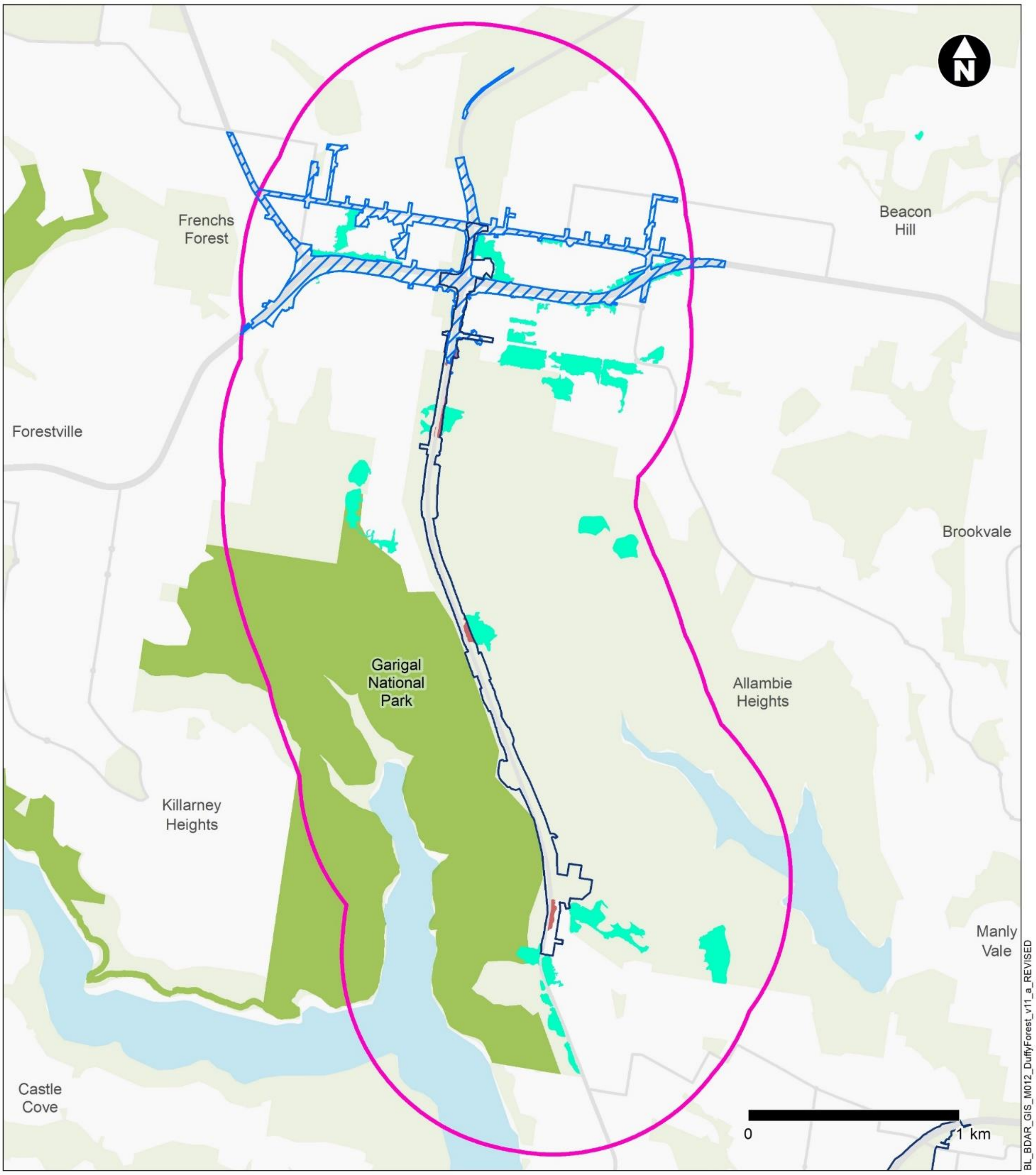
One TEC at risk of a serious and irreversible impact was identified by the BAM credit calculator: Duffys Forest Ecological Community in the Sydney Basin Bioregion (hereafter referred to as Duffys Forest TEC), listed as an EEC under the BC Act. To assist the consent authority to evaluate the nature of an impact on a potential entity at risk of a serious and irreversible impact, the Biodiversity development assessment report must contain details of the assessment of serious and irreversible impact, in accordance with the assessment criteria set out in Section 10.2 of the BAM. The information provided in Table 5.10 is required by the BAM to be provided for potential ecological communities.

Table 5.10 Serious and Irreversible Impact Assessment for Duffys Forest TEC

Assessment requirement	Assessment
(a) the action and measures taken to avoid the direct and indirect impact on the potential entity for an Serious and Irreversible Impact	Impacts to Duffys Forest TEC have been minimised through the design process during preparation of the environmental impact statement, with the footprint adjusted to minimise impacts to areas of Duffys Forest TEC adjoining the southern end of the Wakehurst Parkway. As noted above in Section 4, since the exhibition of the environmental impact statement Transport for NSW has refined the design for the new shared user bridge in the northern extent of the project footprint. The design refinement has reduced the area of Duffys Forest TEC that would be impacted by the project from 1.38 hectares to 1.21 hectares.
(b) the area (ha) and condition of the threatened ecological community to be impacted directly and indirectly by the	Construction of the project would require the removal of 1.21 hectares of Duffys Forest TEC. The areas of TEC to be removed adjoin the Wakehurst Parkway between Killarney

Assessment requirement	Assessment
proposed development. The condition of the endangered ecological community is to be represented by the vegetation integrity score for each vegetation zone	Heights and Frenchs Forest. An additional area of 1.26 hectares would be subject to indirect impacts. The vegetation integrity score of the areas of Duffys Forest TEC to be directly and indirectly impacted varies from 69.1 for the 0.84 hectares of the TEC in good condition, to 40.5 for the 0.37 hectares of the TEC in moderate condition.
(c) a description of the extent to which the impact exceeds the threshold for the potential entity that is specified in the Guidance to assist a decision-maker to determine a serious and irreversible impact	There is currently no threshold for Duffys Forest TEC specified in the Department of Planning, Industry and Environment (Environment, Energy and Science) guidance, nor in the Threatened Biodiversity Data Collection. The webpage for Serious and irreversible impacts (Department of Planning, Industry and Environment (Environment, Energy and Science), 2020) states that thresholds have not been assigned to any TEC, and that in the absence of thresholds, the consent authority can disregard references to considering thresholds in the Department of Planning, Industry and Environment (Environment, Energy and Science) guidance when making their determination.
(d) the extent and overall condition of the potential threatened ecological community within an area of 1000 hectares, and then 10,000 hectares, surrounding the proposed subject land	For this assessment, the 'proposed subject land' is limited to the area of the subject land on and adjoining the Wakehurst Parkway. The Wakehurst Parkway section of the subject land is at the southern extent of the distribution of the Duffys Forest TEC. Based on OEH (2016) mapping with additional aerial photograph review, and excluding areas within the subject land and the areas impacted by the Northern Beaches Hospital road upgrade project and to be impacted by the Mona Vale Road West Upgrade project), there is 28.92 hectares of Duffys Forest TEC mapped within an area of 1000 hectares (refer to Figure 5-3 and around 59.31 hectares of Duffys Forest TEC mapped within an area of 10,000 hectares surrounding the subject land (refer to Figure 5-4). The removal of 1.21 hectares of Duffys Forest TEC represents a reduction of 4 per cent of the area of the TEC within 1000 hectares, and 2 per cent of the area of the TEC within 10,000 hectares. It should be noted that while the assessment of serious and irreversible impacts in accordance with the Biodiversity Assessment Method (OEH, 2017b) does not require consideration of areas future impacts, the area of Duffys Forest TEC to be cleared as part of the Mona Vale Road West Upgrade project has been included for completeness.
(e) an estimate of the extant area and overall condition of the potential threatened ecological community remaining in the IBRA subregion before and after the impact of the proposed development has been taken into consideration	There is a total of 359.63 hectares of Duffys Forest TEC mapped within the Pittwater IBRA subregion (based on OEH (2016) mapping with additional aerial photograph review, and excluding areas within the subject land and the areas impacted by the Northern Beaches Hospital road upgrade project and Mona Vale Road West upgrade project) (refer to Figure 5-4). Together with the 1.21 hectares of Duffys Forest mapped in the subject land, a total of 360.84 hectares of the TEC has been identified in the Pittwater IBRA subregion. Given that the Duffys Forest TEC only occurs within the Pittwater IBRA subregion, this figure also represents the total area of Duffys Forest TEC remaining in NSW. The removal of 1.21 hectares of Duffys Forest TEC represents a reduction of 0.34 per cent of the area of the TEC in the

Assessment requirement	Assessment
	Pittwater IBRA subregion. Following the removal of 1.21 hectares of Duffys Forest TEC for the project, the total area remaining would be 359.63 hectares.
(f) an estimate of the area of the potential threatened ecological community that is in the reserve system within the IBRA region and the IBRA subregion	Of the total of 359.63 hectares of Duffys Forest TEC mapped within the Pittwater IBRA subregion (based on OEH (2016) mapping with additional aerial photograph review, and excluding areas within the subject land and the areas impacted by the Northern Beaches Hospital road upgrade project and Mona Vale Road West Upgrade project), 155.04 hectares (43 per cent) is located within Garigal and Ku-ring-gai National Parks.
(g) the development, clearing or biodiversity certification proposal's impact on: (i) abiotic factors critical to the long-term survival of the potential threatened ecological community; for example, how much the impact will lead to a reduction of groundwater levels or the substantial alteration of surface water patterns (ii) characteristic and functionally important species through impacts such as, but not limited to, inappropriate fire/flooding regimes, removal of understorey species or harvesting of plants (iii) the quality and integrity of an occurrence of the potential threatened ecological community through threats and indirect impacts including, but not limited to, assisting invasive flora and fauna species to become established or causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants which may harm or inhibit growth of species in the potential threatened ecological community	The project may result in water table drawdown beneath patches of Duffys Forest TEC adjoining the Wakehurst Parkway to the east and south of Seaforth Oval. Groundwater modelling for the project has predicted up to three to five metres of water table drawdown beneath these patches of Duffys Forest (by 2027 and 2128 respectively) (Jacobs, 2020b). The Duffys Forest TEC is not considered to be a groundwater dependent ecosystem and would likely only draw on groundwater opportunistically during periods of low rainfall. Further to the above, revised groundwater drawdown modelling has been conducted following exhibition of the environmental impact statement (refer to Annexure G). The findings of the revised groundwater modelling and impact assessments are consistent with and confirmed the findings of Jacobs (2020b). Unmanaged construction activities along the Wakehurst Parkway could result in alteration of surface water patterns allowing soil erosion, siltation and off-site movement of eroded sediments into adjacent areas of the endangered ecological community. However, standard controls would be installed before and maintained throughout the construction period to prevent these impacts. Vegetation occurring along the margins of the Wakehurst Parkway is currently subject to edge effects, and the widening of the road would expand edge effects into new areas. The new edge could be subject to degradation by the establishment and spread of weeds, enriched runoff from road pavement and dumping of rubbish. Management measures would be implemented to minimise the risk of introduction and spread of weeds.
(h) direct or indirect fragmentation and isolation of an important area of the potential threatened ecological community	The Duffys Forest TEC in the subject land is currently fragmented by the existing Wakehurst Parkway and adjoining areas of residential development. The project would result in some increases to the existing fragmentation as a result of the widening of the Wakehurst Parkway. The gap in native vegetation created by the existing Wakehurst Parkway ranges from 10 to 15 metres in the vicinity of patches of Duffys Forest TEC. This gap would increase to 40 to 45 metres across most of the Wakehurst Parkway, and about 60 metres in the northernmost extent of the project.
(i) the measures proposed to contribute to the recovery of the potential threatened ecological community in the IBRA subregion.	The 1.21 hectares of Duffys Forest TEC to be removed would be offset in accordance with the Biodiversity Offsets Scheme.



Legend

- Subject land
- NPWS Estate (OEH, 2018)
- IBRA subregion (DOE, 2014)
- Area within 1,000 ha of the Wakehurst Parkway section of the subject land
- Area impacted by the Northern Beaches Hospital road upgrade project
- Duffys Forest endangered ecological community ground-truthed in the subject land
- Duffys Forest endangered ecological community mapped by OEH (2016) (excluding areas mapped within the subject land and impacted by the Northern Beaches Road Upgrade

Figure 5-3 Duffys Forest TEC extent within 1,000 hectares of the subject land

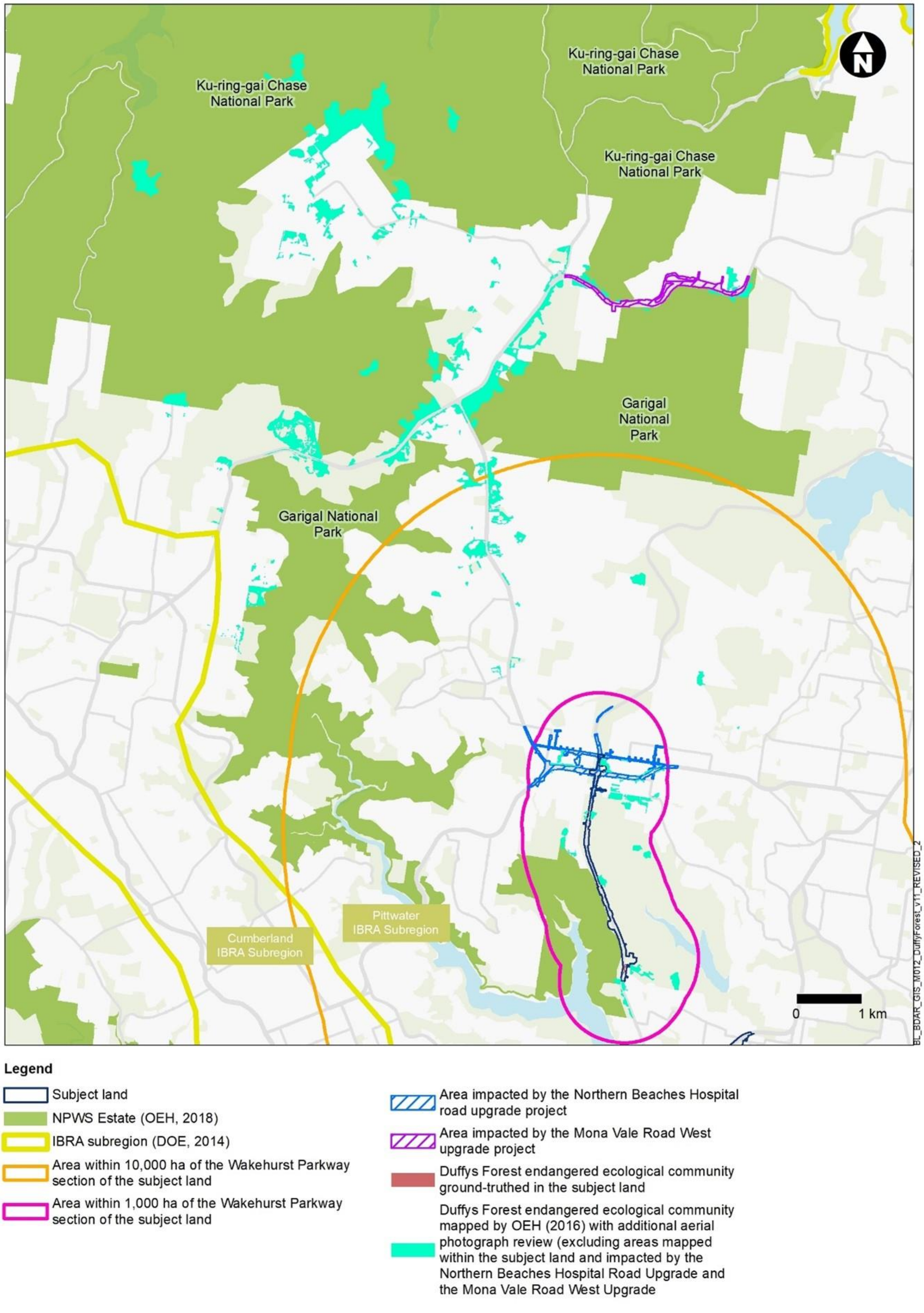


Figure 5-4 Duffys Forest TEC extent in the Pittwater IBRA subregion

5.3.2 Large-eared Pied Bat, Large Bent-winged Bat and Little Bent-winged Bat

Three threatened species at risk of a serious and irreversible impact were recorded in the subject land during targeted surveys or from recent database searches: Large-eared Pied Bat, Large Bent-winged Bat and Little Bent-winged Bat. OEH (2017b) specifies that for these three species, only breeding habitat is subject to assessment to determine serious and irreversible impacts.

Breeding habitat for Large Bent-winged Bat consists of maternity caves that females migrate to in summer. Only three maternity caves are known in NSW and no such caves are located in the subject land. Similarly, Little Bent-winged Bats form maternity colonies in summer, often formed in association with Large Bent-winged Bats (DPIE (EES), 2020d). Only five maternity colonies are known in Australia, and these are not within the subject land.

As the subject land and 100 metre buffer does not support breeding habitat for Large Bent-winged Bat and Little Bent-winged Bat there is no risk of serious and irreversible impacts to these species.

For the purposes of serious and irreversible impact assessment, breeding habitat for the Large-eared Pied Bat is considered present on the subject land if there is (OEH, 2018a):

- Potential breeding habitat, and
- Breeding individuals.

In accordance with *'Species credit' threatened bats and their habitats – NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a), potential breeding habitat is defined as breeding habitat on or within 100 metres of the subject land and the area immediately surrounding the feature. The subject land does not contain habitat features likely to be suitable for breeding. Rocky features of the subject land were inspected during field surveys (WSP, 2018) and no evidence of microbat use was found. Though there is potential breeding habitat within 100 metres of the subject land (Figure 2-6), surveys carried out in accordance with the guidelines failed to detect any breeding individuals. As such, the species is not considered at risk of a serious and irreversible impact.

5.4 Prescribed biodiversity impacts

Clause 6.1 of the NSW Biodiversity Conservation Regulation 2017 identifies actions that are prescribed as impacts to be assessed under the Biodiversity Offsets Scheme. Prescribed biodiversity impacts must be assessed in accordance with Section 9.2 of the BAM.

The prescribed biodiversity impacts in the BAM and their relevance to the project are listed in Table 5.11.

Table 5.11 Prescribed biodiversity impacts specified by the BAM

Prescribed biodiversity impact (BAM)	Relevance to current project
Impacts of development on the habitat of threatened species or ecological communities associated with karst, caves, crevices, cliffs and other features of geological significance	Not relevant– no karst, caves, crevices, cliffs or other features of geological significance in the subject land.
Impacts of development on the habitat of threatened species or ecological communities associated with rocks	Relevant – rock outcrops occur within and next to the subject land. Direct and indirect impacts of the project may adversely impact fauna species that occur in association with rocky habitats, where such habitats would be removed or are located near surface works, such as Large-eared Pied Bat, Red-crowned Toadlet and Rosenberg's Goanna. Refer to Section 5.4.1 for further detail.

Prescribed biodiversity impact (BAM)	Relevance to current project
Impacts of development on the habitat of threatened species or ecological communities associated with human made structures	Relevant – human made structures occur within and next to the subject land. Human made structures such as culverts beneath surface roads and bridges, offer potential roosting habitat to locally occurring threatened microbat species. Direct and indirect impacts of the project may adversely affect threatened fauna species that could utilise these human made structures. Refer to Section 5.4.2 for further details.
Impacts of development on the habitat of threatened species or ecological communities associated with non-native vegetation	Relevant – non-native vegetation occurs within and next to the subject land, as described in Section 3.7.1. Trees and shrubs associated with non-native vegetation offers foraging, nesting and sheltering habitat to locally occurring threatened birds, arboreal mammals and Grey-headed Flying-fox. The removal of non-native vegetation from the subject land may have direct and indirect impacts on these threatened species. Refer to Section 5.4.3 for further details.
Impacts of development on the connectivity of different areas of habitat of threatened species that facilitates the movement of those species across their range	Relevant – while areas of habitat within and adjoining the subject land are currently fragmented by linear infrastructure and residential and commercial development, the proposal will increase this existing fragmentation, mainly where the Wakehurst Parkway would be widened from two lanes to a four lane dual carriageway. This increase in habitat fragmentation may adversely affect the movement patterns of a number of threatened terrestrial fauna species, including Rosenberg's Goanna, Eastern Pygmy-possum, Red-crowned Toadlet and Southern Brown Bandicoot. Refer to Section 5.4.4 for further details.
Impacts of the development on movement of threatened species that maintains their life cycle	
Impacts of development on water quality, water bodies and hydrological processes that sustain threatened species and TECs	Relevant – turbidity and sedimentation of open water within Middle Harbour and its bays could potentially arise from dredging and piling activities, particularly for construction of the Middle Harbour crossing. Unmanaged construction activities near watercourses could increase levels of turbidity and sediment deposition, decrease dissolved oxygen, and change pH levels in receiving environments. Refer to Section 5.4.5 for further details.
Impacts of wind turbine strikes on protected animals	Not relevant – Wind turbines are not proposed as part of this project.
Impacts of vehicle strikes on threatened species of animals or on animals that are part of a TEC	Relevant – the project involves the widening of roads near large tracts of fauna habitat, such as the realignment and upgrade of the Wakehurst Parkway where it adjoins Garigal National Park. Threatened terrestrial fauna species that attempt to cross these widened roads, such as Rosenberg's Goanna and Southern Brown Bandicoot, may be more susceptible to vehicle strike, as they move between areas of habitat on either side of the road to obtain food, shelter, and breeding resources, and to disperse from natal areas or carry out seasonal migrations. No animals that are part of a TEC are located within or near the subject land. Refer to Section 5.4.6 for further details.

5.4.1 Impacts of development on habitat of threatened species or ecological communities associated with rocks

A number of threatened species or ecological communities known and considered likely to occur within the subject land are associated with rocky habitats (Table 5.12). Hawkesbury Sandstone bedrock and boulders were identified at the Burnt Bridge Creek and along the Wakehurst Parkway (WSP, 2018).

Construction of the project would require the removal of rocky features from the subject land, predominantly where the following surface works would occur:

- Connections to and from the Burnt Bridge Creek Deviation at Balgowlah, including the new access road
- Realignment and upgrade of the Wakehurst Parkway, between Killarney Heights and Frenchs Forest.

The removal of rocky features from alongside the Wakehurst Parkway would result in the loss of potential habitat for some threatened species which are considered likely to occur in the subject land (Table 5.12). Rocky features adjacent to the Burnt Bridge Creek Deviation are unlikely to provide habitat for these species.

Table 5.12 Threatened species or ecological communities associated with rocks

<table>
<tr><th>Species or ecological community associated with areas of geological significance</th><th>Importance of rock to the species</th><th>Nature, extent and duration of short and long-term impacts due to rock removal</th><th>Consequences of the impacts for the local and bioregional persistence of the species or ecological communities</th></tr>
<tr><td colspan="4">Threatened species</td></tr>
<tr><td>Red-crowned Toadlet (Pseudophryne australis)</td><td>Inhabits periodically wet drainage lines below sandstone ridges. Shelters under rock</td><td rowspan="2">Existing rocky habitats (eg sandstone slabs, rocks and boulders) that occur within the subject land would be permanently removed for the establishment of construction support sites and for surface road works, resulting in the loss of potential foraging and sheltering habitat.
The area of habitat to be removed is negligible at a bioregional scale. Similar foraging habitat is readily available throughout the surrounding locality and wider bioregion.</td><td rowspan="2">Negligible.
Potential foraging habitat to be removed does not comprise a significant proportion of foraging habitat available to this species in the surrounding locality or wider bioregion.
The loss of a small area of potential foraging habitat is not expected to adversely impact the persistence of this species at a local nor bioregional scale.</td></tr>
<tr><td>Rosenberg's Goanna (Varanus rosenbergi)</td><td>Shelters in rock crevices</td></tr>
</table>

Species or ecological community associated with areas of geological significance	Importance of rock to the species	Nature, extent and duration of short and long-term impacts due to rock removal	Consequences of the impacts for the local and bioregional persistence of the species or ecological communities
Large-eared Pied Bat (*Chalinolobus dwyeri*)	Roosts in caves (near their entrances) and crevices in cliffs and breeds in the roof domes in sandstone caves and overhangs	Rocky features of the subject land comprise sandstone boulders, crevices and ledges. These were inspected during field surveys (WSP, 2018) and no evidence of microbat use was found, nor were any deemed suitable for breeding and/or roosting for the Large-eared Pied Bat. It is therefore unlikely that the species is utilising any rocky features on the subject land for breeding or roosting. Removal of rocky habitat in the subject land is therefore unlikely to impact the species.	Negligible. Given the low likelihood that the species is utilising rocky features in the subject land, their removal is unlikely to adversely impact the persistence of this species at a local or bioregional scale.

5.4.2 Impacts of development on the habitat of threatened species or ecological communities associated with human made structures

A number of threatened species known and likely to occur within the subject land are associated with human made structures (Table 5.13). The nature, extent and duration of short and long-term effects of the removal of human made structures as well as the consequences of the impacts for the local and bioregional persistence of these species or ecological communities is assessed in Table 5.13.

Table 5.13 Potential impacts on species associated with human made structures

Species or ecological communities	Human made structures with potential to be habitat	Nature, extent and duration of short and long-term impacts due to removal of structures	Importance within the bioregion of the habitat to these species or ecological communities	Consequences of the impacts for the local and bioregional persistence of the species or ecological communities
Large Bent-winged Bat (*Miniopterus orianae oceanensis*) Little Bent-winged Bat (*Miniopterus australis*) Southern Myotis (*Myotis macropus*)	Culverts, bridges and buildings	The project would involve the alteration of existing bridges and culverts at the surface connections at Artarmon, surface roads works at Balgowlah and realignment and upgrade of the Wakehurst Parkway that may offer potential microbat roosting habitat.	Low. Potential roosting habitat may be temporarily affected by noise and vibration while bridges are altered during construction of the project.	Negligible. Potential roosting habitat would be temporarily affected during construction and could be used by these species upon the completion of construction.

5.4.3 Impacts of development on the habitat of threatened species or ecological communities associated with non-native vegetation

There are three categories of vegetation not consistent with the definition of any PCTs that occur within the subject land, which are considered as non-native vegetation for the purpose of this assessment:

- Native plantings
- Urban exotic/native
- Exotic plantings.

Non-native vegetation is characterised by highly modified and/or landscaped vegetation that occurs in gardens, parks and road verges within the subject land, such as Artarmon Reserve and Balgowlah Golf Course. The extent of this non-native vegetation is shown in Figure 3-3.These areas generally contain planted native and exotic horticultural specimens or isolated remnant trees within otherwise planted areas.

Commonly occurring species within patches of non-native vegetation include *Casuarina glauca, Grevillea* species, *Callistemon* species, *Murraya paniculata, Eucalyptus microcorys, Nerium oleander, Acacia podalyriifolia, Lophostemon confertus*, *Pennisetum clandestinum, Ehrharta erecta, Axonopus fissifolius*, *Plantago lanceolata, Hypochaeris radicata* and *Trifolium* spp*.* This vegetation offers potential foraging, roosting, sheltering and nesting resources to a number of locally occurring fauna species that are known or are considered highly likely to occur in the subject land, as listed in Table 5.14.

Table 5.14 Potential impacts on threatened species associated with non-native vegetation

Species	Nature, extent and duration of short and long-term impacts due to non-native vegetation removal	Importance within the bioregion of the habitat to these species or ecological communities	Consequences of the impacts for the local and bioregional persistence of the species
Glossy Black-Cockatoo (*Calyptorhynchus lathami*)	Loss of potential foraging habitat offered by *Allocasuarina* spp., where these trees occur in patches of non-native vegetation. This small area of habitat would be removed for the establishment and operation of construction support sites and surface works at Wakehurst Parkway. Non-native vegetation does not support breeding habitat for this species.	Potential non-native vegetation that forms foraging habitat to be removed consists of and small areas of mostly planted exotic and native trees from road verges, parks and urban landscaped areas. The area of foraging habitat to be removed is negligible at a bioregional scale. Similar or higher quality foraging habitat is readily available throughout the surrounding locality and wider bioregion.	Negligible. Potential marginal foraging habitat to be removed does not comprise a significant proportion of foraging habitat available to this species in the surrounding locality or wider bioregion. The loss of a small area of potential foraging habitat is not expected to adversely impact the persistence of this species at a local nor bioregional scale.

Species	**Nature, extent and duration of short and long-term impacts due to non-native vegetation removal**	**Importance within the bioregion of the habitat to these species or ecological communities**	**Consequences of the impacts for the local and bioregional persistence of the species**
Powerful Owl (*Ninox strenua*)	Loss of potential roosting and foraging habitat offered by exotic and native plantings. This small area of habitat would be removed for the establishment and operation of construction support sites and surface works.	Potential non-native vegetation that forms foraging habitat to be removed consists of small areas of mostly planted exotic and native trees from road verges, parks and urban landscaped areas. The area of foraging habitat to be removed is negligible at a bioregional scale. Similar or higher quality foraging habitat is readily available throughout the surrounding locality and wider bioregion.	Negligible. Potential marginal foraging habitat to be removed does not comprise a significant proportion of foraging habitat available to this species in the surrounding locality or wider bioregion. The loss of a small area of potential foraging habitat is not expected to adversely impact the persistence of this species at a local nor bioregional scale
Large Bent-winged Bat (*Miniopterus orianae oceanensis*)	Loss of potential foraging habitat associated with native planted and exotic trees that occur within non-native vegetation. This small area of habitat would be removed for the establishment and operation of construction support sites and surface works at Wakehurst Parkway.	Potential non-native vegetation that forms foraging habitat to be removed consists of small areas of mostly planted exotic and native trees from road verges, parks and urban landscaped areas. The area of foraging habitat to be removed is negligible at a bioregional scale. Similar or higher quality foraging habitat is readily available throughout the surrounding locality and wider bioregion. Similar or higher quality foraging habitat is readily available throughout the surrounding locality and wider bioregion.	Negligible. Potential foraging habitat to be removed does not comprise a significant proportion of foraging habitat available to this species in the surrounding locality or wider bioregion. The loss of a small area of potential marginal foraging habitat is not expected to adversely impact the persistence of these species at a local nor bioregional scale.
Eastern Coastal Free-tailed Bat *(Micronomus norfolkensis)*			
Little Bent-winged Bat (*Miniopterus australis*)			
Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*)			

Species	Nature, extent and duration of short and long-term impacts due to non-native vegetation removal	Importance within the bioregion of the habitat to these species or ecological communities	Consequences of the impacts for the local and bioregional persistence of the species
Grey-headed Flying-fox (*Pteropus poliocephalus*)	Loss of potential foraging habitat offered by non-native vegetation, where planted exotic and native trees that occur in road verges and parks would be removed for the establishment and operation of construction support sites and surface works at Wakehurst Parkway. The Balgowlah Grey-headed Flying-fox camp is not located in the subject land, and therefore would not be directly impacted by the project. No non-native vegetation from the camp would be removed.	Low. Potential non-native vegetation that forms foraging habitat to be removed consists of small areas of mostly planted exotic and native trees from road verges, parks and urban landscaped areas. The area of foraging habitat to be removed is negligible at a bioregional scale. Similar or higher quality foraging habitat is readily available throughout the surrounding locality and wider bioregion.	Negligible. Potential foraging habitat to be removed does not comprise a significant proportion of foraging habitat available to this species in the surrounding locality or wider bioregion. The loss of a small area of potential foraging habitat is not expected to adversely impact the persistence of this species at a local nor bioregional scale.

5.4.4 Impacts of development on the connectivity of different areas of habitat of threatened species that facilitates the movement of those species across their range

The majority of the project would be located underground, with surface connections and roads works carried out at the Gore Hill Freeway, Balgowlah and the Wakehurst Parkway from Killarney Heights to Frenchs Forest (Figure 1-1).

Impacts on habitat connectivity would be limited to where surface road works are proposed, and where native vegetation would be removed for these surface works. Existing fauna habitat connectivity at locations where surface road works are proposed is described in Table 5.15.

Table 5.15 Proposed surface road works

Proposed surface road works	Existing fauna connectivity
Connections to and from the Gore Hill Freeway	Low. The Gore Hill Freeway comprises a 10 lane freeway at this location, and the road corridor is bound by fencing. The Gore Hill Freeway is a significant barrier to fauna movement. Vegetation adjoining the freeway is limited to planted native and exotic trees and mown lawn that offers low quality habitat to locally occurring fauna species. Terrestrial fauna species would be largely absent from these areas. Successful fauna crossings at this location would be limited to highly mobile species of birds and bats.

Proposed surface road works	Existing fauna connectivity
Connections to and from the Burnt Bridge Creek Deviation including surface works at Balgowlah	Low. The Burnt Bridge Creek Deviation comprises a six lane dual carriageway at this location, and the road corridor is bound by fencing. The Burnt Bridge Creek Deviation is a significant barrier to fauna movement. Vegetation adjoining the freeway is limited to stands native and exotic trees and scattered shrubs that offers low quality habitat to locally occurring fauna species. Terrestrial fauna species would be largely absent from these areas; commonly occurring arboreal mammals such as Common Ringtail Possum and Common Brushtail possum may use habitat resources offered by this vegetation on occasion. Successful fauna crossings at this location would be limited to highly mobile species of birds and bats.
Connections to and from the Wakehurst Parkway at Killarney Heights, including realignment and upgrade to the Wakehurst Parkway to Frenchs Forest	Moderate. The Wakehurst Parkway comprises a two lane road at this location. Fully structured native vegetation occurs within and adjoins the road corridor, and this vegetation is continuous with larger tracts of native vegetation contained within Garigal National Park (to the west) and Manly Warringah War Memorial State Park (to the east). There are three existing rope crossings located about 330 metres north of the intersection of the Wakehurst Parkway/Kirkwood Street and 110 and 200 metres south of the intersection of the Wakehurst Parkway/Aquatic Drive. The latter two structures were provided as part of the Northern Beaches Hospital road upgrade project. These rope crossings offer a safe crossing opportunity to locally occurring arboreal mammals. A diversity of fauna species would cross the Wakehurst Parkway to obtain food, shelter, and/or breeding resources, or to disperse from natal areas or carry out seasonal migrations. However, many of these crossings are unsuccessful and result in vehicle strike, evidenced by roadkill that has been recorded along the Wakehurst Parkway. The most commonly recorded roadkill species on the Wakehurst Parkway are Common Brushtail and Ringtail Possums (SMEC, 2015; AMBS, 2006), Swamp Wallabies, Long-nosed Bandicoots and Lace Monitors (wildlifemapping.org/views/map; SMEC, 2011). 20 records of roadkill possums that could use the crossings have been recorded since 1 January 2017 (wildlifemapping.org/views/map: accessed October 2021). Other locally occurring fauna species may perceive the existing gap in habitat as a barrier to movement, or may be deterred by edge effects, such as noise and light associated with existing traffic volumes.

Impacts on habitat connectivity and fauna movement would be greatest where surface road works would be carried out along the Wakehurst Parkway between Killarney Heights and Frenchs Forest, given that existing fauna connectivity is already limited in other areas of the subject land where surface road works are proposed.

Northern Beaches Council is currently revising the Wildlife Corridor Mapping across the local government area, which had not yet been adopted but both sides of the Wakehurst Parkway are considered to be core habitat, with a priority 1 corridor mapped as occurring to the north of the study area near the intersection with Warringah Road (Smith, B. (Team Leader, Biodiversity and Planning, Northern Beaches Council) personal communication May 2020; Smith and Smith (2005)).

The subject land occurs within an area mapped by Southern Sydney Regional Organisation of Council and Sydney Coastal Councils Groups' Connected Corridors for Biodiversity project that is included for its biodiversity connectivity value (Figure 3-1). It also includes in order of ecological value: priority habitats, supporting habitats and supporting areas. Connectivity is greatest in the northern part of the subject land, around Killarney Heights, on either side of the Wakehurst Parkway.

The project would require the removal of native vegetation that currently occurs along the margin of the Wakehurst Parkway. The gap between habitat on the eastern and western side of the Wakehurst Parkway is currently about 12 to 15 metres. This gap would increase to about 35 to 40 metres in the southern portion of the Wakehurst Parkway, and about 18 to 20 metres in the northern portion of the Wakehurst Parkway.

The Wakehurst Parkway is regularly traversed by many species of fauna, including some threatened species (eg Rosenberg's Monitor (*Varanus rosenbergi*)). Commonly recorded roadkill along the section of Wakehurst Parkway within the subject land include Swamp Wallaby (*Wallabia bicolor*), Brush-tail Possum (*Trichosurus vulpecula*), Long-nosed Bandicoot (*Perameles nasuta*) and Echidna (*Tachyglossus aculeatus*) as summarised in SMEC (2011). Roadkill has been recorded across the entire section of the Wakehurst Parkway within the subject land with no obvious clusters evident.

Impacts on smaller, more cryptic species are more difficult to document, since they are less likely to persist long enough to be recorded and are therefore underrepresented in roadkill data (Santos et al., 2011).

This increase in habitat fragmentation (ie a widened gap) could create a further barrier to fauna movement between habitat to the east and west of the Wakehurst Parkway; some fauna species could be deterred by a larger gap in habitat or could be more susceptible to vehicle strike while crossing additional lanes of traffic. However, research into the relative impacts on wildlife of increasing the width and traffic volume of existing roads, versus building new roads, and thus having many smaller roads, versus one or two major roads suggest that in general, increasing the volume and width of one or two larger roads is less likely to significantly impact wildlife (Rhodes et al., 2014). The project includes the provision of a fauna exclusion fence along both the eastern and western margin of the upgraded Wakehurst Parkway. This fauna exclusion fence would prevent fauna from accessing the road and being subjected to vehicle strike. Vehicle strike risk to fauna is discussed further in Section 5.4.6. The design specifications of the fauna exclusion fence would be developed during further design development. It would be designed to exclude small fauna species from the road corridor, such as Eastern Pygmy-possum. Frog fencing would also be added to the fauna exclusion fencing within identified Red-crowned toadlet habitat. The need for gates to manage any fauna on the road side of fauna exclusion fence would also be considered during the development of the design specifications, and would be based on best available knowledge from other Transport for NSW projects and in consultation with NSW National Parks and Wildlife Service and Northern Beaches Council.

The fauna exclusion fence would also guide animals to move along the fence toward a number of fauna underpasses that would be provided beneath the Wakehurst Parkway (Table 5.16). These underpasses (ie concrete box culverts) would facilitate the safe crossing of fauna beneath the road. One underpass would be a dedicated fauna underpass designed to achieve dry passage which would include a natural substrate, such as soil or mulch, as a base consistent with recommendation within the *Wildlife Connectivity Guidelines: Managing wildlife connectivity of road projects* (Draft) (Roads and Maritime Services, 2011). Sandy loam would be preferred if soil is to be used to prevent the generation of a mud substrate.

Two underpasses would be designed to convey surface water flows as well as facilitate fauna crossings. The floor of these culverts would be concrete, with sediment and leaf litter likely to naturally accrete during operation of the project with levels of this natural material fluctuating based on the intensity of the runoff flow. It is anticipated that the combined drainage/fauna underpasses would be dry most of the time as the structure is located in a drainage line that experiences ephemeral flows only, and also given that the road alignment follows a ridgeline. These culverts would include a raised bench on one side of the base of the culvert with a minimum width of 1.2 metres, to allow for the dry passage of animals during periods of high flow. They would be designed to provide dry fauna passage during a one in 1-year ARI three-day storm event or must not have wet sections that retain water for longer than three days.

The heights of all the fauna underpasses are considered adequate for target species, including the Swamp Wallaby, which is likely to be the largest species to potentially use the proposed fauna underpasses.

The dimensions and specifications of fauna underpasses would be refined during further design development. This includes detailing requirements for fauna furniture (for example timber railings or shelter rocks) and appropriate substrate to facilitate the use of underpasses by targeted arboreal fauna. The combined drainage/fauna underpasses would include fauna furniture where it would not affect the hydrological performance. The fauna exclusion fence would tie-in to new fauna fencing provided for the Northern Beaches Hospital road upgrade project at the northern end of Wakehurst Parkway. Removal of the existing fauna fencing installed as part of the Northern Beaches Hospital road upgrade project would be avoided where possible in overlapping construction areas. Where this is not possible, temporary fauna fencing would be installed during construction to ensure fauna are guided to existing underpasses and away from construction areas and/or live traffic.

In addition, three new rope bridges would be provided to facilitate the safe crossing of arboreal fauna above the road and three existing rope bridges would be replaced to allow for the widened road as part of the project (Table 5.16). Two of these were part of the Northern Beaches Hospital Road upgrade project (northernmost crossings (Figure 5-5)). Single span rope canopy bridges would be suspended across the dual carriageway between poles on each side. The rope canopy bridges would be linked to adjacent suitable habitat trees by ropes or ladders tied off onto the support poles and the trees. The rope canopy bridges must have a clearance of no less than 10.6 metres above the road pavement surface.

Fauna crossing locations have considered:

- The even spread of roadkill recorded along Wakehurst Parkway, as described above
- The occurrence/distribution of target species and species habitat along the alignment
- The need to provide sufficient coverage of the full length of the upgraded and realigned section of Wakehurst Parkway
- Design and engineering constraints such as road alignment and topography Location of existing fauna crossings constructed as part of the Northern Beaches Hospital road upgrade project.

The proposed fauna crossings are considered adequate in number and type to facilitate fauna crossings for target species and would be designed to encourage their use.

Any changes to design of underpasses and rope crossings would ensure the minimum requirements for fauna crossings would be met in accordance with *Wildlife Connectivity Guidelines: Managing wildlife connectivity of road projects (draft)* (Roads and Maritime, 2011). Maintenance of any fencing and fauna crossings is critical to the efficacy of these measures and would need to be detailed in an Operational Environmental Management Plan or existing Environmental Management System that incorporates the project.

The indicative locations of fauna crossings are shown in Figure 5-5.

In addition to the specific fauna-crossing structures, a number of culverts that would be constructed for drainage purposes may offer opportunities for smaller fauna species to cross beneath the road (shown on Figure 5-5). While these culverts do not specifically provide for fauna passage and may be inundated following rain, smaller terrestrial mammals, reptiles and amphibians may use these culverts on occasion.

Landscaping near fauna underpasses would be integral to their effectiveness and use by fauna species. Planting of trees and shrubs at fauna underpass approaches would provide connectivity between underpasses and adjacent fauna habitat that has been retained within the subject land. Consideration should be given to planting of feed species for target species, such as banksias for Eastern Pygmy-possum outside of any fauna fencing. Landscaping treatments within underpasses could include the placement of mulch or gravel, rocks and ground timber that offer protection and refuge to some fauna species.

The fauna underpasses, in addition to the drainage culverts and shared user underpasses provided as part of the project, would provide escape routes for fauna in the event of bushfires.

Table 5.16 Wakehurst Parkway fauna crossings

Chainage	Description	Target species that may use crossing structure	
Rope canopy bridge			
10620 (replacement)	Replacement of the existing fauna rope crossing about 330 metres north of Kirkwood Street	**Threatened species** Eastern Pygmy-possum (although to date, this species has not been known to use rope bridges).	**Protected species** Common Brushtail Possum Common Ringtail Possum Sugar Glider Feathertail Glider
11190	One new rope crossing located about 910 metres north of Kirkwood Street		
11660	One new rope crossing located about 1370 metres north of Kirkwood Street		
12160	One new rope crossing located about 885 metres south of Aquatic Drive		
12770 (replacement)	Replacement of the fauna rope crossing about 200 metres southof Aquatic Drive constructed as part of the Northern Beaches Hospital road upgrade project		
12960 (replacement)	Replacement of the fauna rope crossing about 110 metres south of Aquatic Drive constructed as part of the Northern Beaches Hospital road upgrade project		
Fauna underpass			
10970	One new combined drainage/fauna underpass located about 715 metres north of Kirkwood Street 2.4 metres high by 3 metres wide	**Threatened species** Red-crowned Toadlet Rosenberg's Goanna Southern Brown Bandicoot Eastern Pygmy-possum	**Protected species** Commonly occurring reptiles such as Red-bellied Black Snake (*Pseudechis porphyriacus*), Eastern Brown Snake (*Pseudonaja textilis*) Diamond Python (*Morelia spilota*) and Lace Monitor (*Varanus varius)*. Commonly occurring amphibians such as Peron's Tree Frog (*Litoria peronii*). Large terrestrial mammals such as Swamp Wallaby (*Wallabia bicolor)*. Small terrestrial mammals such as Brown Antechinus (*Antechinus stuartii*) and Short Beaked Echidna (*Tachyglossus aculeatus*). Arboreal mammals that may travel along the ground such as Common Brushtail Possum and Common Ringtail Possum.
11290	One new combined drainage/fauna underpass located about 1000 metres north of Kirkwood Street 1.8 metres high by 3 metres wide		
12475	One new dedicated fauna underpass located about 605 metres south of Aquatic Drive 2.4 metres high by 3 metres wide		

<table>
<tr><th>Chainage</th><th>Description</th><th colspan="2">Target species that may use crossing structure</th></tr>
<tr><td>13200 (retained)</td><td>Retained combined drainage/fauna underpass located about 100 metres north of Aquatic Drive 1.8 metres high by 2.4 metres wide constructed as part of the Northern Beaches Hospital road upgrade project</td><td rowspan="2">-</td><td rowspan="2">From Biosis (2020):
• Swamp Wallaby
• Short Beaked Echidna
• Long-nosed Bandicoot (Perameles nasuta)
• Common Brushtail Possum</td></tr>
<tr><td>N/A (retained)</td><td>Retained combined drainage/fauna underpass located under Aquatic Drive about 50 metres east of Wakehurst Parkway 1.8 metres high by 2.4 metres wide constructed as part of the Northern Beaches Hospital road upgrade project</td></tr>
</table>

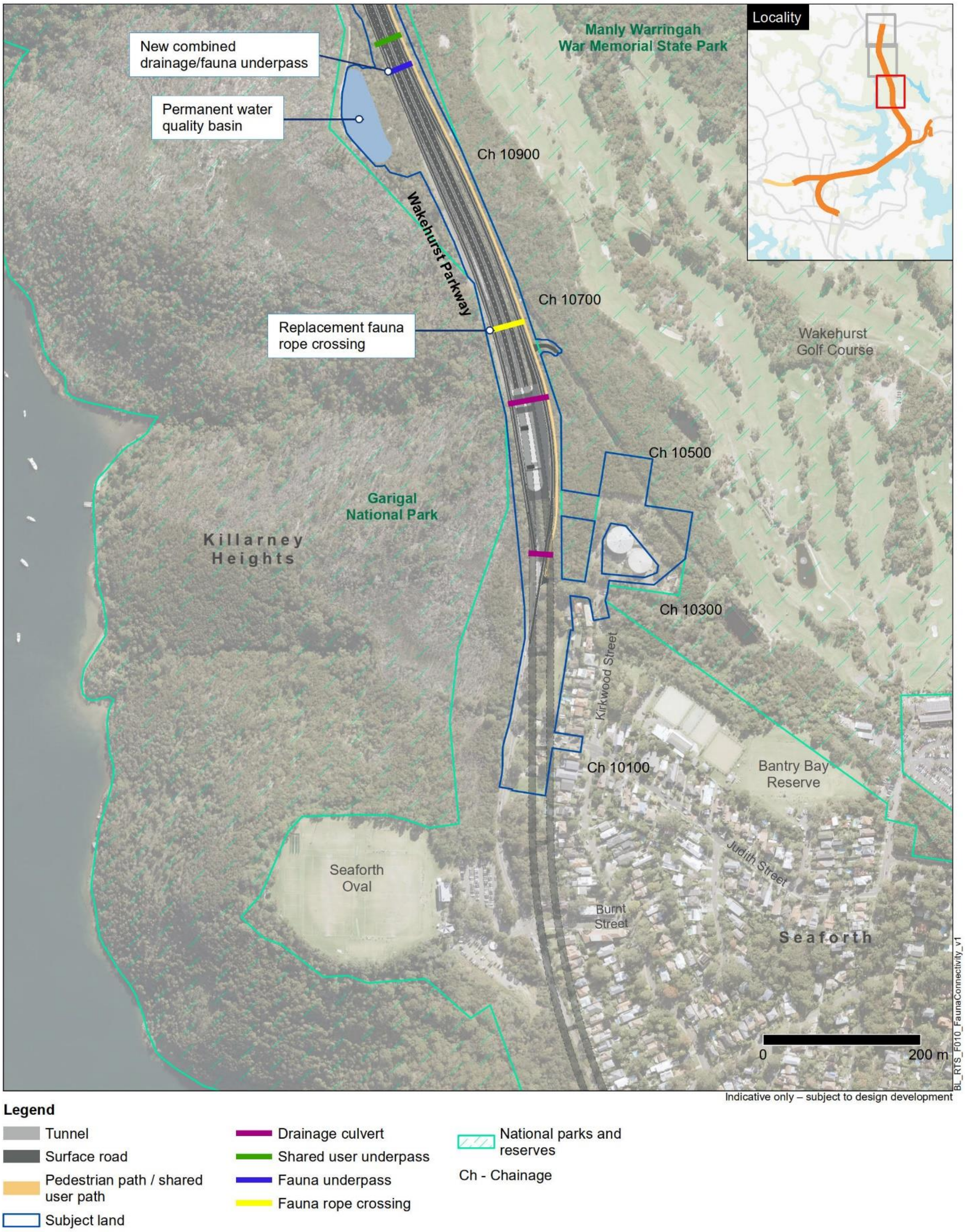


Figure 5-5 Proposed locations of fauna crossing structures (map a)

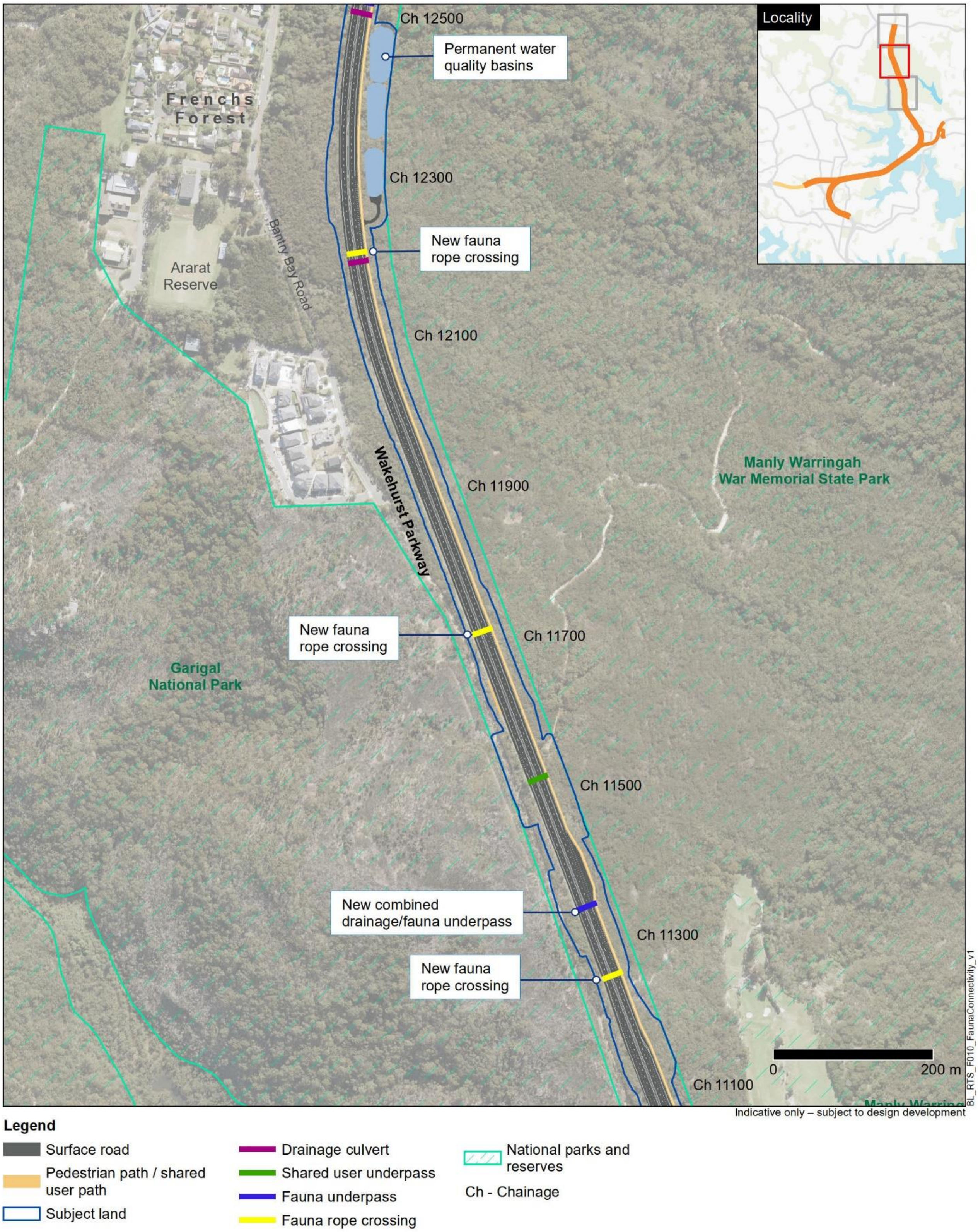


Figure 5-5 Proposed locations of fauna crossing structures (map b)

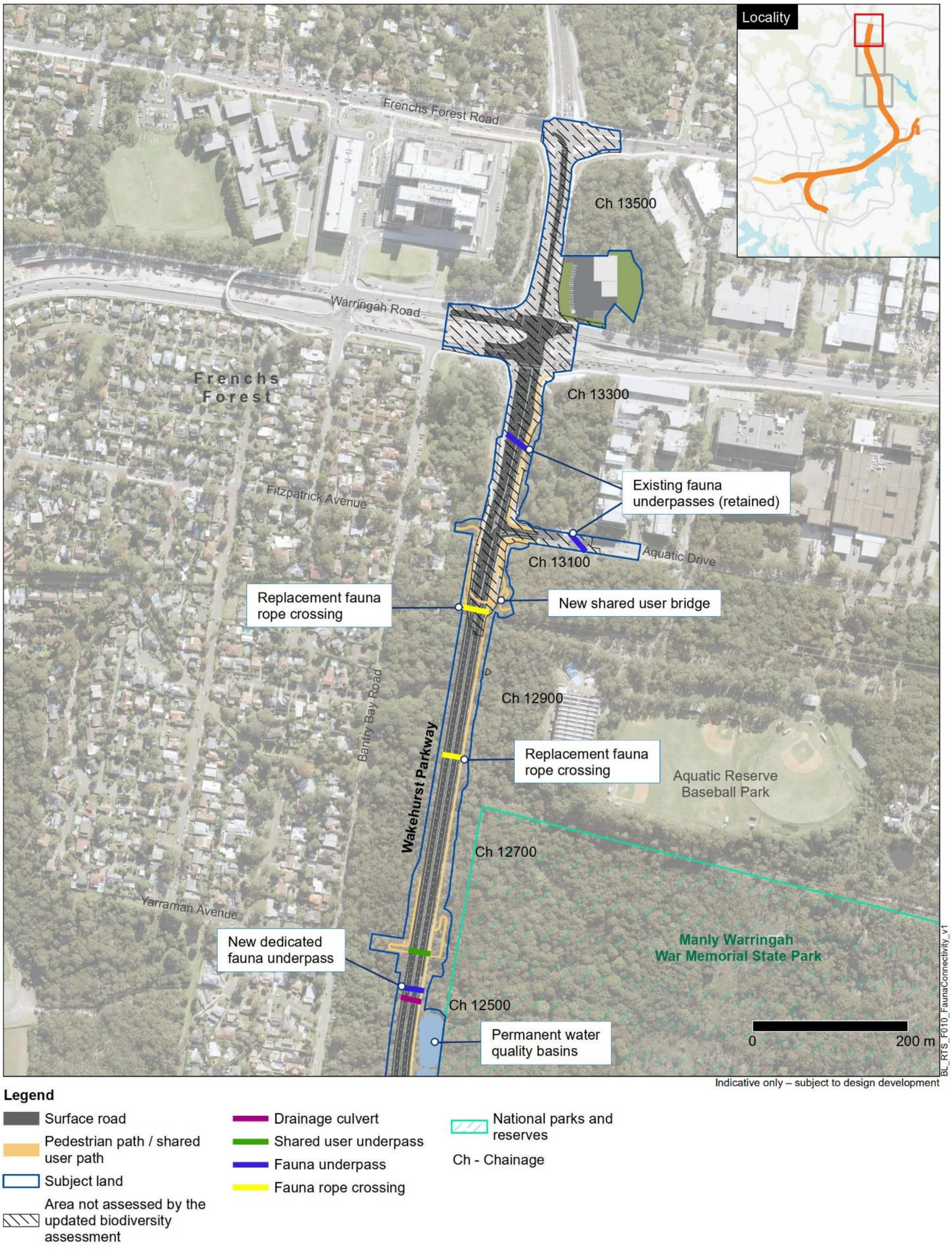


Figure 5-5 Proposed locations of fauna crossing structures (map c)

5.4.5 Impacts of development on water quality, water bodies and hydrological processes that sustain threatened species and threatened ecological communities

5.4.5.1 Marine and intertidal habitats

Construction of the crossing of Middle Harbour, between Northbridge and Seaforth, would involve the installation of immersed tube tunnels that would sit partly within a gravel-lined, dredged tunnel trench and partly on the harbour floor supported on piled foundations. The installation of two temporary cofferdams at Middle Harbour south (BL7) and Middle Harbour north (BL8) would involve piling and rock excavation. These construction activities have the potential to generate silt, disturb and mobilise contaminated sediment and increase the turbidity of waters within and near the subject land. These construction activities have the potential to result in a decrease in water quality and degradation of marine and intertidal habitats, which may adversely impact foraging habitat for threatened species that may use the habitats, including Little Penguin and White-bellied Sea-Eagle, as discussed below.

In order to minimise the impact on the surrounding marine environment, the selected methodology for the project has considered dredging methods and controls to limit the potential for turbidity impacts and mobilisation of sediment. This includes:

- Use of a closed environmental clamshell bucket to dredge the top layer of marine sediment
- Installation of several silt curtains during dredging including:
  - one secured to the dredge barge on a fixed or floating boom two to three metres deep
  - deep draft silt curtains 10 to 12 metres deep situated at either side of the crossing where the majority of the dredging occurs
  - around sensitive areas of aquatic vegetation (ie seagrass beds) adjacent to the dredging footprint
- Sediment loaded into hopper barges positioned next to the dredge with no overflow allowed.

Impacts on marine species and the marine environment within the subject land are assessed in detail by *Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology* (Cardno, 2020b). This section considers potential impacts of the project on threatened birds that may use marine habitats, including the Little Penguin and White-bellied Sea-Eagle.

5.4.5.1.1 Little Penguin

As described in Section 3.6.2.4.15, Little Penguins have been recorded at several locations within the assessment area, including The Spit, Long Bay, Sailors Bay, and in the main channel of Middle Harbour (DPIE (EES), 2020a), where the species likely forages in shallow waters for small shoaling fish, cephalopods, and to a lesser extent, crustaceans (NPWS, 2000).

The main threats to the Little Penguin population are those that affect nesting habitat at Manly, located about six kilometres to the east from the project. This includes overdevelopment of the foreshore, predation by dogs and foxes, movement, noise and light-related disturbance associated with human activities, stormwater runoff and rubbish dumping. The project would not affect nesting habitat for the Little Penguin at Manly.

Works within Middle Harbour (ie construction of the cofferdam, dredging and piling) would cause an increase in turbidity and sedimentation of marine waters, in turn causing localised degradation of potential foraging habitat for the Little Penguin. An increase in suspended sediment near construction activities may adversely impact the occurrence and behaviour of fish and other prey species of the Little Penguin, and adversely impact the health of the Little Penguin.

In order to minimise the impact on the surrounding marine environment, the selected methodology for the project has considered dredging methods and controls to limit the potential for turbidity impacts and mobilisation of sediment (as listed in Section 5.4.5.1).

Accordingly, any potential increase in turbidity and sedimentation of marine waters near construction activities would be minimal, localised and temporary.

The Little Penguin is known to forage widely throughout Sydney Harbour, and the impact of any temporary and localised reduction in foraging habitat or water quality near the project would be negligible. Upon completion of construction and during operation, the marine benthic environment would be rehabilitated, and the project is not expected to cause any further turbidity or sedimentation of marine waters. Construction works within Middle Harbour (ie installation of the cofferdams, dredging and piling) would generate noise that would be transmitted through seabed sediments and the water column. Construction-related underwater noise may be impulsive or continuous, and the propagation of noise would be strongly influenced by water depth and proximity of the source of the noise to the mainland or small islands. The various headlands and islands that are located within and near the subject land, such as Seaforth Bluff, The Spit, Fig Tree Point, Sugarloaf Point and Yeoland Point, are expected to reduce or block acoustic energy that would otherwise propagate through Middle Harbour (JASCO, 2019).

The duration of construction-related underwater noise (noting some activities would be occurring concurrently, and the frequency of noise intensive activities would vary) is expected to be:

- About 12 to 15 months for the installation of temporary cofferdam structures (including dewatering and excavation of rock within cofferdam and trench) at Middle Harbour south cofferdam (BL7) and Middle Harbour north cofferdam (BL8)
- About 15 months for dredging and gravel placement
- About six months for tunnel element immersion.

The installation of the immersed tube tunnels would require one continual work period of around 48 hours for the immersion of each of the six tunnel units. Use of Spit West Reserve construction support site (BL9) outside standard construction hours would be required to provide support each time. Dredging activities would be carried out five days a week within normal construction hours. Although sound conduction mechanisms in aquatic birds such as the Little Penguin are poorly understood (Ketten, 2008; McCauley and Kent Salgado, 2008), it is expected that construction related underwater noise would be perceived by the species, within a certain distance from construction activities.

An acoustic modelling study of underwater sound generated from installing piles and dredging (JASCO, 2019) has identified potential impacts on marine fauna. This study was unable to provide a specific assessment for the Little Penguin due to a lack of scientific studies or literature pertaining to acoustic impacts on the species and therefore a precautionary approach has been applied for the purposes of this assessment. Impulsive or continuous underwater noise as a result of the project may result in altered behaviour of the Little Penguin. The species may avoid foraging in areas subjected to continuous or high levels of sound. Sudden or high levels of sound may have the potential to result in hearing loss or damage to auditory tissues in the Little Penguin. The potential for an impact to occur and the scale or nature of impact would depend on an individual penguin’s proximity to construction activities, lessening as distance from construction activities increases. Given the level of construction activity proposed in the harbour, it is expected that individuals of the species would avoid the area reducing the risk of hearing loss and/or auditory damage occurring. As detailed in the environmental impact statement, piling programs would be refined during further design development to consider reasonable and feasible alternatives, attenuating mitigation methods including trained spotters who would limit works if required and programming to minimise underwater noise.

Upon completion of construction and during operation, the project is not expected to cause alterations in foraging behaviour nor physical injury.

5.4.5.1.2 White-bellied Sea-Eagle

As described in Section 3.6.2.4.10, White-bellied Sea-Eagle species was not recorded during field surveys, however, has been previously recorded throughout Middle Harbour (DPIE (EES), 2020a), where the species may forage for fish, turtles and sea snakes in the marine waters of Sydney Harbour.

The main threats to the White-bellied Sea-Eagle are the loss of habitat due to land development, and the disturbance of nesting pairs by human activity. The project would not directly affect any known nesting habitat, nor does it involve any construction or operational activities that are likely to disturb nesting pairs. The closest known nesting site is located in Newington Nature Reserve, next to the Parramatta River and about 15 kilometres south-east of the project.

Construction of the crossing of Middle Harbour, between Northbridge and Seaforth, would involve the installation of immersed tube tunnels. The installation of two temporary cofferdams (Middle Harbour south and Middle Harbour north cofferdams) would involve dredging of the sea floor, piling and rock excavation.

Works within Middle Harbour (ie installation of the cofferdams and dredging) would cause an increase in turbidity and sedimentation of marine waters, in turn causing localised degradation of potential foraging habitat for the White-bellied Sea-Eagle. An increase in suspended sediment near construction activities may adversely impact the occurrence and behaviour of fish and other prey species. However, the selected methodology for the project has considered dredging methods and controls to limit the potential for turbidity impacts and mobilisation of sediment, in order to minimise the impact on the surrounding marine environment. This includes, but is not limited to, the installation of floating silt curtains and other management measures listed in Section 5.4.5.1. Accordingly, any potential increase in turbidity and sedimentation of marine waters near construction activities would be minimal, localised and temporary.

Foraging conditions for the White-bellied Sea-eagle in Middle Harbour are poor due to existing high levels of on-water activity. The project would increase the levels of on-water activity in Middle Harbour with additional vessels and cofferdam structures. This relatively small increase in on-water activity as a result of the project would contribute to the existing poor foraging conditions for the species. However, impacts are anticipated to be very minor or negligible.

Upon completion of construction and during operation, the project is not expected to adversely impact foraging habitat that occurs within the subject land.

5.4.5.1.3 Threatened shorebirds and wandering seabirds

The subject land does not support suitable habitat for any of the threatened shorebird or wandering seabird species identified during database searches (listed in Annexure A). No threatened shorebird or wandering seabird species were determined to have a moderate or high likelihood of occurring in the subject land.

As identified in Section 3.7.5, the Port of Newcastle construction support site (BL15) is partially within the Hunter Estuary important area shorebird mapping. This mapping identifies that the Hunter Estuary is recognised as being an important area for the BC Act listed Curlew Sandpiper, Terek Sandpiper and Black-tailed Godwit, and the EPBC Act listed Eastern Curlew, Bar-tailed Godwit and Red Knot.

Under the BAM, the presence of important area mapping within the Port of Newcastle construction support site (BL15) requires that the relevant species are assumed to be present and assessed accordingly for potential impacts. Section 5.2.5 of the BAM describes that a species polygon must be prepared, which includes the entire area mapped on the important habitat map that occurs within the Port of Newcastle construction support site (BL15). The area of the Port of Newcastle construction support site (BL15) within the important area mapping contains a thin sliver of the concrete dock and open water of the Hunter River.

As discussed in Section 3.7.5, the Port of Newcastle construction support site (BL15) consists entirely of concrete and a small area of water in the Hunter River where ships are docked, and does not contain any habitat suitable for these six threatened migratory shorebird species. Additionally, there is no habitat adjacent to the Port of Newcastle construction support site (BL15) and the closest known important foraging and roosting sites are located around Stockton and Kooragang Island. Therefore, the proposed activities would not directly impact any habitat for the Curlew Sandpiper, Terek Sandpiper, Black-tailed Godwit, Eastern Curlew, Bar-tailed Godwit or Red Knot. A species polygon for has not be developed and the proposed activity does not require offsetting in accordance with the BAM.

Potential impacts to these six species as a result of the proposed activities would be limited to indirect impacts (ie possible disturbance) to any birds traversing the Hunter River adjacent to the

Port of Newcastle construction support site (BL15). However, prior to migrating, individuals of these six species, or other non-threatened migratory shorebird species, are most likely to occupy and fly between habitats to the north of the Port of Newcastle construction support site (BL15). Therefore, the Hunter River around the Port of Newcastle construction support site (BL15) is not likely to be an important flight path. Considering the proposed activities are consistent with the current use of the Port of Newcastle construction support site (BL15) and surrounding industry, the potential impact of the proposed activity to the local movement of the Curlew Sandpiper, Terek Sandpiper, Black-tailed Godwit, Eastern Curlew, Bar-tailed Godwit or Red Knot is likely to be negligible.

Activities proposed at this site are consistent with its existing use. The project is unlikely to adversely impact any threatened shorebird or wandering seabird species. Any potential indirect impacts on the Hunter Estuary would be managed by standard environmental management measures.

5.4.5.2 Freshwater habitats

The project transects several waterways; Flat Rock Creek (Artarmon and Northbridge), Burnt Bridge Creek (Balgowlah) and a number of unnamed watercourses near the Wakehurst Parkway (Killarney Heights to Frenchs Forest). The catchments of four other waterways fall within the subject land; Willoughby Creek, Manly Creek, Manly Dam and Trefoil Creek. Potential impacts of construction and operation of the project include changes in water quality and surface flows in waterways that offer potential habitat to threatened species such as the Red-crowned Toadlet.

Instream works have been proposed within an existing aboveground watercourse within the northern extent of Flat Rock Reserve and Burnt Bridge Creek. The existing aboveground watercourse within the northern extent of Flat Rock Reserve would be diverted for around 100 metres through a newly constructed culvert at the north eastern perimeter of the Flat Rock Drive construction support site (BL2). The culvert may be temporary or permanent pending council/community preferences and final end use of Flat Rock Reserve. Burnt Bridge Creek would undergo localised adjustment to facilitate an extension of the existing box culvert crossing of the Burnt Bridge Creek Deviation further into the existing Balgowlah Golf Course. Scour protection would also be installed at the downstream limit of the culvert works.

The project would also impact the Balgowlah Golf Course stormwater harvesting dam as part of constructing the new access road between Sydney Road and Burnt Bridge Creek Deviation. However, a suitable alternate location and size for the stormwater harvesting dam would be determined as part of the dedicated consultation and follow on design process associated with the final layout of the new and improved public open space and recreation facilities at Balgowlah. The new dam would be installed and commissioned before the existing dam is decommissioned (refer to Section A4.8 of the submissions report for further details). As discussed in Annexure D, the stormwater harvesting dam is unlikely to provide habitat for native fish. Given that a replacement stormwater harvesting dam would be provided prior to the existing dam being decommissioned, it is expected that potential impacts to common native aquatic fauna would be negligible as comparable habitat will be established prior to the existing dam being decommissioned. Notwithstanding, dewatering procedures would be implemented in the event that native aquatic fauna are encountered to ensure any potential impacts are minimised.

A summary of the potential impacts of construction and operation on surface water are described in detail in Beaches Link and Gore Hill Freeway Connection Technical working paper: Surface water quality and hydrology (Jacobs, 2020a). A summary of these potential impacts and their relevance to freshwater habitat is provided in Table 5.17.

Table 5.17 Potential impacts on freshwater habitats

Potential impact	Construction of the project	Operation of the project
Reduction in water quality	Unmanaged construction activities (such as earthworks, relocation of utilities and removal of vegetation) could result in: soil erosion, siltation and off-site movement of eroded sediments by stormwater, contributing to increased levels of turbidity and sediment deposition, decreased dissolved oxygen, and changed pH levels in waterways. In addition, accidental fuel and chemical spills and contaminated runoff from construction vehicles, plant, equipment or chemical storage areas have the potential to reach downstream waterways, including Willoughby Creek, Flat Rock Creek, existing aboveground watercourse within the northern extent of Flat Rock Reserve, Burnt Bridge Creek, Manly Creek, Manly Dam and Trefoil Creek and a number of unnamed watercourses near the Wakehurst Parkway.	An increase in impervious surfaces would likely result in an increased volume of runoff, which would lead to increased scouring, erosion and sedimentation. Runoff may carry increased sediment loads and nutrients (such as nitrogen and phosphorus) to downstream waterways such as Flat Rock Creek, Burnt Bridge Creek, Manly Creek, Manly Dam and Trefoil Creek.
Change in surface flows	Water extraction from surface waters is not proposed during construction. Surface water availability and flows have the potential to be reduced as a result of groundwater drawdown during construction of the project. Potential impacts from reduced groundwater baseflows to surface waters during construction is provided in Beaches Link and Gore Hill Freeway Connection Technical working paper: Groundwater (Jacobs, 2020b). With regard to Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, further investigations and assessment has been carried out since exhibition of the environmental impact statement, including revised groundwater modelling rand predicted groundwater baseflow reductions 100 years following commencement of operation. The results of the revised modelling and assessment are provided in Annexure G and discussed in the adjacent cell. It should be noted that the groundwater modelling in Jacobs (2020b) and Annexure G is based on a conservative scenario with unconstrained groundwater inflows and full hydraulic connectivity assumed between the surface geology and the tunnel (which would likely be stratified, with disconnected aquifer horizons, limiting the potential for vertical groundwater movement). This means	Annexure G predicts maximum groundwater baseflow reductions at Flat Rock Creek of 526 kilolitres per day, equating to a total flow reduction of 30 per cent, after 100 years of operation. The maximum predicted baseflow reduction to Quarry Creek after 100 years of operation would be 11 kilolitres per day, equating to a total baseflow reduction of 63 per cent; at Burnt Bridge Creek it would be 20 kilolitres per day, equating to a total baseflow reduction of 60 per cent. Beaches Link and Gore Hill Freeway Connection Technical working paper: Groundwater (Jacobs, 2020b) predicts Manly Dam would experience a maximum predicted baseflow reduction of 1.2 kilolitres per day, equating to a total flow reduction of two per cent, after 100 years of operation. Willoughby Creek, Manly Creek and Trefoil Creek would be unaffected or negligibly affected by changes to baseflow as a result of groundwater drawdown. It is noted that groundwater baseflow is just one part of the make up of streamflow (refer to Section 2 of Annexure G). Groundwater baseflow in many areas of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek comprises less than one per cent of streamflow eg in upstream areas of Flat Rock Creek

Potential impact	Construction of the project	Operation of the project
	that the sub-surface drawdown at tunnel depth might not result in the same (or any) drawdown in the water table and might reduce actual drawdown substantially compared to predictions.	and generally less than six per cent in Burnt Bridge Creek (refer to Section 3.3 of Annexure G). As such, the predicted groundwater baseflow reductions would generally equate to less than a three per cent reduction of streamflow for both the mid-stream and downstream parts of Burnt Bridge Creek and the upstream part of Quarry Creek after 100 years of operation. Along the downstream sections of Flat Rock Creek, groundwater baseflows are estimated to comprise a much larger proportion of streamflow; around 67 per cent. The revised groundwater predictions indicate that at the weir of Flat Rock Creek, groundwater baseflow reductions would be expected to reduce total streamflow by 22 per cent. Following rainfall, due to an increased contribution from stormwater, any changes from the project to groundwater baseflow for most parts of Burnt Bridge Creek and the upstream parts of Flat Rock Creek and Quarry Creek would be negligible. The predicted reduction in streamflow for Flat Rock Creek may be offset by discharges from the operational wastewater treatment plant (about 1425 kilolitres per day).
Changes to the geomorphology of watercourses	Treated water discharges from construction wastewater treatment plants have the potential to impact creek channel bed and bank conditions due to changes in baseline volumes and velocities.	Changes to the geomorphology of other watercourses from surface water runoff during operation of the project is considered negligible, given that project stormwater discharges would be via the stormwater network. Drainage works would be designed to prevent scouring of creeks and drainage lines.
	The project would result in temporary minor changes in creek flows and velocities within Burnt Bridge Creek downstream of the project during creek localised adjustment works. Works would be staged to ensure creek flows and velocities are not significantly changed and to avoid downstream erosion and bed and bank stability impacts. Mobilised sediment could build up in the waterways in and downstream of the subject land. Impermeable surfaces created by the project would lead to increases in the volume and rate of runoff, which could cause erosion within the instream channel. Scour protection would be installed at the limit of culvert works.	The project would have a negligible operational impact on the geomorphology of Burnt Bridge Creek.

Potential impact	Construction of the project	Operation of the project
Loss of freshwater and riparian habitat	A small area of riparian vegetation and instream habitat would be removed for the localised adjustment and drainage works at Burnt Bridge Creek and the existing aboveground watercourse within the northern extent of Flat Rock Reserve. The removal of riparian vegetation and instream habitat at both creeks has the potential to impact bank stability and surface water quality if environmental management measures are not implemented.	Rehabilitation and revegetation of disturbed riparian vegetation would occur progressively during construction. The instream works are anticipated to have a minimal and localised impact to instream freshwater habitats during operation.

Potential impacts of construction activities on water quality and surface flows would be managed by the implementation standard management environmental management measures as outlined in Beaches Link and Gore Hill Freeway Connection Technical working paper: Surface water quality and hydrology (Jacobs, 2020a) and Annexure D (Freshwater Ecology Impact Assessment (Cardno, 2020)), including erosion and sediment controls for all work sites and surface work areas. Water treatment devices, such as construction sediment basins, would be located where they collect a high proportion of sediment-laden runoff from disturbed areas of the construction. With the implementation of appropriate measures during construction, impacts to water quality would be temporary and manageable.

As discussed in Table 4.2, discharges from the wastewater treatment plants would be designed to not worsen water quality in the receiving environment during construction and operation. This includes Flat Rock Creek, Willoughby Creek and Burnt Bridge Creek.

During construction, discharges to Flat Rock Creek, Willoughby Creek and Burnt Bridge Creek would be treated to comply with the following discharge criteria:

- The relevant physical and chemical stressors, the guideline values set out in Table 3.3.2 and 3.3.3 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000)
- The ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which will be treated to meet the ANZG (2018) 95 per cent species protection levels
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water).

Where the ANZG (2018) does not provide a default guideline value for a particular pollutant, the approaches set out in the ANZG (2018) for deriving guideline values, using interim guideline values and/or using other lines of evidence such as international scientific literature or water quality guidelines from other countries, will be used.

During operation, discharges to Flat Rock Creek would be treated to comply with the following discharge criteria:

- The relevant physical and chemical stressors, the guideline values set out in Tables 3.3.2 and 3.3.3 of the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000)
- The ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels
- The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water).

Where the ANZG (2018) does not provide a default guideline value for a particular pollutant, the approaches set out in the ANZG (2018) for deriving guideline values, using interim guideline values and/or using other lines of evidence such as international scientific literature or water quality guidelines from other countries, will be used.

As noted in Table 5.17, during construction and operation there would be potential baseflow reductions to Flat Rock Creek, Quarry Creek and Burnt Bridge Creek which would affect surface environmental water availability and flows to these waterways. However, revised modelling and assessment which has occurred since the exhibition of the environmental impact statement indicates that baseflow is only one component of streamflow (refer to Annexure G).

Based on further freshwater ecology investigations detailed in Attachment A of Annexure G, the freshwater sections of Burnt Bridge Creek, Flat Rock Creek and Quarry Creek were found to all have depauperate (ie lacking in numbers of variety of species) assemblages of macroinvertebrates, non-existent assemblages of native fish and generally very few, if any, native macrophytes. This is despite the riparian habitat of many parts of all of the creeks being in reasonable if not good condition and containing mostly native vegetation. Therefore, although much of the freshwater reaches of Burnt Bridge Creek, Flat Rock Creek and Quarry Creek appear healthy, the aquatic ecology is considered to be generally poor. The reasons for such poor condition are likely to be a consequence of generally high levels of some nutrients and dissolved metals in the creeks, regular scouring by stormwater discharges and the presence of weirs in Burnt Bridge Creek and Flat Rock Creek, and steep cascades in all creeks that would prevent some species from colonising the middle to upper reaches.

The detailed field investigations also confirmed the presence of pool habitats in most reaches of the creeks. Therefore, even in periods of low flow eg in dry periods in summer, and considering the revised predictions of groundwater baseflow reductions, it is expected that many of these pools would be deep enough to retain water and therefore aquatic habitat between rainfall events. Also, the predicted reduction in baseflow at Flat Rock Creek may be offset by discharges to the creek from the Gore Hill Freeway operational wastewater treatment plant.

Given the above, it is considered that predictions of changes to groundwater baseflow caused by the project would not substantially alter the flow regime in any of the three creeks to the extent that it would affect instream habitat and that the project would not significantly impact the aquatic ecology of Burnt Bridge Creek, Flat Rock Creek or Quarry Creek. As there are no sensitive species present, there would be no impact on aquatic communities in these creeks, including any threatened freshwater fauna, flora species or ecological communities or endangered populations listed under the *Fisheries Management Act 1994* and/or the EPBC Act.

5.4.5.2.1 Red-crowned Toadlet

One threatened fauna species, Red-crowned Toadlet, is considered highly likely to occur in the northern extent of the subject land, as the species was previously recorded for the Northern Beaches Hospital road upgrade project (SMEC, 2015), directly adjacent to the subject land, in similar habitat. Accordingly, this species is assumed to be present in areas of suitable habitat adjoining the Wakehurst Parkway, which consist of several unnamed and unmapped ephemeral freshwater streams. These first-order ephemeral streams are likely to provide sheltering, foraging and breeding habitat for the Red-crowned Toadlet. Rocks and logs within adjoining riparian vegetation (mainly open forest) offer sheltering habitat outside of the breeding period. Red-crowned Toadlets require acidic conditions for tadpole development and metamorphosis, and temporary pools often dry up before metamorphosis is complete. Changes in water quality have been blamed for loss of this species as a result of urban development (Thumm and Mahony, 1999).

Two areas of potential habitat have been identified in the subject land as shown in Figure 3-8.

During construction, road works and vegetation removal along the Wakehurst Parkway could increase the risk of erosion and sedimentation within the surrounding waterways that offer potential habitat to Red-crowned Toadlet. However, standard sediment and erosion controls would be installed before and maintained throughout the construction period, minimising potential adverse impacts of construction on potential habitat for the species.

The catchments associated with the Red-crowned Toadlet are very small and sit at the top of the ridge. Erosion and sediment control measures to be installed in this area would be temporary and are unlikely to change the wet/dry cycles of the surrounding waterways that offer potential habitat to Red-crowned Toadlet. During operation, the road catchment at the southern-most area of habitat (as shown in Figure 3-8) would be increased by eight per cent during operation. As a result of this increase, the project is likely to have a negligible to minor impact on the wet/dry cycle of the drainage line with a potential minor increase in baseflow.

Water quality treatments are not proposed within the road catchment at the northern end of the Wakehurst Parkway, as part of this project, where the project overlaps with Northern Beaches Hospital road upgrade project. Wet/dry cycles around the Red-crowned Toadlet habitat in this area are therefore not likely to change substantially as there currently are no water quality controls. Adverse impacts to the Red-crowned Toadlet as a result of changes to hydrology are unlikely.

No water quality treatment is currently provided along the Wakehurst Parkway. Road runoff is currently collected through natural drainage lines before reaching Middle Harbour to the west and Manly Dam to the east (Jacobs, 2020a). The project would include the provision of water quality control measures along the Wakehurst Parkway, including swales and water quality basins. MUSIC model results for the Wakehurst Parkway stormwater catchments (Jacobs, 2020a) show that the project would result in an overall beneficial water quality outcome with a reduction in annual suspended solid and phosphorous loads, but an increase in total annual nitrogen loading of 188 kilograms per year for the overall combined Wakehurst Parkway catchments. The increase in nitrogen downstream of the proposed water quality basin at chainage 12335, above the identified potential breeding habitat for Red-crowned Toadlet, would be 44 kilograms per year compared to 36 kilograms per year for the existing condition. These figures may either reduce or become a decrease change during further design development, subject to further testing.

It should be noted that the estimated nitrogen loading value is estimated immediately at the outlet of the basin and modelling has assumed that the exfiltration rate for the basin is zero. As such, the results are conservative as dilution is likely to occur further downstream and should a small exfiltration exist, it is likely the results would reduce further.

Based on these results, it was concluded that the operation of the project at the Wakehurst Parkway would not decrease the water quality of nearby ephemeral and unnamed freshwater waterways, nor Garigal National Park drainage lines, Bantry Bay, Manly Dam or Manly Creek (Jacobs, 2020a).

By implementing a responsive and responsible urban design and landscape plan incorporating appropriate vegetation species composition, planting layout and densities, increases in nitrogen can be effectively captured or diluted before entering ephemeral streams. This, in conjunction with in addition to the implementation of controls to minimise weed infestation and spread, would reduce the risk of increased weeds in Red-crowned Toadlet habitat.

Further, SMEC (2015) recorded the Red-crowned Toadlet just east of Wakehurst Parkway near Aquatic Drive. At this location the existing nitrogen levels are 163 kilograms per year. This indicates that the Red-crowned Toadlet tolerates considerably higher total nitrogen levels than are modelled to be discharged from the water quality basin at chainage 12335. Therefore, it is unlikely that the species would be impacted by the predicted increase in total nitrogen levels. Given that potential construction impacts on Red-crowned Toadlet habitat would be managed by the implementation of standard management and environmental management measures as described above and outlined in Beaches Link and Gore Hill Freeway Connection Technical working paper: Surface water quality and hydrology (Jacobs, 2020a), and that water quality of Red-crowned Toadlet habitat is unlikely to be significantly impacted during operation of the project, adverse impacts on potential Red-crowned Toadlet habitat are unlikely.

5.4.6 Impacts of vehicle strikes on threatened species or on animals that are part of a threatened ecological community

The susceptibility of threatened fauna species known or considered highly likely to occur in the subject land to vehicle strike is summarised in Table 5.18. No threatened ecological communities that are specific to fauna are within or adjacent to the subject land.

Table 5.19 summarises the impacts of the project on habitat connectivity and the movement of fauna.

Table 5.18 Threatened fauna species susceptible to vehicle strike

Species	Home range	Likelihood of vehicle strike
Reptiles		
Red-crowned Toadlet (*Pseudophryne australis*)	Around 50 metres from ephemeral drainage lines suitable for breeding (Thumm and Mahony, 1999).	Moderate. A slow-moving species that is unlikely to be able to evade vehicles quickly. However, unlikely to travel large distance from preferred habitat (ie ephemeral drainage lines). A review of road strike records (wildlifemapping.org/views/data and SMEC, 2011) and BioNet records found only one road strike record of the species within NSW. This record was from Lisarow, on the Central Coast in 1998.This is a very small species that would be difficult to detect during any survey of roadkill (Santos, Carvalho and Mira, 2011).
Rosenberg's Goanna (*Varanus rosenbergi*)	At least 100 hectares (Rismiller et. al., 2007)	High. A slow-moving species that is unlikely to be able to evade vehicles quickly. Feeds on carrion, and may forage for roadkill occurring on the road or road verge. Given home range size, they are likely to be rare in the landscape, however any strike is likely to impact the local population, due to low numbers.
Mammals		
Eastern Pygmy-possum (*Cercartetus nanus*)	Average for females: 0.38 hectares Average for males: 0.68 hectares, but up to 19.50 hectares (Law et. al., 2013)	Moderate. A semi-arboreal species but is known to traverse along the ground. A review of road strike data in the Northern Beaches local government area found Eastern Pygmy-possum recorded on the roadside of the Wakehurst Parkway, with an additional sighting as roadkill on Morgan Road, Belrose and another in the residential area of Powderworks Road in Elanora Heights beneath the Warriewood Escarpment (SMEC, 2011). This species is also likely to be under-represented in roadkill data.

Species	Home range	Likelihood of vehicle strike
Southern Brown Bandicoot (eastern) (*Isoodon obesulus obesulus*)	0.5-9 hectares, individuals can go several hundred metres at a time within that range, as summarised in Li et. al., (2015)	Moderate. Likelihood is increased if road transects home range of an individual, which would be at risk of vehicle strike during nocturnal foraging activities

There are few accounts of individual roadkill specific to the species listed in Table 5.18, however larger, more conspicuous species such as possums and swamp wallabies are regularly recorded as roadkill along the Wakehurst Parkway (eg there are at least 20 records of roadkill possums that could use the crossings recorded since 1 January 2017(wildlifemapping.org/views/map: accessed October 2021).

The four threatened species (Table 5.18) that could potentially be at risk of vehicle strike are likely to be more difficult to detect and their remains more likely to be removed before detection than conspicuous, common species (Santos, Carvalho and Mira, 2011), however impacts from vehicle strike are possible for all of these species and mitigation to reduce vehicle strike should be implemented. This is detailed in Section 6.

Table 5.19 Impacts on habitat connectivity and the movement of threatened species

Species	Areas of connectivity and movement requirements	Nature, extent and duration of short and long-term impacts to connectivity	Importance of the area of connectivity within the bioregion	Consequences of the impacts for the local and bioregional persistence of the species
Amphibians				
Red-crowned Toadlet (*Pseudophryne australis*)	Native vegetation occurring to the east and west of the Wakehurst Parkway	Realignment and upgrade of the Wakehurst Parkway would require the permanent removal of habitat currently adjoining the road. The habitat gap is currently about 12 to 15 metres. This gap would increase to about 35 to 40 metres in the southern portion of the Wakehurst Parkway, and about 18 to 20 metres in the northern portion of the Wakehurst Parkway.	The Wakehurst Parkway is currently a barrier to fauna movement between a large area of habitat in Garigal National Park to the west, and Manly Warringah War Memorial State Park to the east. The species may attempt to cross the Wakehurst Parkway to access foraging, breeding habitat, or to find mates or disperse from their natural range.	Minimal. Though the project would increase the gap between areas of habitat along the Wakehurst Parkway, there would be no additional barriers to movement. A dedicated underpass would be provided at the location of potential habitat for the species, designed to facilitate the crossing of this species and frog fencing would be added to the fauna exclusion fencing within identified Red-crowned toadlet habitat to exclude the species from the Wakehurst Parkway and prevent road strike.
Reptiles				
Rosenberg's Goanna (*Varanus rosenbergi*)	Native vegetation occurring to the east and west of the Wakehurst Parkway	Widening of the Wakehurst Parkway would require the permanent removal of habitat currently adjoining the road. The habitat gap is currently about 12 to 15 metres. This gap would increase to about 35 to 40 metres in the southern portion of the Wakehurst Parkway, and about 18 to 20 metres in the northern portion of the Wakehurst Parkway.	The Wakehurst Parkway is currently a barrier to fauna movement between a large area of habitat in Garigal National Park to the west, and Manly Warringah War Memorial State Park to the east. The species may attempt to cross the Wakehurst Parkway to access foraging, breeding habitat, or to find mates or disperse from their natural range.	Minimal. Fauna exclusion fencing to be installed would prevent fauna from accessing the road and being subjected to vehicle strike. The fauna exclusion fence should also guide animals to move along the fence toward a number of underpasses that will be provided beneath the Wakehurst Parkway, designed to facilitate the safe crossing of this species beneath the road.

Species	Areas of connectivity and movement requirements	Nature, extent and duration of short and long-term impacts to connectivity	Importance of the area of connectivity within the bioregion	Consequences of the impacts for the local and bioregional persistence of the species
Mammals				
Eastern Pygmy-possum (*Cercartetus nanus*)	Native vegetation occurring to the east and west of the Wakehurst Parkway	Widening of the Wakehurst Parkway would require the permanent removal of habitat currently adjoining the road. The habitat gap is currently about 12 to 15 metres. This gap would increase to about 35 to 40 metres in the southern portion of the Wakehurst Parkway, and about 18 to 20 metres in the northern portion of the Wakehurst Parkway.	The Wakehurst Parkway is currently a barrier to fauna movement between a large area of habitat in Garigal National Park to the west, and Manly Warringah War Memorial State Park to the east. The species may attempt to cross Wakehurst Parkway to access foraging, breeding habitat, or to find mates or disperse from their natal range.	Minimal. Fauna exclusion fencing to be installed for the full extent of the Wakehurst Parkway in the subject land and designed to exclude small fauna species from the road corridor, such as Eastern Pygmy-possum, which would prevent vehicle strike. The fauna exclusion fence should also guide animals to move along the fence toward a number of underpasses that would be provided beneath the Wakehurst Parkway, facilitating the safe crossing of fauna beneath the road. It would be designed to facilitate Eastern Pygmy-possum crossing \. A number of rope canopy bridges will be provided to facilitate the safe crossing of arboreal fauna above the road. Though the species has not been previously recorded on rope canopy bridges, it is possible the species could utilise rope bridges given their arboreal nature. Small marsupial mammals have previously been recorded using rope canopy bridges (eg Feathertail Glider, Antechinus sp.) (Sandpiper Ecological Surveys, 2018).

Species	Areas of connectivity and movement requirements	Nature, extent and duration of short and long-term impacts to connectivity	Importance of the area of connectivity within the bioregion	Consequences of the impacts for the local and bioregional persistence of the species
Southern Brown Bandicoot (eastern) (*Isoodon obesulus obesulus*)	Native vegetation occurring to the east and west of the Wakehurst Parkway			Minimal. Fauna exclusion fencing to be installed would prevent fauna from accessing the road and being subjected to vehicle strike, designed to exclude small fauna species from the road corridor. The fauna exclusion fence should also guide animals to move along the fence toward a number of underpasses that will be provided beneath the Wakehurst Parkway, designed to facilitate the safe crossing of this species beneath the road.

5.5 Impacts on Matters of National Environmental Significance

Four Matters of National Environmental Significance are known or considered highly likely to occur in the subject land: *Syzygium paniculatum*, Large-eared Pied Bat and Grey-headed Flying-fox were recorded in the subject land, while White-bellied Sea-Eagle is considered highly likely to occur in Middle Harbour. An additional Matter of National Environmental Significance, Coastal Upland Swamps in the Sydney Basin Bioregion, does not occur within the subject land but may be impacted by water table drawdown as a result of the project. Significant Impact Assessments have been completed for these matters and are provided in Annexure E.

The Significant Impact Assessment for *Syzygium paniculatum* concluded that the project would not have a significant impact on the species. The removal of one individual of the species from an area of disturbed habitat next to the Wakehurst Parkway does not comprise a significant proportion of the local population of the species or of its habitat in the surrounding locality.

The Significant Impact Assessment for White-bellied Sea-Eagle found that impacts to this species are not likely to be significant due to the small amount of potential foraging habitat that would be temporarily removed (due the construction of temporary cofferdams). This habitat would be reinstated upon the completion of construction.

The Significant Impact Assessment for Large-eared Pied Bat found that impacts to this species are not likely to be significant due indirect impacts to adjacent breeding habitat being temporary in nature and unlikely to lead to population decline. The project would remove approximately 13.51 hectares of potential foraging habitat for the species adjacent to the Wakehurst Parkway and the Burnt Bridge Creek Deviation. This habitat is subject to edge effects from the adjacent roads and, in the case of the Burnt Bridge Creek Deviation, residential development and the Balgowlah Golf Course. Its removal does not comprise a significant proportion of foraging habitat available to the species in the surrounding locality.

The Significant Impact Assessment for Grey-headed Flying-fox concluded that the project would not have a significant impact on the species. The removal of 20.52 hectares of vegetation, which contains varying abundance of the blossom and fruit trees that form part of the Grey-headed Flying-fox diet, does not comprises a significant proportion of foraging habitat available to the species in the surrounding locality. The Balgowlah Grey-headed Flying-fox camp is located in the vegetated area between Balgowlah Road and Burnt Bridge Creek Deviation, around 120 metres from the subject land. The project would not directly impact the camp as the camp is located outside of the subject land and no habitat would be removed from the camp.

The construction noise assessment identified that predicted construction noise at the camp would be similar to, or less than, noise levels generated by existing day time road traffic noise on the Burnt Bridge Creek Deviation. Some noise generating construction activities would result in worst case noise levels that would exceed existing day time road traffic noise levels on the Burnt Bridge Creek Deviation, as identified in Table 5-9. These activities include:

- Burnt Bridge Creek Deviation surface works (northbound)
- Burnt Bridge Creek Deviation surface works (southbound)
- Kitchener Street construction support site (BL11).

Construction noise impacts would be minimised by the following measures:

- Mitigation measures such as quieter construction methods or the use of temporary noise barriers in close proximity to the construction activities will be used wherever feasible and reasonable to minimise noise impacts to the Grey-headed Flying-fox camp. For the Kitchener Street construction support site (BL11), the arrangement of the site layout would maximise acoustic shielding (ie locations of site sheds, offices and fixed structures) to minimise noise impacts from within the site to the direction of the Grey-headed Flying-fox camp.
- Where feasible and reasonable, noise intensive works with the potential of impacting the Grey-headed Flying-fox camp (ie demolition involving rock hammering or resurfacing works) will be programmed to avoid September to February.

- Where works cannot be avoided, reasonable and feasible management measures would be deployed in consultation with a suitability qualified ecologist and a monitoring plan implemented. The monitoring plan would involve behavioural monitoring at the camp during noisy activities by a suitability qualified ecologist, with mechanisms to stop work should adverse behaviours be observed.

The species could disperse to other camps in the surrounding locality if sufficiently disturbed by construction noise, although this would be unlikely, given that predicted construction noise impacts should be similar to existing noise levels, and measures are proposed to minimise noise impacts. If the species does disperse to alternative camps, Grey-headed Flying-foxes could re-occupy the Balgowlah camp during times of low construction noise, and/or upon the completion of construction of the project. The project is unlikely to introduce diseases or invasive species that would impact this species. As such the project does not require referral to DAWE in accordance with the EPBC Act.

The Significant Impact Assessment for Coastal Upland Swamps in the Sydney Basin Bioregion concluded that the project would not have a significant impact on this TEC. The project would not result in clearing of any areas of Coastal Upland Swamp, and most indirect impacts are also unlikely given that the mapped areas of the TEC are not in proximity to any surface works. Two areas mapped as the community are located above areas of predicted minor water table drawdown and may be subject to adverse impacts from the lowering of the groundwater table beneath them. As discussed in Attachment B of Annexure G of this updated biodiversity assessment, these areas of swamp are likely to be connected to perched water tables, rather than the regional aquifer, and it is therefore unlikely that Coastal Upland Swamp would be affected by water table drawdown as a result of the project. As such the project does not require referral to DAWE in accordance with the EPBC Act.

Sixty-four other threatened fauna species listed under the EPBC were identified as known or considered likely to occur in the subject land (as listed in Annexure A). The removal of flowering and fruiting trees, shrubs and ground layer vegetation as part of the project would result in the negligible loss of potential foraging and sheltering habitat to a number of threatened fauna species listed under the EPBC Act that are known or considered likely to occur in the subject land. The extent of terrestrial fauna habitat to be removed (around 13.98 hectares of PCTs and 6.80 hectares of other vegetation such as native plantings, urban native/exotic and native revegetation) does not comprise a substantial portion of foraging habitat available in the wider locality. Large tracts of habitat available in the wider locality, associated with native vegetation, are contained within Garigal National Park, Manly Warringah War Memorial State Park, Ku-ring-gai Chase National Park, Lane Cove National Park, smaller bushland reserves, golf courses, residential gardens and street trees.

Construction of the crossing of Middle Harbour as described in Chapter 5 (Project description) of the environmental impact statement has the potential to generate silt, disturb and mobilise contaminated sediment and increase the turbidity of waters within and near the subject land. This decrease in water quality may result in the degradation of foraging habitat for a number of threatened marine species listed under the EPBC Act known and likely to occur in the subject land, as assessed by Beaches Link and Gore Hill Freeway Connection Technical working paper: Marine ecology (Cardno, 2020b). Several installed floating silt curtains would be implemented to ensure turbidity and sedimentation of marine waters near construction activities would be minimal, localised and temporary.

5.6 Impacts on Groundwater dependent ecosystems

Water table drawdown would occur as a result of the project, because groundwater would flow into the project tunnels and lower pressure (and groundwater levels) in the surrounding aquifer (Jacobs, 2020b). Drawdown of the water table can cause wetlands to become recharge instead of discharge zones, altering the soil water regime and water chemistry, which then influences the vegetation and fauna communities. A prolonged period of drawdown can result in the disconnection of the root zone from the water table, resulting in the subsequent drying out of the ecosystem over time (Serov, Kuginis and Williams, 2012). Drawdown may also result in reductions in groundwater baseflow to connected surface water systems.

Based on the extent of water table drawdown as a result of the project, as described in Annexure G:

- Some of the areas of groundwater dependent ecosystems (as mapped by BOM (2018)) that adjoins Flat Rock Creek would be subject to water table drawdown impacts. Water table drawdown in this area would also impact the baseflow of Flat Rock Creek and Quarry Creek
- No high priority groundwater dependent ecosystems as identified by NSW Office of Water (2011) are located in the subject land or adjacent areas. The closest high priority groundwater dependent ecosystem to the subject land is Coastal Saltmarsh, mapped around 540 metres to the west of the Wakehurst Parkway section of the subject lands by OEH (2016). The project would not result in direct or indirect impacts to this area of Coastal Saltmarsh
- Areas of Coastal Upland Swamp in the Sydney Basin Bioregion, which may be sensitive to changes to groundwater flows, would be subject to potential water table drawdown impacts.

About 10.50 hectares of PCT 1778: Coastal Sandstone Foreshores Forest, PCT 1841: Coastal enriched sandstone moist forest and PCT 1828: Coastal Sandstone Gallery Rainforest, is mapped by OEH (2016) within the area of predicted water table drawdown. The area adjoins Flat Rock Creek and is mapped as having moderate to high potential for groundwater interaction. The mapped area of vegetation extends from elevations of 0 metres AHD along Flat Rock Creek to 40 metres AHD on steep gully slopes.

As discussed in Annexure G, drawdown beneath this vegetation is predicted to be less than five metres at the upstream end of Flat Rock Creek, about 11 metres at the upstream end of Quarry Creek, and less than one metre at the confluence of Flat Rock Creek and Quarry Creek. However, it should be noted that these values of estimated drawdown are based on the conservative approach of the tunnel being unlined, having no measures to limit inflow. Vegetation growing on the upper slopes of the sandstone ridges is likely to be supported by perched aquifers that are isolated from the regional water table. Drawdown in the regional aquifer is therefore likely to have minor spatial impacts on vegetation health, so the magnitude of risk would be small given that the vegetation community is not solely dependent on regional groundwater.

The small alluvial aquifer of Flat Rock Creek at the Quarry Creek confluence would be recharged by the releases of up to about 1425 kilolitres per day of treated water from the project operational wastewater treatment plant discharge into Flat Rock Creek at Artarmon. This may replace any baseflow losses and sustain vegetation communities dependent on groundwater in the shallow alluvium.

Coastal Upland Swamp in the Sydney Basin Bioregion may also be sensitive to changes to groundwater flows. This TEC would not be directly impacted by the project. The closest mapped patch of Coastal Upland Swamp is 95 metres west of the Wakehurst Parkway in Garigal National Park. As stated in Attachment B of Annexure G of this report, drawdown beneath this patch is modelled to be between zero and one metre by 2028 and for the subsequent 100 modelled years. The groundwater dependence of this swamp is uncertain, as the water level is currently approximately 10 metres below ground level. The water table beneath this swamp may be affected by drawdown, but it is likely that the swamp receives water from surface runoff and subsurface drainage from upslope perched aquifers, and that the availability of this water to support the swamp would not be affected.

Another small (0.07 hectare) area of Coastal Upland Swamp was identified north of Bantry Bay Oval. Groundwater drawdown beneath this vegetation is modelled to be less than three metres. The regional water level is approximately 50 metres below ground level, so this swamp is likely to be connected to perched water tables, rather than the regional aquifer. Perched aquifers are predominantly fed by localised rainwater, or from downward drainage from upslope aquifers. It is therefore unlikely that this section of upland swamp would be affected by drawdown from the project (see Attachment B of Annexure G of this report for further detail).

As noted in Section 3.8, Burnt Bridge Creek has been considered a low ecological value groundwater dependent ecosystem. However, with consideration of the additional groundwater modelling in Annexure G, the percentage of potential baseflow loss is considered a low level of risk to Burnt Bridge Creek and unlikely to have a significant impact.

5.7 Impact summary

Table 5.20 provides standard list of the impacts considered in the updated biodiversity assessment and provides a summary of the impact assessment carried out, as well as which impacts require offsetting.

Table 5.20 Summary of impacts

Impact	Biodiversity values	Nature of impact	Extent of impact	Duration
Removal of 12.77 hectares of native vegetation, comprising PCTs (non-TEC)	PCT 1250: Sydney Peppermint – Smooth-barked Apple – Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion PCT 1783: Red Bloodwood – Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast PCT 1824: Mallee – Banksia – Tea-tree – Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin PCT 1841: Smooth-barked Apple – Turpentine – Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region PCT 1845: Smooth-barked Apple – Red Bloodwood – Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney.	Direct	Site based	Long term
Removal of 1.21 hectares of TEC	PCT 1786: Red Bloodwood – Silvertop Ash - Stringybark open forest on ironstone in the Sydney region consistent with Duffys Forest TEC.	Direct	Site based	Long term
Removal of 20.52 hectares threatened fauna species habitat and habitat features	Native vegetation, native revegetation and plantings providing potential threatened fauna species habitat.	Direct	Site based	Long term
Removal of threatened plants	*Syzygium paniculatum* (Magenta Lilly Pilly) (one individual).	Direct	Site based	Long term
Aquatic impacts	Potential impacts on water quality of Flat Rock Creek during drainage works associated with an upstream tributary of Flat Rock Creek. Temporary minor loss of aquatic habitat values during localised adjustment of Burnt Bridge Creek.	Direct and indirect	Site based	Short term and during construction

Impact	Biodiversity values	Nature of impact	Extent of impact	Duration
Groundwater dependent ecosystems	Low potential groundwater dependent ecosystems at Flat Rock Creek and Coastal Upland Swamp have the potential to be impacted by water table drawdown.	Indirect	Local	Long-term
Changes to hydrology	Temporary minor loss of aquatic habitat values during localised adjustment of Burnt Bridge Creek.	Direct	Site based	Short-term and during construction
Fragmentation of identified biodiversity links and habitat corridors	Areas of habitat adjoining the Wakehurst Parkway.	Direct	Local	Long-term
Edge effects on 8.33 hectares of adjacent native vegetation and habitat	Native vegetation and fauna habitat to be retained next to the subject land.	Indirect	Site based	Long-term
Injury and mortality of fauna	Protected any threatened species that may occur in the subject land.	Direct	Site based	During construction and operation
Invasion and spread of weeds	Native vegetation and fauna habitat to be retained next to and/or near the subject land.	Indirect	Site based	During construction
Invasion and spread of pests	Native vegetation and fauna habitat to be retained next to and/or near the subject land.	Indirect	Local	During construction
Invasion and spread of pathogens and disease	Native vegetation and fauna habitat to be retained next to and/or near the subject land.	Indirect	Site based	During construction
Noise, light and vibration	Protected and threatened fauna species that may occur within the subject land on a temporary, transient or permanent basis. Fauna adjacent to the Wakehurst Parkway would be subject to potential noise and vibration impacts from rock hammering and potentially, controlled blasting.	Direct/ indirect	Local	During construction

6 Environmental Management Measures

Biodiversity impacts cannot be avoided for many aspects of the project. As such, the measures listed in Table 6.1 should be implemented to minimise impacts on terrestrial biodiversity.

Management measures that relate to avoiding, minimising and mitigating impacts in marine environments (ie Middle Harbour) and freshwater environments are included in Table D2-1 of the submissions report. While measures pertaining to marine ecology, surface water quality and hydrology and groundwater are not duplicated in Table 6.1, these measures would also be relevant to avoiding, minimising and mitigating impacts on wandering seabirds, shorebird species, Little Penguin and Red-crowned Toadlet and their habitats within and near the subject land.

The BAM requires consideration of the timing, frequency, responsibility and risk of failure of management measures, and of the risk and consequence of any residual impacts. Accordingly:

- Environmental management measures would mostly be implemented prior to or during construction of the project
- The responsibility of implementing environmental management measures would be allocated to either the contractor/s or Transport for NSW
- No measures listed in Table 6.1 are anticipated to be at risk of failure.

Further, monitoring requirements are included in Table 6.1, where adaptive management may be required and to determine the effectiveness of environmental management measures (eg proposed fauna connectivity measures and measures to minimise impacts on Grey-headed Flying-foxes).

While Section 4 describes how impacts on biodiversity have been avoided, and Table 6-1 outlines how impacts on biodiversity would be minimised, the project would have residual impacts on biodiversity. A residual impact is any impact on a biodiversity value, after all reasonable measures have been taken to avoid and minimise the impact. In accordance with the BAM, offset requirements must be calculated for residual impacts on biodiversity. Section 7 outlines the offsets that have been calculated for residual impacts of the project on native vegetation, threatened flora and fauna species and aquatic habitat.

Table 6.1 Environmental management measures

Impact	Environmental management measure
Impacts on flora and fauna	Biodiversity awareness training will be provided for contractors prior to commencement of construction works to ensure an understanding of potential threatened species, populations and ecological communities that may be impacted during the project, and the environmental management measures proposed to minimise and/or manage potential impacts including the contractor's responsibilities under the unexpected species finds procedures included in *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).
	Exclusion zones will be set up at the limit of clearing in accordance with *Guide 2: Exclusion zones* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA 2011).
Removal of native vegetation and threatened species habitat	Vegetation removal including the clearing of native vegetation and fauna habitat will be further minimised during further design development and detailed construction planning to the extent reasonably practicable.
	Vegetation removal along the Wakehurst Parkway will be timed to avoid the winter breeding period for the Eastern Pygmy-possum (May to July), where feasible and reasonable.
	Vegetation removal will be carried out in accordance with *Guide 4: Clearing of vegetation and removal of bushrock* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).
	The unexpected species find procedure included in *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011) will be followed if threatened ecological communities, flora or fauna species, not assessed in the biodiversity assessment, are identified in the subject land.
	Vegetation will be re-established within the subject land, where feasible, in accordance with *Guide 3: Re-establishment of native vegetation* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).
	Pre-clearing surveys for threatened fauna species will be carried out in accordance with *Guide 1: Pre-clearing process* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011). This will include inspections of hollows and dead timber for Eastern Pygmy-possum. Surveys will also include human made structure that have been identified as potentially providing habitat for microbats and are subject to demolition or modification.
	The area required and layout of Flat Rock Drive construction support site (BL2) will be refined during further design development and detailed construction planning to avoid direct impacts on PCT 1841, where feasible and reasonable.
	During site establishment of the Wakehurst Parkway north construction support site (BL14), the project will ensure that the revegetated area within the eastern section of the site (planted as part of the Northern Beaches Hospital road upgrade project with species consistent with Duffys Forest endangered ecological community) is fenced adequately so that it is avoided and protected from disturbance during construction. During operation, this revegetation area will continue to be protected and managed.

Impact	Environmental management measure
Removal of threatened flora species	Pre-clearing surveys for threatened flora species will be carried out in accordance with *Guide 1: Pre-clearing process* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).
	Prior to clearing, the location of the individual of *Syzygium paniculatum* next to the Wakehurst Parkway will be confirmed. If the individual is outside the construction footprint, but in close proximity to the boundary, the need for a site-specific exclusion zone will be investigated to minimise potential indirect impacts. Should the individual be within the construction footprint, further design investigation will be carried out to determine if impacts can be avoided where reasonable and feasible.
	The unexpected species find procedure will be followed under *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011) if threatened flora species, not assessed in the biodiversity assessment, are identified in the subject land.
Construction noise, vibration and light	Mitigation measures such as quieter construction methods or the use of temporary noise barriers in close proximity to the construction activities will be used wherever feasible and reasonable to minimise noise impacts to the Grey-headed Flying-fox camp. For the Kitchener Street construction support site (BL11), the arrangement of the site layout will maximise acoustic shielding (ie locations of site sheds, offices and fixed structures) to minimise noise impacts from within the site to the direction of the Grey-headed Flying-fox camp.
	Where feasible and reasonable, noise intensive works with the potential of impacting the Grey-headed Flying-fox camp (ie demolition involving rock hammering or resurfacing works) will be programmed to avoid September to February.
	A person experienced in flying-fox behaviour (ie able to identify each stage of the reproductive cycle, ABLV-vaccinated and trained to rescue flying-foxes if required) will monitor disturbance levels within the Grey-headed Flying-fox camp at Balgowlah during construction activities that result in noise levels at the camp that exceed the pre-construction ambient noise levels. Monitoring would occur at representative periods (eg fortnightly) while pups are being carried (August-February).
	Adaptive management measures to minimise impacts on Grey-headed Flying-foxes will be developed in consultation with Department of Planning, Industry and Environment (Environment, Energy and Science) and an appropriately qualified expert in Grey-headed Flying-fox biology and behaviour, if Grey-headed Flying-fox behaviour during monitoring suggests that disturbance levels are high.
	Artificial light impacts on native fauna in the operational phase of the project will be minimised to the extent reasonably practicable through further design development, where the project adjoins tracts of fauna habitat (eg along the Wakehurst Parkway) consistent with the requirements of Australian Standard *AS 4282 – 2019 Control of obtrusive effects of outdoor lighting* (Standards Australia, 2019).
	Activity-specific controls will be developed to manage impacts from high noise and vibration generating activities (eg controlled blasting and rock hammering) on Large-eared Pied Bat along the Wakehurst Parkway. The controls will be prepared in consultation with a suitably qualified and experienced microbat specialist and implemented during surface road works as required.

Impact	Environmental management measure
	Controlled blasting, rock hammering and other potential high noise generating activities along the Wakehurst Parkway will be managed to minimise noise and vibration levels to adjacent fauna habitat where practicable, including but not limited to: • Use of noise suppression devices on plant and equipment in accordance with the manufacturer's specifications • Regularly maintain plant and equipment to minimise noise levels when in use. • Substituting plant or processes to reduce noise.
Injury and mortality of fauna	Fauna will be managed in accordance with *Guide 9: Fauna handling of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).
	Pre-clearing surveys for non-threatened fauna species will be carried out in accordance with *Guide 1: Pre-clearing process* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011). Surveys will also include human made structures that have been identified as potentially providing habitat for microbats and are subject to demolition or modification.
	An observer appropriately trained to spot Little Penguins will be used during marine construction activities. A stop-work procedure would be developed in consultation with a suitably qualified and experienced ecologist and implemented upon evidence of the species in the proximity of the works area.
	Connectivity measures will be designed during further design development in accordance with the *Wildlife Connectivity Guidelines: Managing wildlife connectivity of road projects (Draft)* (Roads and Maritime, 2011), taking into account best available knowledge and consider measures to facilitate the crossing of threatened fauna species including the Eastern Pygmy-possum, Red-crowned Toadlet, Southern Brown Bandicoot and Rosenberg's Goanna. Maintenance requirements for fauna crossings and fauna exclusion fencing will be developed during further design development and incorporated into an Operational Environmental Management Plan or existing Environmental Management System as relevant.
	Fauna exclusion fencing will be designed to exclude small fauna species from the road corridor such as Eastern Pygmy-possum and will be installed for the full extent of Wakehurst Parkway within the subject land. In addition, frog fencing will be added to the fauna exclusion fencing within identified Red-crowned Toadlet habitat. The design specifications of the fauna exclusion fence will be developed during further design development including the need for access gates to manage any fauna on the road side of fauna exclusion fence based on best available knowledge from other Transport for NSW projects¸ and in consultation with NSW National Parks and Wildlife Service and Northern Beaches Council.
	Monitoring will occur during pre-construction, construction and post-construction phases of the project to determine the effectiveness of the proposed fauna connectivity measures and exclusion fencing to be provided as part of the project. Pre-construction baseline monitoring will commence prior to project construction works impacting fauna habitat adjacent to the Wakehurst Parkway and include adequate sampling of threatened and protected targeted fauna species in line with relevant guidelines.

Impact	Environmental management measure
	A construction/post-construction ecological monitoring program will be developed prior to construction in consultation with Department of Planning, Industry and Environment (Environment, Energy and Science Group) and Northern Beaches Council. The program will include monitoring of targeted fauna species, threatened or protected species, and pest species, in addition to key performance criteria that trigger the need for and feasibility of potential corrective actions. The program will consider the pre-construction baseline monitoring results and ecological monitoring data collected for the Northern Beaches Hospital road upgrade project where relevant. Post-construction monitoring will extend for 10 years after the opening of the project.
	Removal of the existing fauna fencing installed as part of the Northern Beaches Hospital road upgrade project will be avoided where possible in overlapping construction areas. Where this is not possible, temporary fauna fencing will be installed during construction to ensure fauna are guided to existing underpasses and away from construction areas and/or live traffic.
Invasion and spread of weeds, pests, pathogens and disease	Weed species will be managed in accordance with *Guide 6: Weed management* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).
	Pathogens will be managed in accordance with *Guide 7: Pathogen management* of the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011).
Water table drawdown impact on groundwater dependent ecosystems	Following completion of environmental management measure SG2 from Table D2-1 of the submissions report, a focussed study will be carried out consultation with Department of Planning, Industry and Environment (Environment, Energy and Science Group) to confirm potential baseflow reductions at Burnt Bridge Creek, Flat Rock Creek and Quarry Creek due to groundwater drawdown, and whether this might have an increased effect on freshwater ecology in the affected watercourses and nearby groundwater dependent ecosystems. The study will consider how existing site features affect the interaction between surface water and groundwater along the affected reaches of these watercourses, and the hydraulic connectivity in the underlying geology. Where ecological impacts are predicted to be worse than that presented as part of the environmental impact statement/submissions report, feasible and reasonable mitigation measures to address the impacts will be identified in consultation with a suitably qualified and experienced specialist, incorporated into the detailed design, and implemented during construction. The mitigation measures considered will include tunnel linings.

7 Offsetting required

7.1 Offset credit requirements under the Biodiversity Offsets Scheme

7.1.1 Ecosystem credits

The ecosystem credits required to offset the direct impacts of the project, as determined using the BAM credit calculator, are listed in Table 7.1. A total of 383 ecosystem credits are required to offset the direct impacts of the project.

Offsets for indirect impacts are in addition to BAM credit obligations and are at the discretion of the Minister for Planning and Public Spaces (DPIE, 2019). For indirect impacts resulting in isolated patches, offsets were calculated by reducing vegetation integrity values for these areas to zero, effectively treating these areas as direct impacts. For indirect impacts resulting in new edges, offsets were calculated based on a percentage of the biodiversity credit value of the affected patches. The vegetation integrity value within these areas is conservatively estimated to be reduced by 20 per cent, as an average along the 20 metres from the edge of the area directly impacted. This level of vegetation integrity reduction is likely to be appropriate given the varying vegetation integrity across the construction footprint and the extent of proposed environmental management measures, which should mitigate some of the potential indirect impacts of the project.

The number of ecosystem credits calculated for the potential indirect impacts of the project is 45, with details provided in Table 7.2 below.

The full biodiversity offset credit reports are provided in Annexure F of this report. Figure 7-1 identifies the areas within and adjoining the subject land that require biodiversity offsets.

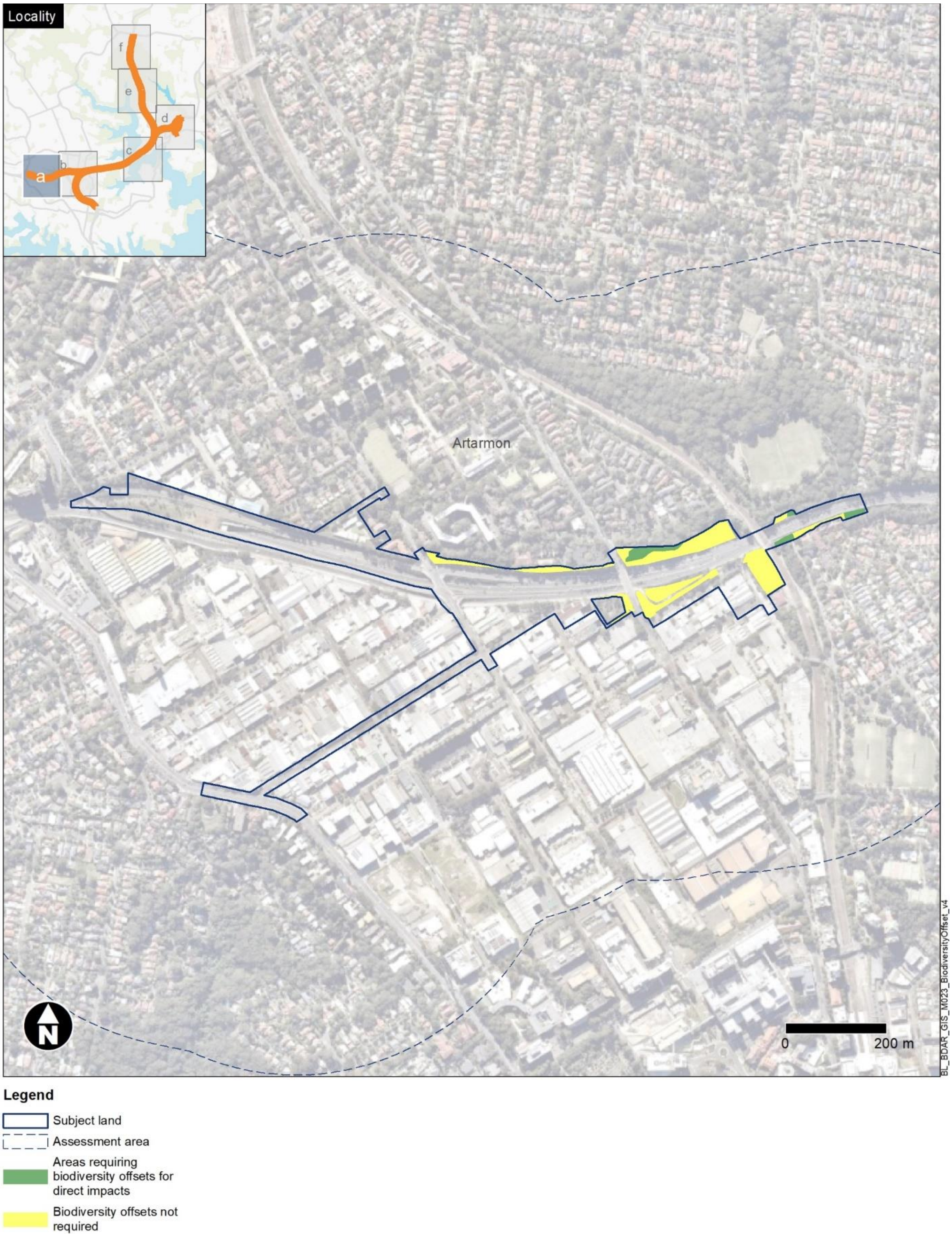


Figure 7-1 Offsetting requirements (map a)

Legend

- Subject land
- Assessment area
- Areas requiring biodiversity offsets for direct impacts
- Biodiversity offsets not required

Figure 7-1 Offsetting requirements (map b)

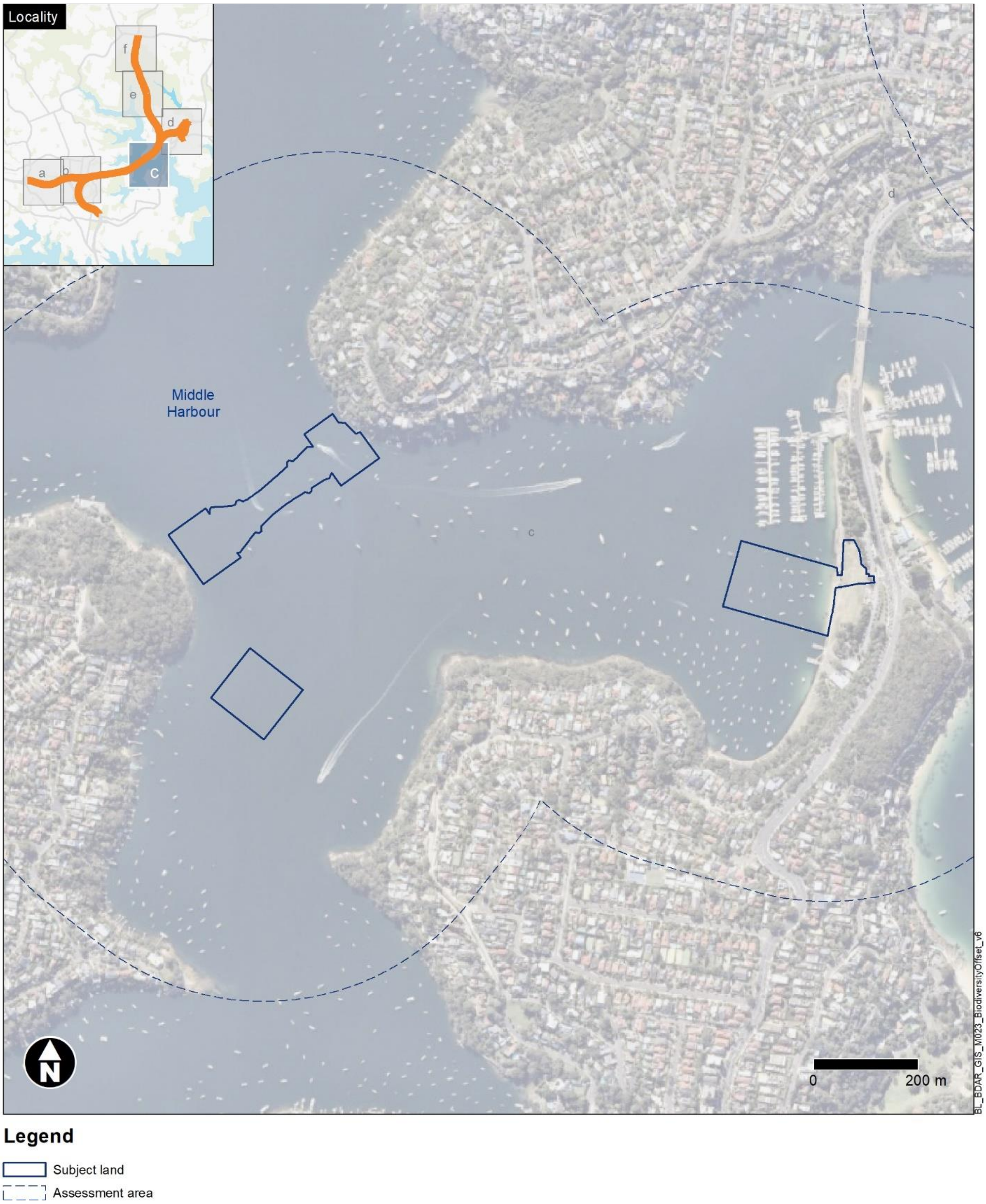
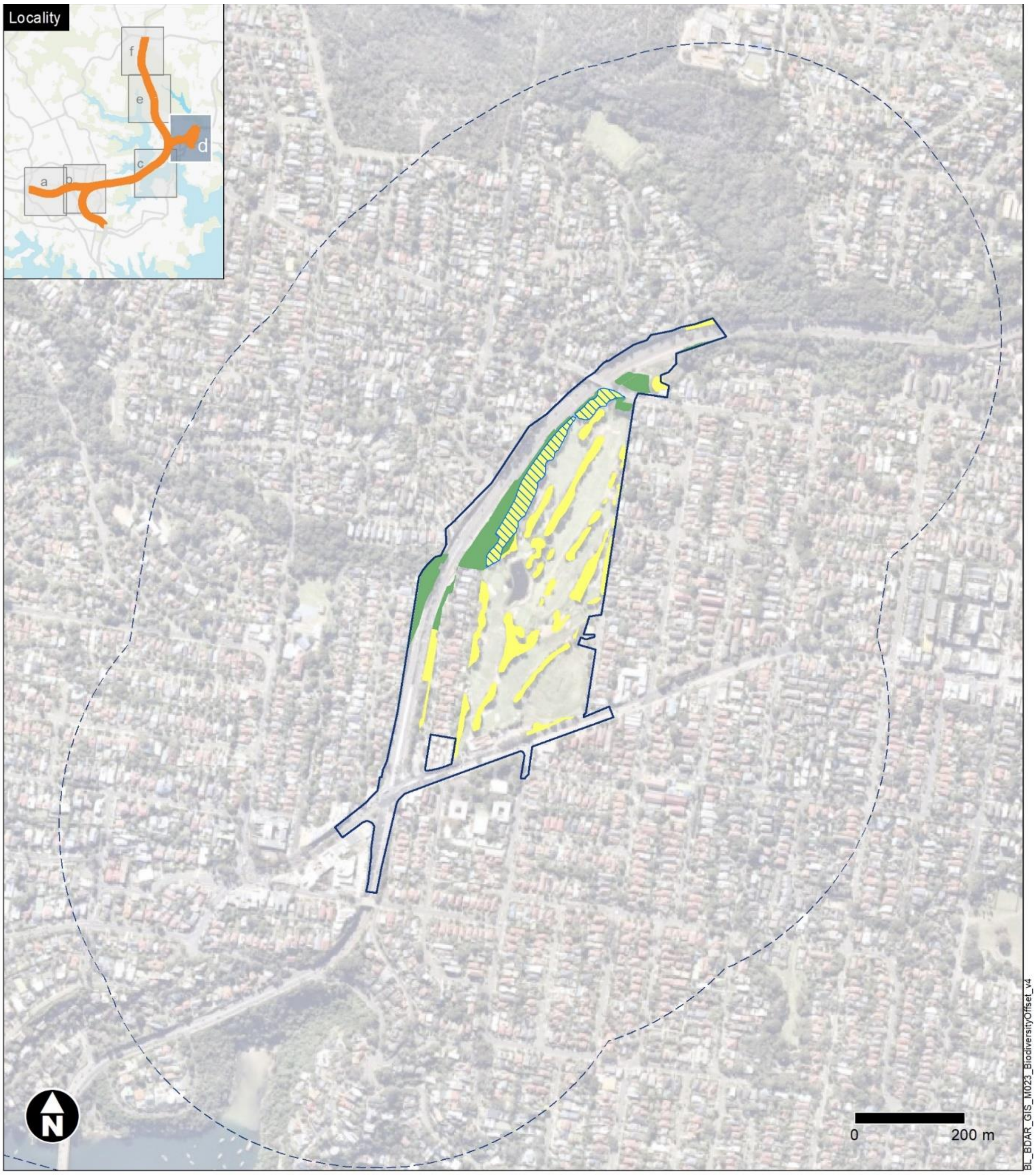


Figure 7-1 Offsetting requirements (map c)



Legend

Subject land

Assessment area

Exclusion zone

Areas requiring biodiversity offsets for direct impacts

Biodiversity offsets not required

Figure 7-1 Offsetting requirements (map d)

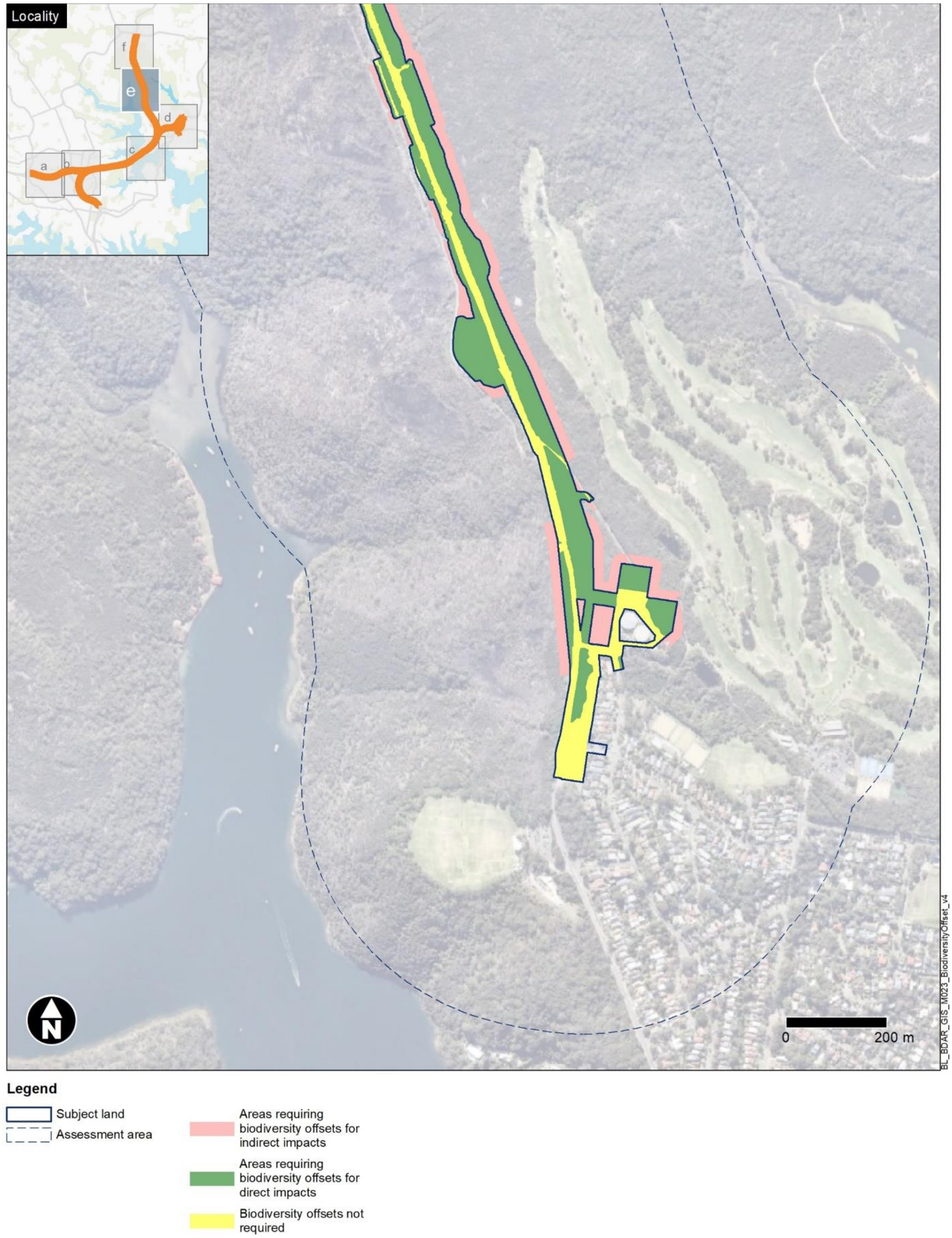
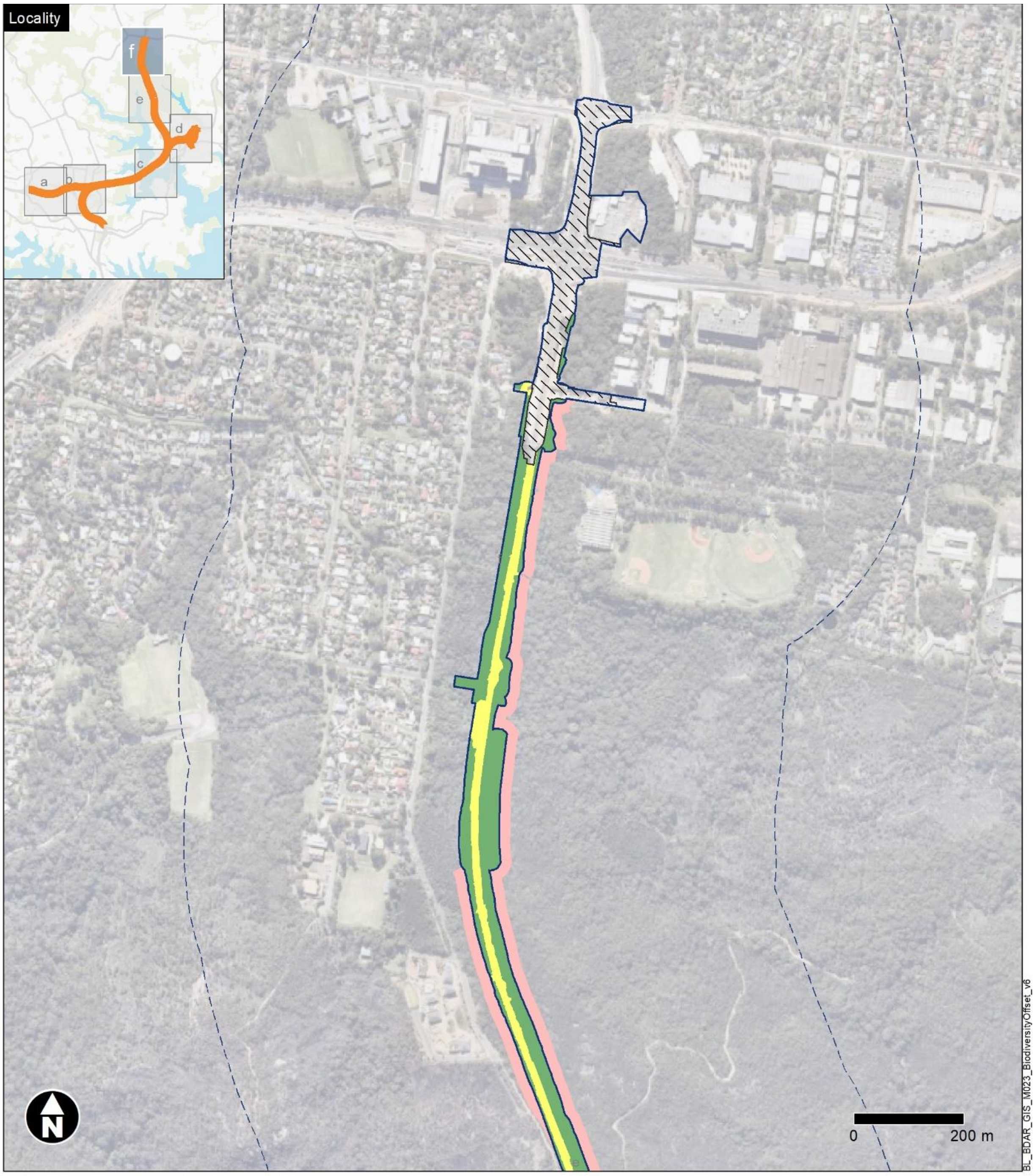


Figure 7-1 Offsetting requirements (map e)



Legend

- Subject land
- Assessment area
- Area not assessed by the updated biodiversity assessment
- Areas requiring biodiversity offsets for indirect impacts
- Areas requiring biodiversity offsets for direct impacts
- Biodiversity offsets not required

Figure 7-1 Offsetting requirements (map f)

Table 7.1 Ecosystem credits - direct impacts

Zone	PCT name	Vegetation integrity loss	Area impacted (ha)	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Ecosystem credits required
1250 Moderate/ Good - Good	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	82.5	0.20	High	1.50	6
1250 Moderate/ Good - Moderate		54	0.40	High	1.50	8
1783 Moderate/ Good	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	62.9	4.23	High	1.50	100
1786 Moderate/ Good - Good	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (Duffys Forest EEC)	69.1	0.84	High	2.00	29
1786 Moderate/ Good - Moderate		40.5	0.37	High	2.00	7
1824 Moderate/ Good	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	66.4	6.18	High	1.50	154
1841 Moderate/ Good	Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	65.3	1.37	High	1.75	39
1841_Revegetation		37.7	1.29	High	1.75	21
1845 Moderate/ Good	Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	78.1	0.39	High	2.50	19
Total						**383**

Table 7.2 Ecosystem credits - indirect impacts

Zone	PCT name	Vegetation integrity loss	Area impacted (ha)	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Ecosystem credits required
Isolated patches						
1783 Moderate/ Good	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	62.9	0.05	High	1.50	1
1824 Moderate/ Good	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	66.4	0.01	High	1.50	1
New edges						
1250 Moderate/ Good - Good	Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	16.5	0.22	High	1.50	1
1783 Moderate/ Good	Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	12.58	2.59	High	1.50	12
1786 Moderate/ Good - Good	Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region (Duffys Forest TEC)	13.82	1.26	High	2.00	9
1824 Moderate/ Good	Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	13.28	4.20	High	1.50	21
Total						**45**

7.1.2 Species credits

The species credits required to offset the impacts of the project, as determined using the BAM credit calculator, are listed in Table 7.3.

Table 7.3 Species credits summary

Species	Vegetation zone name	Area per vegetation zone	Individuals/ total area	Biodiversity risk weighting	Species credits
Syzygium paniculatum (Magenta Lilly Pilly)	1250_Mod_Good-Good	N/A	1 individual	2	2
Red-crowned Toadlet (*Pseudophryne australis*)	1250_Mod_Good-Good 1783_Mod_Good 1786_Mod_Good-Moderate 1824_Mod_Good	0.20 ha 0.66 ha 0.07 ha 0.05 ha	0.98 ha	1.5	24
Eastern Pygmy-possum (*Cercartetus nanus*)	1250_Mod_Good-Good 1783_Mod_Good 1786_Mod_Good-Good 1786_Mod_Good-Moderate 1824_Mod_Good 1845_Mod_Good	0.20 ha 4.23 ha 0.84 ha 0.37 ha 6.18 ha 0.39 ha	12.21 ha	2	397
Large-eared Pied-bat (*Chalinolobus dwyeri*)	1250_Mod_Good-Good 1250_Mod_Good-Moderate 1783_Mod_Good 1786_Mod_Good-Good 1786_Mod_Good-Moderate 1824_Mod_Good 1841_Mod_Good 1845_Mod_Good	0.20 ha 0.40 ha 4.23 ha 0.84 ha 0.37 ha 6.18 ha 0.90 ha 0.39 ha	13.51 ha	3	658
Total					**1081**

7.1.3 Like-for-like and variation credits

The BAM credit calculator generated two reports prescribing the offset options for each credit class: a like-for-like credit report and a variation credit report. These reports set out the PCT classes, trading groups, requirement for offsets to contain hollow-bearing trees (HBTs) and IBRA subregions that ecosystem credits must be sourced from, and the species and IBRA subregions that species credits must be sourced from, in order to satisfy the offset obligation.

For like-for-like offsets, credits must be sourced from the Pittwater, Cumberland, Sydney Cataract, Wyong and Yengo subregions or any IBRA subregion that is within 100 kilometres of the outer edge of the impacted site.

For variation offsets, credits must be sourced from the Sydney Basin IBRA Region, or any IBRA subregion that is within 100 kilometres of the outer edge of the impacted site.

The like-for-like and variation offset options for ecosystem credits are listed in Table 7.4. The like-for-like and variation offset options for species credits are listed in Table 7.5.

Table 7.4 Like-for-like and variation offset options for ecosystem credits

PCT name	Credits required (direct impacts)	Credits required (indirect impacts)	HBTs required?	PCTS listed in credit report that can be used for like for like offsets	Variation offset options
1250: Sydney Peppermint - Smooth-barked Apple - Red Bloodwood shrubby open forest on slopes of moist sandstone gullies, eastern Sydney Basin Bioregion	14	2	Yes	Sydney Coastal Dry Sclerophyll Forests (including PCTs 1083, 1138, 1156, 1181, 1183, 1250, 1253, 1619, 1620, 1621, 1623, 1624, 1625, 1627, 1632, 1636, 1638, 1642, 1643, 1681, 1776, 1777, 1778, 1780, 1782, 1783, 1785, 1786, 1787)	Any PCT in the Dry Sclerophyll Forests formation (Shrubby subformation) in a Tier 4 or higher trading group Must include HBTS (including artificial)
1783: Red Bloodwood - Scribbly Gum/Old-man Banksia open forest on sandstone ridges of northern Sydney and the Central Coast	100	15	No	Sydney Coastal Dry Sclerophyll Forests (as per list for 1250)	Any PCT in the Dry Sclerophyll Forests formation (Shrubby subformation) in a Tier 4 or higher trading group
1786: Red Bloodwood - Silvertop Ash - Stringybark open forest on ironstone in the Sydney region	36	9	Required for 7 credits only	Duffys Forest Ecological Community in the Sydney Basin Bioregion (including PCT 1786)	Any PCT in the Dry Sclerophyll Forests formation (Shrubby subformation) in a Tier 3 or higher trading group (EEC or higher conservation status) HBTS (including artificial) required for 7 credits only.
1824: Mallee - Banksia - Tea-tree - Hakea heath-woodland of the coastal sandstone plateaus of the Sydney basin	154	22	No	Sydney Coastal Heaths (including PCTs 772, 881, 882, 1134, 1143, 1641, 1822, 1823, 1824, 1826)	Any PCT in the Heathlands formation in a Tier 4 or higher trading group
1841: Smooth-barked Apple - Turpentine - Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region	60	0	No	North Coast Wet Sclerophyll Forests (including PCTs 661, 686, 694, 1217, 1237, 1244, 1285, 1841, 1843, 1915	Any PCT in the Wet Sclerophyll Forests formation (Shrubby subformation) in a Tier 3 or higher trading group

PCT name	Credits required (direct impacts)	Credits required (indirect impacts)	HBTs required?	PCTS listed in credit report that can be used for like for like offsets	Variation offset options
1845: Smooth-barked Apple - Red Bloodwood - Blackbutt tall open forest on shale sandstone transition soils in eastern Sydney	19	0	Yes	Northern Hinterland Wet Sclerophyll Forests (including PCTs 1281, 1845)	Any PCT in the Wet Sclerophyll Forests formation (Grassy subformation) in a Tier 1 trading group Must include HBTS (including artificial)

Table 7.5 Like-for-like and variation offset options for species credits

Species	Credits required	Like-for-like offset options	Variation offset options
Syzygium paniculatum (Magenta Lilly Pilly)	2	*Syzygium paniculatum* Anywhere in NSW	Any plant species with endangered or higher conservation status Located in the Pittwater, Cumberland, Sydney Cataract, Wyong and Yengo IBRA subregions, or any IBRA subregion that is within 100 kilometres of the outer edge of the impacted site.
Red-crowned Toadlet (*Pseudophryne australis*)	24	Red-crowned Toadlet Anywhere in NSW	Any fauna species with vulnerable or higher conservation status Located in the Pittwater, Cumberland, Sydney Cataract, Wyong and Yengo IBRA subregions, or any IBRA subregion that is within 100 kilometres of the outer edge of the impacted site.
Eastern Pygmy-possum (*Cercartetus nanus*)	397	Eastern Pygmy-possum Anywhere in NSW	Any fauna species with vulnerable or higher conservation status Located in the Pittwater, Cumberland, Sydney Cataract, Wyong and Yengo IBRA subregions, or any IBRA subregion that is within 100 kilometres of the outer edge of the impacted site.
Large-eared Pied-bat (*Chalinolobus dwyeri*)	658	Large-eared Pied-bat Anywhere in NSW	Any fauna species with vulnerable or higher conservation status Located in the Pittwater, Cumberland, Sydney Cataract, Wyong and Yengo IBRA subregions, or any IBRA subregion that is within 100 kilometres of the outer edge of the impacted site.

7.2 Aquatic offsets

The Department of Primary Industries (DPI) (2013) *Policy and guidelines for fish habitat conservation and management* specify that significant environmental impacts (direct and indirect) are to be offset by environmental compensation. DPI (2013) calculates habitat compensation on a minimum 2:1 basis for all Key Fish Habitat lost; a greater compensation ratio may be considered if offsets cannot be sourced near the impact, or are not of the same habitat type as that impacted.

DPI (2013) uses a rate of $52 per square metre, or $104 per square metre to meet the 2:1 offsetting requirement. This rate is consistent with aquatic ecosystem services rates calculated by Costanza *et al.* (1997, cited in DPI, 2013), and is subject to annual inflation from 1 July each financial year. The rate above is from the 2013–14 financial year. The cost per square metre would be confirmed with NSW Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) (formerly DPI (Fisheries)) but for the purposes of this assessment the current rate has been estimated (from annual rates of Consumer Price Index of 1.5 per cent in 2014-15, 1.0 per cent in 2015-16 and 1.9 per cent 2016-17) to be $115 per square metre.

A localised adjustment of Burnt Bridge Creek would be carried out to facilitate an extension of the existing box culvert crossing of the Burnt Bridge Creek Deviation. Instream works would be over a length of 15 metres which includes culvert extension and scour protection. For the purposes of considering offsets under the *Policy and guidelines for fish habitat conservation and management* (NSW DPI, 2013), this section of waterway has been conservatively assigned as Type 2 Key Fish Habitat.

Assuming a bed width of about four metres, this would result in an estimated net loss of 60 square metres of Type 2 – moderately sensitive Key Fish Habitat. Accordingly, this would equate to an offset requirement of about $6900.

The offsets for aquatic habitat are limited to the area of fish habitat impacted and are considered separately from impacts offset under the BAM and are discussed further in Annexure D (Freshwater Ecology Impact Assessment (Cardno, 2020a)). Final offset calculations will be carried out following further design development and in consideration of further detailed site investigations carried out since the exhibition of the environmental impact statement.

7.3 Delivery of offsets

In accordance with the available options for offsetting under the Biodiversity Offsets Scheme, the measures proposed to address the offset obligation would include one or more of the following:

- Purchase and retirement of an appropriate number and class of like-for-like biodiversity credits from landholders participating in the Biodiversity Offsets Scheme
- Payment to the NSW Biodiversity Conservation Fund, administered by the Biodiversity Conservation Trust. Under this model the Biodiversity Conservation Trust takes on the responsibility for purchasing the required credits.

Consistent with the requirements of Section 7.14(4) of the BC Act, offsets must be achieved prior to the commencement of construction impacts on biodiversity values.

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Annexure A – Habitat assessment tables

Likelihood of occurrence criteria (WSP, 2018)

Likelihood	Criteria
Recorded	The species was observed in the subject land during the current survey
High	It is highly likely that a species inhabits the subject land and is dependent on identified suitable habitat (ie for breeding or important life cycle periods such as winter flowering resources), has been recorded recently in the locality (10 kilometres) and is known or likely to maintain resident populations in the subject land. Also includes species known or likely to visit the subject land during regular seasonal movements or migration.
Moderate	Potential habitat is present in the subject land. Species unlikely to maintain sedentary populations, however may seasonally use resources within the subject land opportunistically or during migration. The species is unlikely to be dependent (ie for breeding or important life cycle periods such as winter flowering resources) on habitat within the subject land, or habitat is in a modified or degraded state. Includes cryptic flowering flora species that were not seasonally targeted by surveys and that have not been recorded.
Low	It is unlikely that the species inhabits the subject land and has not been recorded recently in the locality (10 kilometres). It may be an occasional visitor, but habitat similar to the subject land is widely distributed in the local area, meaning that the species is not dependent (ie for breeding or important life cycle periods such as winter flowering resources) on available habitat. Specific habitat is not present in the subject land or the species are a non-cryptic perennial flora species that were specifically targeted by surveys and not recorded.
None	Suitable habitat is absent from the subject land.

Threatened ecological communities

TECs listed under the BC Act	TECs listed under the EPBC Act	Potential occurrence in subject land
Blue Gum High Forest in the Sydney Basin Bioregion (Critically Endangered)	Blue Gum High Forest of the Sydney Basin Bioregion (Critically Endangered)	Moderate Some parts of the subject land may support potential habitat for this TEC.
	Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion (Endangered)	Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.
Coastal Saltmarsh in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	Subtropical and Temperate Coastal Saltmarsh (Vulnerable)	Low The subject land does not support preferred habitat for this TEC.
Coastal Upland Swamp in the Sydney Basin Bioregion (Endangered)	Coastal Upland Swamps in the Sydney Basin Bioregion (Endangered)	Low The subject land does not support preferred habitat for this TEC, however several patches of this TEC are mapped near the alignment (OEH, 2016), with the closest patch mapped 30 metres to the east near the Wakehurst Parkway.
	Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered)	Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.
Duffys Forest Ecological Community in the Sydney Basin Bioregion (Endangered)		Recorded Occurs in the subject land in areas next to the Wakehurst Parkway.
Eastern Suburbs Banksia Scrub in the Sydney Basin Bioregion (Endangered)	Eastern Suburbs Banksia Scrub of the Sydney Region (Endangered)	Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.

TECs listed under the BC Act	TECs listed under the EPBC Act	Potential occurrence in subject land
Freshwater Wetlands on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)		Low The subject land does not support preferred habitat for this TEC.
Kurnell Dune Forest in the Sutherland Shire and City of Rockdale (Endangered)		Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.
Littoral Rainforest in the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	Littoral Rainforest and Coastal Vine Thickets of Eastern Australia (Critically Endangered)	Low The subject land does not support preferred habitat for this TEC.
Lowland Rainforest in the NSW North Coast and Sydney Basin Bioregions (Endangered)		Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.
Pittwater and Wagstaffe Spotted Gum Forest in the Sydney Basin Bioregion (Endangered)		Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.
	Posidonia australis seagrass meadows of the Manning-Hawkesbury ecoregion (Endangered)	Low The subject land does not support preferred habitat for this TEC.
River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria (Critically Endangered)	Low The subject land does not support preferred habitat for this TEC.
Shale Sandstone Transition Forest in the Sydney Basin Bioregion (Endangered)	Shale Sandstone Transition Forest of the Sydney Basin Bioregion (Critically Endangered)	Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.

TECs listed under the BC Act	TECs listed under the EPBC Act	Potential occurrence in subject land
Southern Sydney sheltered forest on transitional sandstone soils in the Sydney Basin Bioregion (Endangered)		Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.
Swamp Oak Floodplain Forest of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)	Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland ecological community (Endangered)	Low The subject land does not support preferred habitat for this TEC.
Swamp Sclerophyll Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions (Endangered)		Low The subject land does not support preferred habitat for this TEC.
Sydney Freshwater Wetlands in the Sydney Basin Bioregion (Endangered)		Low The subject land does not support preferred habitat for this TEC.
Sydney Turpentine-Ironbark Forest (Endangered)	Turpentine-Ironbark Forest in the Sydney Basin Bioregion (Critically Endangered)	Moderate Some parts of the subject land may support potential habitat for this TEC.
The Shorebird Community occurring on the relict tidal delta sands at Taren Point (Endangered)		Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.
Themeda grassland on seacliffs and coastal headlands in the NSW North Coast, Sydney Basin and South East Corner Bioregions (Endangered)		Low The subject land does not support preferred habitat for this TEC.
Western Sydney Dry Rainforest in the Sydney Basin Bioregion (Endangered)	Western Sydney Dry Rainforest and Moist Woodland on Shale (Critically Endangered)	Low The subject land does not support preferred habitat for this TEC, and is located outside of the geographic range of this TEC.

Threatened flora species

All habitat requirements from DPIE (EES) (2020d) and historical records from Bionet (DPIE (EES) 2020a) unless otherwise specified.

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Acacia bynoeana (Bynoe's Wattle)	E	V	Occurs from Morisset south to the Southern Highlands and west to the Blue Mountains. It grows mainly in heath or dry sclerophyll forest on sandy soils and seems to prefer open, sometimes disturbed sites such as trail margins and recently burnt areas.	0	16	Moderate. There are no recent records of the species within the locality (most recent record is dated 1951). Associated vegetation types that provide potential habitat for the species occur within the subject land. Therefore, the species is considered to have potential to occur within the subject land	Bionet (10 km buffer), EPBC Protected Matters search, BAM credit calculator outputs
Acacia clunies-rossiae (Kanangra Wattle)	V		Grows in the Kowmung and Coxs River areas entirely within Kanangra-Boyd and Blue Mountains National Parks. Found in dry sclerophyll forest on skeletal soils on rocky slopes, or on alluvium along creeks.	0	1	Low. Subject land is far outside of current known distribution of the species, which is located over 80 km to the west. The single record of the species in the 10 km buffer is listed in Bionet as a planted specimen.	Bionet (10 km buffer)
Acacia prominens (Gosford Wattle) population, Hurstville and Kogarah local government areas	EP		Grows in open situations on clayey or sandy soils. The population in Hurstville and Kogarah local government areas is disjunct from other populations and occurs at the southern limit of the species' range.	0	0	None. Listing applies to individuals in the Hurstville and Kogarah local government areas.	BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Acacia pubescens (Downy Wattle)	V	V	Distributed within the Bankstown-Fairfield-Rookwood areas and the Pitt Town area. Known from Cooks River/ Castlereagh Ironbark Forest, Shale/ Gravel Transition Forest and Cumberland Plain Woodland on alluviums, shales and at the intergrade between shales and sandstones.	0	36	Low. The existing records of the species are over 9.5 km west of the subject land. The subject land is located outside the species' known distribution. Although associated vegetation types that provide potential marginal habitat for the species occur within the subject land, the species is considered unlikely to occur within the subject land.	Bionet (10 km buffer), EPBC Protected Matters search
Acacia terminalis subsp. *terminalis* (Sunshine Wattle)	E	E	Grows in scrub and dry sclerophyll woodland on sandy soils in mostly near-coastal area from Botany Bay and the northern foreshore of Port Jackson. Recent collections are mainly from the Quarantine Station, Clifton Gardens, Dover Heights, Parsley Bay, Nielsen Park, Cooper Park, Chifley and Watsons Bay.	27	337	Moderate. Some potential suitable habitat is present in the form of associated PCTs. Numerous records in the locality.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Allocasuarina glareicola	E	E	Primarily restricted to the Richmond (NW Cumberland Plain) district, but with an outlier population found at Voyager Point, Liverpool. Grows in Castlereagh woodland on lateritic soil in open woodland.	0	0	Low. The subject land is located outside the species' known distribution. The species has not been recorded within the locality and no suitable habitat was identified within the subject land.	EPBC Protected Matters search
Allocasuarina portuensis	E	E	Known from only a single population within Sydney Harbour National Park. The original habitat	0	104	Low. No suitable habitat was identified within the subject land.	Bionet (10 km buffer), EPBC Protected

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
(Nielsen Park She-oak)			is tall closed woodland. There are no plants left at the original site, however propagated plants have been established at a number of locations at Nielsen Park and nearby areas.				Matters search, BAM calculator outputs
Amperea xiphoclada var. pedicellata	E4	X	Known only from the type specimen collected in 1892 from Sydney, NSW. The species has not been observed since and is presumed to be extinct. Previously widespread in heath, woodland and forest in low-fertility, sandy soils.	0	1	Low. Known only from the type specimen collected in 1892. No suitable habitat was identified within the subject land.	Bionet (10 km buffer)
Ancistrachne maidenii	V		Restricted to northern Sydney, around St Albans - Mt White - Maroota - Berowra areas and to the Shannon Creek area south-west of Grafton. Grows in dry sclerophyll forest on sandstone-derived soils. Habitat requirements appear to be specific and associated with a transitional geology between Hawkesbury and Watagan soil landscapes.	0	0	Low. Subject land is outside of the known distribution of the species, with the closest record about 20 kilometres to the north-west.	BAM calculator outputs
Asterolasia buxifolia	E		Known from a single site at a granite outcrop in the riparian zone of the Lett River. Rediscovered in 2000, little is known about the species.	0	1	Low. The species is not generally known to occur within the Sydney Basin; the single record of the species within 10 km of the site (dated from 2008) may be	Bionet (10 km buffer)

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			Apparently restricted to dense riparian scrub along rocky watercourses with a granitic substrate.			inaccurate. No associated vegetation types that provide habitat for the species were identified within the subject land.	
Asterolasia elegans	E	E	Occurs in sheltered forests on mid- to lower slopes and valleys on Hawkesbury Sandstone. Known from only seven populations north of Sydney in the Baulkham Hills. Hawkesbury and Hornsby Local Government Areas. Found in sheltered forests on mid- to lower slopes and valleys.	0	0	Low. The species is not known from the Sydney Metro CMA (DPIE (EES) 2020d) and the species has not been recorded within the locality. Although marginal habitat was recorded on site it is generally highly disturbed and the species is considered unlikely to occur within the subject land.	EPBC Protected Matters search, BAM calculator outputs
Astrotricha crassifolia (Thick-leaf Star-hair)	V	V	Occurs in dry sclerophyll woodland on sandstone. Resprouter from root suckers or basal stem buds after fire. Occurs near Patonga and in Royal NP and on the Woronora Plateau.	0	0	Low. Subject land is outside of the known distribution of the species, with the closest record over 22 kilometres to the north.	BAM calculator outputs
Caladenia tessellata (Thick Lip Spider Orchid)	E	V	Known from the Sydney area (old records), Wyong, Ulladulla and Braidwood in NSW. Generally found in grassy sclerophyll woodland on clay loam or sandy soils, though the population near Braidwood is in low woodland with stony soil.	0	6	Low. The species has not been recorded within the locality since 1945 and is thought to no longer occur within the Sydney region. Although marginal habitat for the species was recorded these areas are highly disturbed.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Callistemon linearifolius (Netted Bottle Brush)	V		Occurs chiefly from Georges River to the Hawkesbury River, with recent records for the Sydney area limited to the Hornsby Plateau area near the Hawkesbury River. Grows in dry sclerophyll forest.	4	27	Known – recorded next to Burnt Bridge Creek, where it occurs as planted individuals.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Camarophyllopsis kearneyi	E		Known only from the type location in Lane Cove Bushland Park (DPIE (EES), 2020d). Found growing under ferns and on creek banks (DECC, 2008b).	1	1	Low. Only know from type locality at Lane Cove Bushland Park.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Chamaesyce psammogeton (Sand Spurge)	E		Found sparsely along the coast from south of Jervis Bay to Queensland. Grows on fore-dunes, pebbly strandlines and exposed headlands, often with Spinifex (*Spinifex sericeus*).	0	11	Low. The species has been recorded once within the broader locality (2002). No associated vegetation types that provide habitat for the species were identified within the subject land.	Bionet (10 km buffer)
Cryptostylis hunteriana (Leafless Tongue Orchid)	V	V	Recorded from the Gibraltar Range south to Victoria, chiefly in coastal districts but also extends on to tablelands. Does not appear to have well defined habitat preferences and is known from a range of communities, including swamp-heath and woodland.	0	1	Low. There is one record of the species in the 10 km buffer of the subject land dated from 1954. The species has not recently been recorded within the locality and associated vegetation types that might provide potential habitat for the species were not recorded.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Cynanchum elegans (White-flowered Wax Plant)	E	E	Restricted to the east coast of NSW, inland to Merriwa. Occurs on margins of dry rainforest, also	0	0	Low. The species has not been recorded within the locality and associated vegetation types that	EPBC Protected Matters search

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			littoral rainforest, open forest and woodland, and scrub.			might provide potential habitat for the species were not recorded.	
Darwinia biflora	V	V	Recorded in Ku-ring-gai, Hornsby, Baulkham Hills and Ryde local government areas. Occurs on the edges of weathered shale-capped ridges, where these intergrade with Hawkesbury Sandstone.	0	291	Low. The subject land is outside the known distribution of the species (eastern limit is at Cowan). The closest record of the species is over 4.5 km west of the subject land.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Darwinia glaucophylla	V		Confined to the Gosford area, where it is currently known from some 15 sites. It occurs in heaths and woodlands often in association with sandstone rock platforms.	0	0	Low. The subject land is outside of the known distribution of the species, with the closest record about 25 km to the north.	BAM calculator outputs
Darwinia peduncularis	V		Occurs as local disjunct populations in coastal NSW with a couple of isolated populations in the Blue Mountains. Usually grows on or near rocky outcrops on sandy, well drained, low nutrient soil over sandstone.	0	0	Low. The subject land is outside of the known distribution of the species, with the closest record about 13 km to the west.	BAM calculator outputs
Deyeuxia appressa	E	E	A highly restricted NSW endemic known only from two pre-1942 records in the Sydney area, south of Bankstown and in Killara. Has not been collected since and may now be extinct in the wild due to habitat loss and development within these areas. Almost	0	3	Low. Subject land is outside of the historical distribution of the species, which has not been recorded for over 75 years.	Bionet (10km buffer), EPBC Protected Matters search

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			nothing is known of the species' habitat and ecology.				
Dichanthium setosum (Bluegrass)	V	V	Occurs on the New England Tablelands, North West Slopes and Plains and the Central Western Slopes of NSW, as well as in Queensland and Western Australia. Associated with heavy basaltic black soils and red-brown loams with clay subsoil.	0	1	None. The subject land falls outside the species' known distribution, with the single record in the locality dated from 1913. There is no suitable habitat for the species within the subject land.	Bionet (10km buffer)
Diuris arenaria	E		This species occurs in coastal heath and dry grassy eucalypt forest on sandy flats. Grows in gently undulating country in eucalypt forest with a grassy understorey on clay soil.	0	1	Low. One record in the Sydney region dated from 2001. Associated vegetation types that might provide potential habitat for the species were not recorded. No suitable habitat was identified within the subject land.	Bionet (10 km buffer)
Diuris bracteata	E	X	All known extant populations fall within the Gosford and Wyong local government areas, with one historical record from Gladesville in northern Sydney. Occurs in dry sclerophyll woodland and forest with a predominantly grassy understorey.	0	1	Low. The subject land falls outside the species' current known distribution.	Bionet (10 km buffer), BAM calculator outputs
Doryanthes palmeri (Giant Spear Lily)	V		Occurs in far north-east NSW and south-east Queensland. Habitat is exposed rocky outcrops on infertile soils or on bare rock.	0	2	None. The subject land is far outside of the current known distribution of the species, and the records in the 10 km buffer are planted specimens.	Bionet (10 km buffer)

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Epacris purpurascens var. purpurascens	V		Grows in sclerophyll forest, scrubs and swamps on sandstone from Gosford and Sydney districts. Found in a range of habitat types, most of which have a strong shale soil influence.	6	135	Moderate. The species has been recorded in the vegetation surrounding Artarmon Oval as a part of this study.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Eucalyptus camfieldii (Camfield's Stringybark)	V	V	Occurs in scattered locations within a restricted distribution from Raymond Terrace south to Waterfall. Grows in poor coastal country in shallow sandy soils overlying Hawkesbury Sandstone, in coastal heath mostly on exposed sandy ridges. Occurs mostly in small scattered stands near the boundary of all coastal heaths and low open woodland of the slightly more fertile inland areas.	2	82	Moderate. Recent records of the species occur within the broader locality and associated vegetation types which provide potential habitat for the species were recorded within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Eucalyptus nicholii (Narrow-leaved Black Peppermint)	V	V	Occurs from Nundle to north of Tenterfield where it grows in dry grassy sclerophyll woodland on shallow soils of slopes and ridges. Planted as urban trees, windbreaks and corridors.	1	17	Low. Not likely to occur naturally as the subject land is outside the species' known natural distribution and no associated vegetation types were recorded within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer)
Eucalyptus pulverulenta (Silver-leaved Gum)	V	V	Found in two quite separate areas, the Lithgow to Bathurst area and the Monaro (Bredbo to Bombala). Grows in shallow soils	0	1	Low. Not likely to occur naturally as the subject land is outside the species' known natural distribution and no associated vegetation	Bionet (10km buffer)

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			as an understorey plant in open forest.			types were recorded within the subject land.	
Eucalyptus scoparia (Wallangarra White Gum)	E	V	In NSW it is known from only three locations near Tenterfield, including Bald Rock National Park. Found in open eucalypt forest, woodland and heaths on well-drained granite/rhyolite hilltops, slopes and rocky outcrops, typically at high altitudes (DPIE (EES), 2020d). Widely planted as an urban street tree and in gardens.	0	2	Low. Not likely to occur naturally as the subject land is outside the species' known natural distribution and no associated vegetation types were recorded within the subject land.	Bionet (10km buffer)
Genoplesium baueri (Bauer's Midge Orchid)	E	E	Recorded from locations between Ulladulla and Port Stephens, with over half of records dating from before 1960. No recent collections have been made from Sydney suburbs. Grows in dry sclerophyll forest and moss gardens over sandstone.	0	61	Moderate. The species has been recorded within the locality and potential habitat was recorded within the subject land.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Genoplesium plumosum (Tallong Midge Orchid)	CE	E	Currently known from only two areas - the village of Tallong and its immediate environs, and a site in Morton National Park south-east of Wingello. Occurs exclusively in heathland on very shallow soils, often with lichens and mosses on sandstone conglomerate rock shelves.	0	0	Low. The subject land falls outside of the current known distribution of the species.	BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Grammitis stenophylla (Narrow-leaf Finger Fern)	E		A fern which occurs in coastal regions from Queensland to the NSW south coast. It grows in moist places, usually near streams, on rocks or in trees, in rainforest and moist eucalypt forest.	0	3	Low. The three records of the species in the 10 km buffer of the subject land are dated from 1881 to 1949; the subject land appears to be outside current known distribution of the species. Although an associated vegetation type was identified within the subject land, it is of marginal quality.	Bionet (10km buffer), BAM calculator outputs
Grevillea caleyi (Caley's Grevillea)	CE	E	Restricted to an 8 km square area around Terrey Hills, around 20 kilometres north of Sydney. Occurs in three major areas of suitable habitat, namely Belrose, Ingleside and Terrey Hills/Duffys Forest. All sites occur on the ridgetop between elevations of 170 to 240 metres above sea level, in association with laterite soils and a vegetation community of open forest, generally dominated by *Eucalyptus sieberi* and *Corymbia gummifera*.	0	782	Moderate. Although not recently recorded from within the locality the species has been recorded frequently within the broader locality and associated vegetation types that provide habitat for the species were recorded within the subject land. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Grevillea juniperina subsp. *juniperina* (Juniper-leaved Grevillea)	V		Endemic to western Sydney. Grows on reddish clay to sandy soils derived from Wianamatta Shale and Tertiary alluvium.	0	1	Low. The subject land falls outside of the current known distribution of the species.	Bionet (10km buffer)

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Grevillea shiressii	V	V	Known from two populations near Gosford, on tributaries of the lower Hawkesbury River. Grows along creek banks in wet sclerophyll forest with a moist understorey in alluvial sandy or loamy soils.	0	0	Low. The subject land falls outside of the current known distribution of the species.	EPBC Protected Matters search, BAM calculator outputs
Haloragodendron lucasii	E	E	Known locations of this species are confined to a very narrow distribution on the north shore of Sydney. Grows in dry sclerophyll forest; reported to grow in moist sandy loam soils in sheltered aspects, and on gentle slopes below cliff-lines near creeks in low open woodland. Associated with high soil moisture and relatively high soil-phosphorus levels.	0	34	Moderate. The species has been recorded within the broader locality and associated vegetation types that provide habitat for the species occur within the subject land. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Hibbertia procumbens (Spreading Guinea Flower)	E		Known from several locations only on the Central Coast in the Gosford and Wyong local government areas. Majority of known populations occur within scrub/heath on skeletal sandy soils. May also be found associated with hanging swamp on sandy deposits.	0	0	Low. The subject land falls outside of the current known distribution of the species.	BAM calculator outputs
Hibbertia puberula	E		Widespread, but never common. Extends from Wollemi National Park south to Morton National Park and the south coast near	0	2	Moderate. Although the species has not been recorded recently within the subject land (records within 10 km buffer dated 1946	Bionet (10 km buffer), BAM

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			Nowra. Favours low heath on sandy soils or rarely in clay, with or without rocks underneath.			and 1954), vegetation associations representing potential habitat were identified within the subject land. In addition, recent work on the species has shown the species to be widespread (Toelken and Miller, 2012) although not common. Therefore, the species is considered to have potential to occur within the subject land.	calculator outputs
Hibbertia spanantha (Julian's Hibbertia)	CE	CE	Endemic to NSW where it is restricted to three locations. Grows in forest with canopy species including *Eucalyptus pilularis, E. resinifera, Corymbia gummifera* and *Angophora costata* and open understorey. The soil is identified as a light clay occurring on a shale sandstone soil transition.	0	5	Low. The subject land is outside the current known distribution of the species, and no associated vegetation types were recorded within the subject land.	Bionet (10 km buffer), BAM calculator outputs
Hibbertia superans	E		Occurs from Baulkham Hills to South Maroota, with 16 known sites, and at one locality at Mount Boss, inland from Kempsey. Occurs on sandstone ridgetops often near the shale/sandstone boundary, in both open woodland and heathland, and appears to prefer open disturbed areas, such as tracksides.	1	1	Low. The subject land falls outside the species known main distribution. There is a single isolated record within the broader locality of the project near Allambie Heights however the record's accuracy is low (within 20 km) and falls well outside the species' main distribution (next nearest record is greater than 17 kilometres to the west). Although an associated vegetation type was	Bionet (1.5km buffer), Bionet (10 km buffer)

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
						recorded (marginal habitat) the species has not been recorded within the locality and it is considered unlikely that the species would occur.	
Hygrocybe anomala var. ianthinomarginata	V		Known from the type locality in Lane Cove Bushland Park with other records from the Royal National Park and the Blue Mountains National Park. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.	1	1	Low. The only record in the locality is from Lane Cove Bushland Park. There is no suitable habitat for the species within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Hygrocybe aurantipes	V		Known from the type locality in Lane Cove Bushland Park with other records from the Blue Mountains National Park and Hazelbrook. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.	2	1	Low. The only record in the locality is from Lane Cove Bushland Park. There is no suitable habitat for the species within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Hygrocybe austropratensis	E		Known only from the type locality in Lane Cove Bushland Park. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.	1	1	Low. The only record in the locality is from Lane Cove Bushland Park. There is no suitable habitat for the species within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Hygrocybe collucera	E		Known only from the type locality in Lane Cove Bushland Park. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.	1	1	Low. The only record in the locality is from Lane Cove Bushland Park. There is no suitable habitat for the species within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Hygrocybe griseoramosa	E		Known only from the type locality in Lane Cove Bushland Park. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.	1	1	Low. The only record in the locality is from Lane Cove Bushland Park. There is no suitable habitat for the species within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Hygrocybe lanecovensis	E		Known only from the type locality in Lane Cove Bushland Park. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.	1	1	Low. The only record in the locality is from Lane Cove Bushland Park. There is no suitable habitat for the species within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Hygrocybe reesiae	V		Known from the type locality in Lane Cove Bushland Park with other records from the Blue Mountains National Park in Hazelbrook and Tasmania. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.	3	2	Low. The only record in the locality is from Lane Cove Bushland Park. There is no suitable habitat for the species within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Hygrocybe rubronivea	V		Known from the type locality in Lane Cove Bushland Park with other records from the Blue	1	1	Low. The only record in the locality is from Lane Cove Bushland Park.	Bionet (1.5km buffer), Bionet (10 km buffer),

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			Mountains and south east Queensland. Occurs in gallery warm temperate forests associated with alluvial sandy soils. Substrates include soil, humus, or moss.			There is no suitable habitat for the species within the subject land.	BAM calculator outputs
Kunzea rupestris	V	V	Restricted, with most locations in the Maroota - Sackville - Glenorie area and one outlier in Ku-ring-gai Chase National Park. Grows in shallow depressions on large flat sandstone rock outcrops. Characteristically found in short to tall shrubland or heathland.	0	1	Low. The subject land falls outside of current known distribution of the species.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Lasiopetalum joyceae	V	V	Has restricted range occurring on lateritic to shaley ridgetops on the Hornsby Plateau south of the Hawkesbury River; currently known from 34 sites between Berrilee and Duffys Forest. Grows in heath and open woodland in sandy soils on sandstone.	0	10	Moderate. The species has been recorded within the locality and associated vegetation types that provide potential habitat for the species occur within the subject land. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Leptospermum deanei	V	V	Occurs in Hornsby, Warringah, Ku-ring-gai and Ryde local government areas in woodland on lower hills and slopes or near creeks, sandy alluvial soil or sand over sandstone. Occurs in riparian scrub and open forest.	0	38	Moderate. The species has been recorded in the broader locality. Associated vegetation types that provide habitat to the species have also been recorded within the subject land. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Macadamia integrifolia (Macadamia Nut)		V	Occurs in south-east Queensland, growing in remnant rainforest. Not known to occur naturally in the wild in NSW.	0	2	Low. Not likely to occur naturally as the subject land is outside the species' known natural distribution and no associated vegetation types were recorded within the subject land.	Bionet (10km buffer)
Melaleuca biconvexa (Biconvex Paperbark)	V	V	Occurs as scattered and dispersed populations found in Jervis Bay in the south and the Gosford/Wyong area in the north. Grows in damp places, often near streams, low-lying areas on alluvial soils of low slopes or sheltered aspects.	0	2	Low. The species has not been recorded recently within the locality and associated vegetation types that provide habitat for the species were not recorded.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Melaleuca deanei (Deane's Paperbark)	V	V	Occurs in two distinct areas, in the Ku-ring-gai/Berowra and Holsworthy/Wedderburn areas, with more isolated occurrences at Springwood, Wollemi National Park, Yalwal and Central Coast areas. The species occurs mostly in ridgetop woodland, with only five per cent of sites in heath on sandstone.	0	46	Low. The species has not been recorded recently within the locality and the subject land is at the limit of the species distribution. Although an associated vegetation type was recorded within the subject land it is likely to provide only marginal habitat for the species.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Melaleuca groveana (Grove's Paperbark)	V		Widespread, scattered populations in coastal districts north of Yengo National Park to southeast Queensland. Grows in heath and shrubland, often in exposed sites, in low coastal hills, escarpment ranges and	0	0	Low. The subject land falls outside the current known distribution of the species, with the closest record over 50 km to the north.	BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			tablelands. Also occurs in dry shrubby open forest and woodlands.				
Micromyrtus blakelyi	V		Restricted to areas near the Hawkesbury River, north of Sydney. Distribution extends from north of Maroota in the north, to Cowan in the south. Typically occurs within heathlands in shallow sandy soil in cracks and depressions of sandstone rock platforms.	0	0	Low. The subject land falls outside the current known distribution of the species, with the closest record about 25 km to the north-west.	BAM calculator outputs
Microtis angusii (Angus's Onion Orchid)	E	E	Currently known from only one site at Ingleside, north of Sydney. Preferred natural habitat of this orchid is not easy to define as the Ingleside location is highly disturbed, with the dominant species introduced weeds. Occurs on soils that have been modified but were originally those of the restricted ridgetop lateritic soils in the Duffys Forest- Terrey Hills- Ingleside and Belrose areas.	1	92	Moderate. The species has been recorded in proximity to the subject land (single record from 2002 near Seaforth Oval) and associated vegetation types that provide potential habitat for the species occur within the subject land. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Persicaria elatior	V	V	Tall Knotweed has been recorded in south-eastern NSW (Mt Dromedary (an old record), Moruya State Forest near Turlinjah, the Upper Avon River catchment north of Robertson, Bermagui, and Picton Lakes. In	0	0	Low. The species has not been recorded recently within the locality and associated vegetation types that provide habitat for the species were not recorded.	EPBC Protected Matters search

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			northern NSW it is known from Raymond Terrace and the Grafton area. This species normally grows in damp places, especially beside streams and lakes. Occasionally in swamp forest or associated with disturbance.				
Persoonia hirsuta (Hairy Geebung)	E	E	The species has a scattered distribution around Sydney, from Singleton in the north to Bargo in the south and the Blue Mountains to the west. Found in sandy soils in dry sclerophyll open forest, woodland and heath on sandstone or very rarely on shale.	0	38	Moderate. The species has been recorded within the locality and associated vegetation types that provide habitat for the species were recorded within the subject land. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs
Persoonia mollis subsp. *maxima*	E	E	Highly restricted, known from the Hornsby Heights-Mt Colah area north of Sydney. Occurs in sheltered aspects of deep gullies or on the steep upper hillsides of narrow gullies on Hawkesbury Sandstone.	0	0	Low. The subject land falls outside the current known distribution of the species, with the closest record about 13 km to the north-west.	EPBC Protected Matters search, BAM calculator outputs
Pimelea curviflora var. *curviflora*	V	V	Confined to the coastal area around the Sydney and Illawarra regions, with populations between northern Sydney and Maroota. Formerly recorded around the Parramatta River and Port Jackson region. Occurs on	10	88	Moderate. The species has been recorded frequently within the locality and associated vegetation types that provide potential habitat for the species were recorded within the subject land. Therefore, the species is considered to have	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search,

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			shaley/lateritic soils over sandstone and shale/sandstone transition soils on ridgetops and upper slopes amongst woodlands.			potential to occur within the subject land.	BAM calculator outputs
Pimelea spicata (Spiked Rice-flower)	E	E	Occurs in two disjunct areas: the Cumberland Plain and Illawarra, where it occurs on well-structured clay soils. On the Cumberland Plain, it is associated with Grey Box communities and in the coastal Illawarra it occurs commonly in Coast Banksia open woodland.	0	0	Low. The species has not been recorded within the locality and the subject land is outside the species know distribution (DPIE (EES) 2020d). No associated vegetation types were recorded within the subject land.	EPBC Protected Matters search
Pomaderris prunifolia in the Auburn, Strathfield and Bankstown Local Government Areas	EP		Known from only three sites in the Parramatta, Auburn, Strathfield and Bankstown local government areas. At one site it occurs along a road reserve near a creek, on sandstone, and at another it occurs on shale soils.	0	1	None. Listing applies to individuals in the Auburn, Strathfield and Bankstown local government areas.	Bionet (10km buffer)
Prasophyllum fuscum (Slaty Leek Orchid)	CE	V	Reported to be confined to the Blue Mountains area. Grows in moist heath, often along seepage lines; the known population grows in moist sandy soil over sandstone amongst sedges and grasses in a regularly slashed area.	0	1	Low. The species has not recently been recorded within the locality and no associated vegetation types that provide habitat for the species were recorded within the locality.	Bionet (10km buffer)

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Prostanthera densa (Villous Mint-bush)	V	V	This species has been recorded from the Currarong area in Jervis Bay, Royal National Park (Marley), Cronulla, Helensburgh and Port Stephens (Nelson Bay). Generally grows in sclerophyll forest and shrubland on coastal headlands and near coastal ranges, chiefly on sandstone, and rocky slopes near the sea.	0	1	Low. The subject land falls outside of the current known distribution of the species.	Bionet (10km buffer)
Prostanthera junonis (Somersby Mintbush)	E	E	Has a north-south range of approximately 19 km on the Somersby Plateau in the Gosford and Wyong local government areas. Occurs on both the Somersby and Sydney Town soil landscapes on gently undulating country over weathered Hawkesbury sandstone within open forest/low woodland/open scrub.	0	0	Low. Although there were previously records of this species near the subject land at Wakehurst Parkway, these have subsequently been reclassified to *Prostanthera marifolia.* The subject land is outside the distribution of the species, which is considered to be restricted to the Somersby Plateau (DPIE (EES) 2020d).	EPBC Protected Matters search, BAM calculator outputs
Prostanthera marifolia (Seaforth Mintbush)	CE	CE	Currently only known from the northern Sydney suburb of Seaforth and has a very highly restricted distribution, fragmented by urbanisation into three small sites. Occurs in localised patches, in or within close proximity to the endangered Duffys Forest ecological community. Located on deeply weathered clay-loam soils	169	178	Moderate. The species has been recorded within the locality (nearest record is 32 m from the subject land) and associated vegetation associations that provide habitat for the species were recorded on site. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			associated with ironstone and scattered shale lenses.				
Rhizanthella slateri (Eastern Underground Orchid)	V	E	Occurs from south-east Queensland to south-east NSW. Currently known from fewer than 10 locations in NSW. Habitat requirements are poorly understood, and no particular specific vegetation type has been associated with the species, although it is known to occur in sclerophyll forest.	0	0	Low. The species has not been recorded recently within the locality. Although an associated vegetation type was recorded within the subject land it is likely to provide only marginal habitat for the species.	EPBC Protected Matters search
Rhodamnia rubescens (Scrub Turpentine)	CE	CE	Occurs in coastal districts north from Batemans Bay in NSW to areas inland of Bundaberg in Queensland. Populations typically occur in coastal regions and occasionally extend inland onto escarpments. Found in littoral, warm temperate and subtropical rainforest and wet sclerophyll forest usually on volcanic and sedimentary soils.	1	20	Moderate. The species has been recorded within the locality in urban reserves. Marginal habitat occurs in the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Rhodomyrtus psidioides (Native Guava)	CE	CE	Occurs from Broken Bay, approximately 90 km north of Sydney, to Maryborough in Queensland. Typically restricted to coastal and sub-coastal areas of low elevation, but can occur up to 120 km inland. Pioneer species found in littoral, warm temperate	0	0	Low. The subject land falls outside of current known distribution of the species.	BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			and subtropical rainforest and wet sclerophyll forest often near creeks and drainage lines.				
Sarcochilus hartmannii (Hartman's Sarcochilus)	V	V	Distributed from the Richmond River in northern NSW to Gympie in south-east Queensland. Occurs on cliff faces on steep narrow ridges supporting eucalypt forest and clefts in volcanic rock from 500 to 1000 m in altitude.	0	1	Low. The species is not known to occur within the Sydney MCA (OEH, 2017) and has not been recorded recently in the locality (nearest recent record is over 150 kilometres north). No associated vegetation types were recorded and the subject land appears to be outside the species know distribution range.	Bionet (10km buffer)
Senecio spathulatus (Coast Groundsel)	E		Occurs in Nadgee Nature Reserve (Cape Howe) and between Kurnell in Sydney and Myall Lakes National Park (with a possible occurrence at Cudmirrah) where it grows on frontal dunes.	0	1	Low. The species has not recently been recorded within the locality (one record dated 1916 within 10 km buffer). No associated vegetation types were recorded.	Bionet (10km buffer)
Syzygium paniculatum (Magenta Lilly Pilly)	E	V	Found in a narrow, linear coastal strip from Upper Lansdowne to Conjola State Forest. On the south coast the species occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral (coastal) rainforest. On the central coast it occurs on gravels, sands, silts and clays in riverside gallery	12	180	Known. One in-situ remnant and 13 planted individuals were recorded in and next to the subject land during current surveys.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
			rainforests and remnant littoral rainforest communities.				
Tetratheca glandulosa (Glandular Pink-bell)	V		Restricted to the Baulkham Hills, Gosford, Hawkesbury, Hornsby, Ku-ring-gai, Pittwater, Ryde, Warringah, and Wyong local government areas. Associated with shale-sandstone transition habitat where shale-cappings occur over sandstone. Occupies ridgetops, upper-slopes and to a lesser extent mid-slope sandstone benches. Soils are generally shallow, consisting of a yellow, clayey/sandy loam, and may include stony lateritic fragments. Vegetation structure varies from heaths and scrub to woodlands/open woodlands, and open forest.	10	315	Moderate. The species has been recorded frequently within the locality and associated vegetation types that provide potential habitat have been recorded throughout the subject land. Therefore, the species is considered to have potential to occur within the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs
Tetratheca juncea (Black-eyed Susan)	V	V	Confined to the local government areas of Wyong, Lake Macquarie, Newcastle, Port Stephens, Great Lakes and Cessnock. Usually found in low open forest/woodland with a mixed shrub understorey and grassy groundcover but has also been recorded in heathland and moist forest.	0	6	Low. The subject land falls outside the current known distriubution of the species, which is now restricted to the northern portion of the Sydney Basin.	Bionet (10km buffer)

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Thesium australe (Austral Toadflax)	V	V	Found in very small populations scattered across eastern NSW, along the coast, and from the Northern to Southern Tablelands. Grows on coastal headlands or grassland and grassy woodland away from the coast; often found in association with *Themeda triandra* (Kangaroo Grass).	0	0	Low. The species is not currently known from the Sydney Metro CMA with only a single historic record occurring within the CMA (1803). The next nearest record is over 60 km to the south-west and therefore the subject land is outside the species known distribution. Additionally, no suitable habitat for the species was recorded.	EPBC Protected Matters search
Triplarina imbricata (Creek Triplarina)	E	E	Found only in a few locations in the ranges south-west of Glenreagh and near Tabulam in north-east NSW. The species was previously recorded in Parramatta, near Sydney, however, the species is no longer thought to occur in this area. Occurs along watercourses in low open forest with *Tristaniopsis laurina* (Water Gum) or in montane bogs.	0	1	Low. The subject land falls outside the current known distriubution of the species. Although marginal habitat for the species occurs within the subject land it is generally highly disturbed and considered unlikely to inhabit areas within the subject land.	Bionet (10km buffer)
Wahlenbergia multicaulis (Tadgell's Bluebell in the local government areas of Auburn, Bankstown, Baulkham Hills, Canterbury,	EP		There are 13 known sites, two of which are in northern Sydney (Thornleigh and Mt Ku-Ring-Gai) with the remainder in western Sydney. Grows in a variety of habitats including forest, woodland, scrub, grassland and the edges of watercourses and	0	1	None. Listing applies to individuals in the Auburn, Bankstown, Baulkham Hills, Canterbury, Hornsby, Parramatta and Strathfield local government areas.	Bionet (10 km buffer), BAM calculator outputs

Scientific Name (Common Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]
Hornsby, Parramatta and Strathfield)			wetlands. Typically occurs in damp, disturbed sites.				
Wilsonia backhousei (Narrow-leafed Wilsonia)	V		Found on the coast between Mimosa Rocks National Park and Wamberal north of Sydney. Grows at the margins of salt marshes and lakes.	0	49	Low. No suitable habitat present in the subject land.	Bionet (10km buffer)
Zannichellia palustris	E		Known from the lower Hunter and in Sydney Olympic Park. Grows in fresh or slightly saline stationary or slowly flowing water. NSW populations behave as annuals, dying back completely every summer.	0	2	Low. The subject land falls outside the current known distribution of the species.	Bionet (10km buffer)

1. Listed on the BC Act as V= Vulnerable, E=Endangered species, CE= Critically Endangered, E4= presumed extinct
2. Listed on the EPBC Act as V= Vulnerable, Endangered, CE= Critically Endangered, X= Extinct
3. Data source: EPBC Search= database search using the Protected Matters Search Tool on the Department of Agriculture, Water and the Environment web site, BioNet = search of the Department of Planning, Industry and Environment atlas database

Threatened fauna species

All habitat requirements from DPIE (EES) (2020d) and historical records from Bionet (DPIE (EES) 2020a) unless otherwise specified.

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Amphibians								
Giant Burrowing Frog (*Heleioporus australiacus*)	V	V	Found on the sandstone geology of the Sydney Basin, and south to Jervis Bay. There is a marked preference for sandstone ridgetop habitat It occurs in semi-permanent to ephemeral sand or rock based streams, and infrequently in semi-permanent to permanent constructed dams with a sandy silt or clay base. (DAWE, 2020b)	0	49	Low-moderate. The species was not identified during field surveys. The headwaters of small ephemeral watercourses near Wakehurst Parkway, in the northern extent of the subject land, offers potential habitat to the species.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species
Green and Golden Bell Frog (*Litoria aurea*)	E	V	This species occurs in fragment patches near coastal locations from Vic to south of the NSW-QLD border. For breeding it uses a wide range of waterbodies, including both natural and man-made structures, such as marshes, dams, and stream sides, and ephemeral wetlands.	0	631	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Green-thighed Frog (*Litoria brevipalmata*)	V		Green-thighed Frogs occur in a range of habitats from rainforest and moist eucalypt forest to dry eucalypt forest and heath, typically in areas where surface water gathers after rain.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	BAM calculator outputs	Species
Stuttering Frog (*Mixophyes balbus*)	E	V	Terrestrial species, found in rainforest, Antarctic beech forest or wet sclerophyll forest.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species	EPBC Protected Matters search	Species
Giant Barred Frog (*Mixophyes iteratus*)	E	E	Giant Barred Frogs are found along freshwater streams with permanent or semi-permanent water, generally (but not always) at lower elevation.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Red-crowned Toadlet (*Pseudophryne australis*)	V		Confined to the Sydney Basin, from Pokolbin in the north, the Nowra area to the south, and west to Mt Victoria in the Blue Mountains. Occurs in open forests, mostly on Hawkesbury and Narrabeen Sandstones. Inhabits periodically wet drainage lines below sandstone ridges that often have shale lenses or cappings.	144	333	High. Recent surveys for Red-Crowned Toadlet for the Northern Beaches Hospital road upgrade project (SMEC, 2015) recorded the species in the northern extent of the subject land, where potential breeding and foraging habitat present around Wakehurst Parkway.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species
Birds								
Magpie Goose (*Anseranas semipalmata*)	V		Occurs in shallow wetlands such as large swamps and dams, especially with dense growth of rushes or sedges, and with permanent lagoons and grassland nearby.	0	10	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species	Bionet (10km buffer)	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Regent Honeyeater (*Anthochaera phrygia*)	CE	CE	Occurs mostly in box-ironbark forests and woodland and prefers wet, fertile sites such as along creek flats, broad river valleys and foothills.		22	Low. The species was not identified during field surveys. The subject land does not support preferred habitat, and preferred feed trees occur in low abundances.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species/ Ecosystem
Fork-tailed Swift (*Apus pacificus*)		M	In NSW, the Fork-tailed Swift is recorded in all regions. It is almost exclusively aerial. Occurs over a range of habitats, including inland plains, cliffs and beaches, settled areas (including towns, urban areas and cities), riparian woodland and tea-tree swamps, low scrub, heathland, saltmarsh, grassland and sandplains, rainforests, wet sclerophyll forest or open forest or plantations of pines (DAWE, 2020b).	2	14	Low. The species was not identified during field surveys. The species is almost entirely aerial, and therefore is unlikely to use terrestrial fauna habitat features occurring within the subject land, as the subject land does not support preferred habitat.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Dusky Woodswallow (*Artamus cyanopterus cyanopterus*)	V		The Dusky Woodswallow occurs throughout most of New South Wales. Primarily inhabit dry, open eucalypt forests and woodlands, including mallee associations, with an open or sparse understorey of eucalypt saplings, acacias and other shrubs, and ground-cover of grasses or sedges and fallen woody debris. It has also been recorded in shrublands, heathlands and very occasionally in moist forest or rainforest.	0	23	Moderate. Marginal habitat on edge of Wakehurst Parkway.	Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Australasian Bittern (*Botaurus poiciloptilus*)	E	E	Requires permanent wetlands with tall dense vegetation, particularly bulrushes and spike rushes.	0	10	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), EPBC Protected Matters search	Ecosystem
Bush Stone-curlew (*Burhinus grallarius*)	E		Found throughout most of Australia. Inhabits open forests and woodlands with a sparse grassy ground layer and fallen timber.	1	18	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species. Woodland in the subject land has a heathy understorey.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Gang-gang Cockatoo (*Callocephalon fimbriatum*)	V		In spring and summer, generally found in tall mountain forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests. In autumn and winter, the species often moves to lower altitudes in drier more open eucalypt forests and woodlands, particularly box-gum and box-ironbark assemblages, or in dry forest in coastal areas and often found in urban areas. Favours old growth forest and woodland attributes for nesting and roosting.	0	87	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem
Gang-gang Cockatoo population, Hornsby and Ku-ring-gai Local Government Areas (*Callocephalon fimbriatum*)	EP		This endangered population is found in the Ku-ring-gai and Hornsby local government areas. The population is believed to be largely confined to an area bounded by Thornleigh and Wahroonga in the north, Epping and North Epping in the south, Beecroft and Cheltenham in the west and Turramurra/South Turramurra to the east. It is known to inhabit areas of Lane Cove National Park, Pennant Hills Park and other forested gullies in the area.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Glossy Black-Cockatoo (*Calyptorhynchus lathami*)	V		Occurs in eucalypt woodland and forest with Casuarina/Allocasuarina spp. Nests in large tree hollows.	4	137	High. Preferred foraging trees species (*Allocasuarina* and *Casuarina* species) occur within areas of native vegetation in the subject land. Species was not observed using a large tree hollow identified in the northern extent of the subject land, near Wakehurst Parkway; the subject land is unlikely to support preferred nesting habitat for the species.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem
Spotted Harrier (*Circus assimilis*)	V		Occurs throughout the Australian mainland, except in densely forested or wooded habitats of the coast, escarpment and ranges, and rarely in Tasmania. Found most commonly in native grassland, but also occurs in agricultural land, foraging over open habitats including edges of inland wetlands.	0	2	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), BAM calculator outputs	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Brown Treecreeper (eastern subspecies) (*Climacteris picumnus victoriae*)	V		The eastern subspecies lives in eastern NSW in eucalypt woodlands through central NSW and in coastal areas with drier open woodlands. Found in eucalypt woodlands (including Box-Gum Woodland) and dry open forest of the inland slopes and plains inland of the Great Dividing Range; mainly inhabits woodlands dominated by stringybarks or other rough-barked eucalypts, usually with an open grassy understorey, sometimes with one or more shrub species.	0	1	Moderate. Marginal habitat on edge of Wakehurst Parkway.	Bionet (10km buffer)	Ecosystem
Oriental Cuckoo (*Cuculus optatus*)		M	The Oriental Cuckoo occur in eastern New South Wales, eastern Queensland and Cape York Peninsula, and top end of Northern Territory. Habitat includes rainforest margins, monsoon forest, vine scrub, riverine thickets, wetter densely canopied eucalypt forest, paperbark swamp, mangroves.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Varied Sittella (*Daphoenositta chrysoptera*)	V		The Varied Sittella inhabits most of mainland Australia except the treeless deserts and open grasslands. It inhabits eucalypt forests and woodlands, especially rough-barked species and mature smooth-barked gum with dead branches, mallee and *Acacia* woodland.	1	10	High. The species was not identified during field surveys. However, it has previously been recorded in the subject land by the Gore Hill Freeway.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem
White-fronted Chat (*Epthianura albifrons*)	V, EP		In NSW, occurs in association with damp, open habitats below 1000 metres elevation along the coast (such as wetlands and saltmarsh), and in association with waterways in the west. Forage for insects on the ground. Nests in low vegetation elevated from the ground.	0	48	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Ecosystem
White-fronted Chat population in the Sydney Metropolitan Catchment Area (*Epthianura albifrons*)	EP		Two isolated sub-populations of White-fronted Chats are currently known from the Sydney Metropolitan Catchment Management Authority (CMA) area; one at Newington Nature Reserve on the Parramatta River and one at Towra Point Nature Reserve in Botany Bay. These sub-populations are separated from each other by 25 kilometres of urbanised land, across which the Chats are unlikely to fly.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Red Goshawk (*Erythrotriorchis radiatus*)	CE	V	The species is very rare in NSW. In NSW, preferred habitats include mixed subtropical rainforest, *Melaleuca* swamp forest and riparian *Eucalyptus* forest of coastal rivers.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Species
Little Penguin (*Eudyptula minor*)	EP		This endangered population occurs from just north of Smedley's Point to Cannae Point, North Sydney Harbour, Manly. Only known breeding population on the mainland in NSW. A range of nest sites are used by the penguins at Manly including under rocks on the foreshore, under seaside houses and structures, such as stairs, in wood piles and under overhanging vegetation including lantana and under coral tree roots.	0	34	High. There are a small number of records near the subject land, at the Spit and Sailors Bay. The species was not identified during field surveys. Species occurs in Sydney Harbour and may forage in Middle Harbour within the subject land on occasion. The species nests at Manly and as such, the subject land does not support nesting habitat for the species.	Bionet (10km buffer)	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Grey Falcon (*Falco hypoleucos*)	E		The Grey Falcon is sparsely distributed in NSW, chiefly throughout the Murray-Darling Basin, with the occasional vagrant east of the Great Dividing Range. The breeding range has contracted since the 1950s with most breeding now confined to arid parts of the range. There are possibly less than 5000 individuals left. Population trends are unclear, though it is believed to be extinct in areas with more than 500mm rainfall in NSW. Usually restricted to shrubland, grassland and wooded watercourses of arid and semi-arid regions, although it is occasionally found in open woodlands near the coast. Also occurs near wetlands where surface water attracts prey. Like other falcons it utilises old nests of other birds of prey and ravens, usually high in a living eucalypt near water or a watercourse.	0	0	Low. The species was not identified during field surveys. Species only occurs as a vagrant in coastal areas – largely restricted to the arid zone.	EPBC Protected Matters search	Ecosystem
Swinhoe's Snipe (*Gallinago megala)*		M	Breeds in central and southern Siberia. During the non-breeding season Swinhoe's Snipe occurs at the edges of wetlands (wet paddy fields, swamps and freshwater streams), grasslands, drier cultivated areas (including crops of rapeseed and wheat) and market gardens (DAWE, 2020b).	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Pin-tailed snipe (*Gallinago stenura)*		M	Breeds in Russia. During non-breeding period the Pin-tailed Snipe occurs in or at the edges of shallow freshwater swamps, ponds and lakes with emergent, sparse to dense cover of grass/sedge or other vegetation. Also found in drier, more open wetlands such as claypans in more arid parts of species' range and sewage ponds; not normally in saline or inter-tidal wetlands (DAWE, 2020b)	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	-
Little Lorikeet (*Glossopsitta pusilla*)	V		The Little Lorikeet is distributed widely across the coastal and Great Divide regions of eastern Australia from Cape York to SA. Forages primarily in the canopy of open *Eucalyptus* forest and woodland, yet also finds food in *Angophora*, *Melaleuca* and other tree species. Riparian habitats are particularly used, due to higher soil fertility and hence greater productivity.	6	41	Moderate. Nectivorous trees and shrubs within the subject land offer potential foraging habitat to the species. The two hollow-bearing trees identified in the subject land offer potential nesting habitat.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Painted Honeyeater (*Grantiella picta*)	V	V	The species is nomadic and occurs at low densities throughout its range with the greatest concentrations being on the inland slopes of the Great Dividing Range in NSW, Victoria and southern Queensland. Inhabits Boree/ Weeping Myall (*Acacia pendula*), Brigalow (*A. harpophylla*) and Box-Gum Woodlands and Box-Ironbark Forests.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
White-bellied Sea-Eagle (*Haliaeetus leucogaster*)	V		In New South Wales it is widespread along the east coast, and along all major inland rivers and waterways. Occurs in coastal areas such as bays and inlets, beaches, reefs, lagoons, estuaries and mangroves; and at, or in the vicinity of freshwater swamps, lakes, reservoirs, billabongs and saltmarsh.	24	273	High. The species was not recorded during field surveys, however, has been previously recorded throughout Middle Harbour. The subject land offers foraging habitat to the species, due to the presence of preferred prey species that inhabit Middle Harbour. The subject land also offers potential perching habitat, due to the presence of trees that occurs along the foreshore at The Spit, Seaforth and Clontarf.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Little Eagle (*Hieraaetus morphnoides*)	V		The Little Eagle is distributed throughout the Australian mainland occupying habitats rich in prey within open eucalypt forest, woodland or open woodland. Sheoak or acacia woodlands and riparian woodlands of interior NSW are also used.	0	20	Low-moderate. The species was not identified during field surveys. Large tracts of native vegetation in and adjoining the northern extent of the subject land offer potential foraging and nesting habitat.	Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem
White-throated Needletail (*Hirundapus caudacutus*)		V, M	In Australia the species is widespread in eastern and south-eastern Australia, from the islands in Torres Strait and the tip of Cape York south to Tasmania. It does not breed in Australia. Occurs in airspace over open forest, rainforest, heathland, farmlands, sandy beaches, mudflats and islands (DAWE, 2020b).	11	79	Low. The species was not identified during field surveys. Species rarely settles on land.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Black Bittern (*Ixobrychus flavicollis*)	V		The Black Bittern has a wide distribution, from southern NSW north to Cape York and along the north coast to the Kimberley region. Inhabits both terrestrial and estuarine wetlands, generally in areas of permanent water and dense vegetation. Where permanent water is present, the species may occur in flooded grassland, forest, woodland, rainforest and mangroves.	2	38	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Swift Parrot (*Lathamus discolor*)	E	CE	Breeds in Tasmania during spring and summer, migrating in the autumn and winter months to south-eastern Australia from Victoria and the eastern parts of South Australia to south-east Queensland. In NSW mostly occurs on the coast and south west slopes. On the mainland they occur in areas where eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking bugs) infestations. Favoured feed trees include winter flowering species such as Swamp Mahogany *Eucalyptus robusta*, Spotted Gum *Corymbia maculata*, Red Bloodwood *C. gummifera*, Forest Red Gum *E. tereticornis*, Mugga Ironbark *E. sideroxylon*, and White Box *E. albens*.	5	58	Moderate. The species was not identified during field surveys. Nectivorous trees within the subject land offer marginal foraging habitat to the species, however, the subject land does not support preferred habitat for the species. The species breeds in Tasmania, and as such, the subject land does not support nesting habitat for the species. Species credit habitat for the Swift Parrot is defined by Important Area habitat mapping. The subject land is not mapped within the draft Important Areas of habitat for Swift Parrot as mapped by DPIE.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Square-tailed Kite (*Lophoictinia isura*)	V		Found in a variety of timbered habitats including dry woodlands and open forests. Shows a particular preference for timbered watercourses. Breeding is from July to February, with nest sites generally located along or near watercourses, in a fork or on large horizontal limbs.	3	17	Moderate. The species was not identified during field surveys. Large tracts of native vegetation in and adjoining the northern extent of the subject land offer potential foraging habitat.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem
Black-chinned Honeyeater (eastern subspecies) (*Melithreptus gularis gularis*)	V		Eastern subspecies occurs from the tablelands and western slopes of the Great Dividing Range to the north-west and central-west plains and the Riverina. It is rarely recorded east of the Great Dividing Range. Inhabits forests or woodlands dominated by box and ironbark eucalypts where it forages for insects and nectar.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Black-faced Monarch (*Monarcha melanopsis)*		M	The Black-faced Monarch mainly occurs in rainforest ecosystems, including semi-deciduous vine-thickets, complex notophyll vine-forest, tropical (mesophyll) rainforest, subtropical (notophyll) rainforest, mesophyll (broadleaf) thicket/shrubland, warm temperate rainforest, dry (monsoon) rainforest and (occasionally) cool temperate rainforest.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Spectacled Monarch (*Monarcha trivirgatus*)		M	The Spectacled Monarch prefers thick understorey in rainforests, wet gullies and waterside vegetation, as well as mangroves.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	-
Yellow Wagtail (*Motacilla flava*)		M	This species occupies a range of damp or wet habitats with low vegetation, from damp meadows, marshes, waterside pastures, sewage farms and bogs to damp steppe and grassy tundra. In the north of its range it is also found in large forest clearings.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	-
Satin Flycatcher (*Myiagra cyanoleuca*)		M	Satin Flycatchers inhabit heavily vegetated gullies in eucalypt-dominated forests and taller woodlands, and on migration, occur in coastal forests, woodlands, mangroves and drier woodlands and open forests (DAWE, 2020b).	0	0	Low-Moderate, Large tracts of native vegetation within and adjoining the northern extent of the subject land offers potential habitat to the species.	EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Orange-bellied Parrot (*Neophema chrysogaster*)	CE	CE	Orange-bellied Parrot breeds in the south-west of Tasmania and migrates in autumn to spend the winter on the mainland coast of south-eastern South Australia and southern Victoria. On the mainland, the Orange-bellied Parrot spends winter mostly within 3 km of the coast in sheltered coastal habitats including bays, lagoons, estuaries, coastal dunes and saltmarshes.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	Species
Turquoise Parrot (*Neophema pulchella*)	V		In NSW, occurs from the coastal plains to the western slopes of the Great Diving Range. Found along the edges of eucalypt woodland adjoining clearings, timbered ridges and creeks in farmland. Forages on the ground for seeds and grasses. Nests in a tree hollow, log or post.	0	3	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Cotton Pygmy-Goose (*Nettapus coromandelianus*)	E		Although once found from north Queensland to the Hunter River in NSW, the species is now only a rare visitor to NSW. Freshwater lakes, lagoons, swamps and dams, particularly those vegetated with waterlilies and other floating and submerged aquatic vegetation.	0	4	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Barking Owl (*Ninox connivens*)	V		Inhabits woodland and open forest, including fragmented remnants and partly cleared farmland. Sometimes able to successfully breed along timbered watercourses in heavily cleared habitats (eg western NSW) due to the higher density of prey on these fertile riparian soils. Roost in shaded portions of tree canopies, including tall midstorey trees with dense foliage such as Acacia and Casuarina species. Requires very large permanent territories in most habitats due to sparse prey densities.	2	35	Moderate. The species was not identified during field surveys. Large tracts of native vegetation in and adjoining the northern extent of the subject land offer potential foraging habitat, due to the presence of prey species. Species was not observed using a large tree hollow identified in the northern extent of the subject land, near Wakehurst Parkway; the subject land is unlikely to support preferred nesting habitat for the species.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Powerful Owl (*Ninox strenua*)	V		In NSW, the Powerful Owl is widely distributed throughout the eastern forests from the coast inland to tablelands. It inhabits a range of vegetation types, from woodland and open sclerophyll forest to tall open wet forest and rainforest requiring large tracts of forest or woodland habitat but can occur in fragmented landscapes as well. Powerful Owls nest in large tree hollows (at least 0.5 m deep), in large eucalypts (diameter at breast height of 80-240 cm) that are at least 150 years old.	359	1136	High. This species was recorded by WSP (2018) at Flat Rock Reserve, next to the subject land, during call play-back surveys.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem
Eastern Osprey (*Pandion cristatus (syn. P. haliaetus)*)	V	M	Favour coastal areas, especially the mouths of large rivers, lagoons and lakes. Feed on fish over clear, open water. Breed from July to September in NSW. Nests are made high up in dead trees or in dead crowns of live trees, usually within one kilometre of the sea.	3	49	Moderate. Middle Harbour within the subject land offers potential foraging habitat to the species. The subject land is not known to support nesting habitat for the species.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs, EPBC Protected Matters search	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Scarlet Robin (*Petroica boodang*)	V		In NSW, it occurs from the coast to the inland slopes. The Scarlet Robin lives in dry eucalypt forests and woodlands. The understorey is usually open and grassy with few scattered shrubs.	1	7	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Flame Robin (*Petroica phoenicea*)	V		In NSW, the species breeds in tall moist eucalypt forests and woodlands in upland areas. In winter, moves to dry forests, open woodlands and grasslands of the inland slopes and plains.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	BAM calculator outputs	Ecosystem
Glossy Ibis (*Plegadis falcinellus*)		M	The Glossy Ibis' preferred habitat for foraging and breeding are fresh water marshes at the edges of lakes and rivers, lagoons, flood-plains, wet meadows, swamps, reservoirs, sewage ponds, rice-fields and cultivated areas under irrigation (DoEE, 2019b).	0	45	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Superb Parrot (*Polytelis swainsonii*)	V	V	Occurs across Riverina area in summer, migrates along Macquarie and Namoi Rivers to northern NSW in winter. Inhabits timbered watercourses and nearby woodlands. Requires deep hollows or hollow limbs for nesting, typically in Red Gums.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Species/ Ecosystem
Wompoo Fruit-Dove (*Ptilinopus magnificus*)	V		Occurs along the coast and coastal ranges from the Hunter River in NSW to Cape York Peninsula. It is rare south of Coffs Harbour. Occurs in, or near rainforest, low elevation moist eucalypt forest and brush box forests.	0	2	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Ecosystem
Rose-crowned Fruit-Dove (*Ptilinopus regina*)	V		Rose-crowned Fruit-doves occur mainly in sub-tropical and dry rainforest and occasionally in moist eucalypt forest and swamp forest, where fruit is plentiful.	0	3	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species	Bionet (10 km buffer), BAM calculator outputs	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Superb Fruit-Dove (*Ptilinopus superbus*)	V	V	The Superb Fruit-dove occurs principally from north-eastern in Queensland to north-eastern NSW. Inhabits rainforest and similar closed forests.	6	38	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Rufous Fantail (*Rhipidura rufifrons*)		M	In east and south-east Australia, the Rufous Fantail mainly inhabits wet sclerophyll forests, often in gullies dominated by eucalypts, usually with a dense shrubby understorey often including ferns. They also occur in subtropical and temperate rainforests (DAWE, 2020b).	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	-
Australia Painted Snipe (Painted snipe) (*Rostratula australis*)	E	E	The Australian Painted Snipe is restricted to Australia. Prefers fringes of swamps, dams and nearby marshy areas where there is a cover of grasses, lignum, low scrub or open timber.	0	6	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), EPBC Protected Matters search	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Diamond Firetail (*Stagonopleura guttata*)	V		Widely distributed in NSW, the species is found in grassy eucalypt woodlands, open forest, mallee, Natural Temperate Grasslands, secondary derived grasslands, riparian area and occasionally in wooded farmland.	0	2	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Ecosystem
Freckled Duck (*Stictonetta naevosa*)	V		The Freckled Duck is found primarily in south-eastern and south-western Australia. Prefer permanent freshwater swamps and creeks with heavy growth of Cumbungi, Lignum or Tea-tree. During drier times they move from ephemeral breeding swamps to more permanent waters such as lakes, reservoirs, farm dams and sewage ponds.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Ecosystem
Eastern Grass Owl (*Tyto longimembris*)	V		In NSW the Eastern Grass Owl are more likely to be resident in the north-east. Found in areas of tall grass, including grass tussocks, in swampy areas, grassy plains, swampy heath, and in cane grass or sedges on flood plains.	0	2	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Masked Owl (*Tyto novaehollandiae*)	V		Occurs from the eastern coast of NSW inland to the western plains. Found in eucalypt forests and woodlands from sea level to 1100 m. Hunts in and along the edges of forests, including roadsides for arboreal and terrestrial mammals. Roosts and nests in large tree hollows within moist eucalypt forested gullies.	1	9	Moderate. The species was not identified during field surveys. Large tracts of native vegetation in and adjoining the northern extent of the subject land offer potential foraging habitat, due to the presence of prey species. The subject land is unlikely to support preferred nesting habitat for the species.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Sooty Owl (*Tyto tenebricosa*)	V		Occurs in rainforest, including dry rainforest, subtropical and warm temperate rainforest, as well as moist eucalypt forests. Nests in very large tree-hollows.	2	4	Low-moderate. Large tracts of native vegetation in and adjoining the northern extent of the subject land offer marginal foraging habitat, due to the presence of prey species, although wet forest and rainforest communities are absent from the subject land. The subject land is unlikely to support preferred nesting habitat for the species.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem
Seabirds								
Common Noddy (*Anous stolidus*)		M	Seabird species have similar habitat requirements, occurring in pelagic oceanic habitats, and have therefore been assessed together.	0	4	Low. These species were not identified during field surveys.	Bionet (10 km buffer), EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Flesh-footed Shearwater (*Ardenna carneipes*)	V			0	3	The subject land does not support preferred habitat for the species. These pelagic species are unlikely to occur in marine and intertidal habitats offered by Middle Harbour within the subject land.	Bionet (1.5km buffer), EPBC Protected Matters search	EEC/Marine
Sooty Shearwater (*Ardenna grisea*)		M		0	11		Bionet (10km buffer, EPBC Protected Matters search	-
Wedge-tailed Shearwater (*Ardenna pacificus*)		M		0	28		Bionet (1.5km buffer), Bionet (10 km buffer)	-
Short-tailed Shearwater (*Ardenna tenuirostris*)		M		0	75		Bionet (1.5km buffer), Bionet (10 km buffer)	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Streaked Shearwater (*Calonectris leucomelas*)		M		0	1		Bionet (10 km buffer), EPBC Protected Matters search	-
Antipodean Albatross (*Diomedea antipodensis*)	V	V		0	0		EPBC Protected Matters search	blank
Gibson's Albatross (*Diomedea antipodensis gibsoni*)	V	V		0	0		EPBC Protected Matters search	-
Grey-headed Albatross (*Diomedea chrysostoma*)		EM		0	1		Bionet (10km buffer)	-
Southern Royal Albatross (*Diomedea epomophora*)		VM		0	0		EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Wandering Albatross (*Diomedea exulans*)	E	V		0	10		Bionet (10 km buffer), EPBC Protected Matters search	EEC/Marine
Northern Royal Albatross (*Diomedea sanfordi*)		E		0	0		EPBC Protected Matters search	-
Lesser Frigatebird (*Fregata ariel*)		M		0	2		Bionet (10 km buffer), EPBC Protected Matters search	-
Greater Frigatebird (*Fregata minor*)		M		0	0		EPBC Protected Matters search	-
White-bellied Storm-Petrel (Tasman Sea) (*Fregetta grallaria grallaria*)		V		0	0		EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Southern Giant Petrel (*Macronectes giganteus*)	E	E		0	3		Bionet (10km buffer), EPBC Protected Matters search	EEC/Marine
Northern Giant Petrel (*Macronectes halli*)	V	V		0	1		Bionet (10km buffer), EPBC Protected Matters search	EEC/Marine
Fairy Prion (southern) (*Pachyptila turtur subantarctica*)		V		0	0		EPBC Protected Matters search	-
Sooty Albatross (*Phoebetria fusca*)	V	VM		0	1		Bionet (10km buffer), EPBC Protected Matters search	EEC/Marine

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Gould's Petrel (*Pterodroma leucoptera*)	V	E		0	2		Bionet (10km buffer), EPBC Protected Matters search	EEC/Marine
Kermadec Petrel (*Pterodroma neglecta*)	V	V		0	0		EPBC Protected Matters search	EEC/Marine
Little Shearwater (*Puffinus assimilis*)	V			0	2		Bionet (10km buffer)	EEC/Marine
Long-tailed Jaeger (*Stercorarius longicaudus*)		M		0	2		Bionet (10km buffer)	-
South Polar Skua (*Stercorarius maccormicki*)		M		0	1		Bionet (10km buffer)	
Arctic Jaeger (*Stercorarius parasiticus*)		M		0	5		Bionet (10km buffer)	-
Pomarine Jaeger (*Stercorarius pomarinus*)		M		0	3		Bionet (10km buffer)	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Buller's Albatross (*Thalassarche bulleri*)		VM		0	0		EPBC Protected Matters search	-
Northern Buller's Albatross (*Thalassarche bulleri platei*)		V		0	0		EPBC Protected Matters search	-
Shy Albatross (*Thalassarche cauta* (syn. T. cauta cauta))	V	VM		0	3		Bionet (10km buffer), EPBC Protected Matters search	EEC/Marine
White-capped Albatross (*Thalassarche cauta steadi*)		V		0	0		EPBC Protected Matters search	-
Chatham Albatross (*Thalassarche eremita*)		E		0	0		EPBC Protected Matters search	-
Campbell Albatross (*Thalassarche impavida*)		V		0	0		EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Black-browed Albatross (*Thalassarche melanophris*)	V	V		0	8		Bionet (10km buffer), EPBC Protected Matters search	EEC/Marine
Salvin's Albatross (*Thalassarche salvini*)		V		0	0		EPBC Protected Matters search	-
White-tailed Tropicbird (*Phaethon lepturus*)		M		0	3		Bionet (10 km buffer)	-
Terns								
White-winged Black Tern (*Chlidonias leucopterus*)		M	Terns have similar habitat requirements, sometimes occurring in estuaries and harbours and foraging on intertidal mudflats and sandflats, and have therefore been assessed together.	0	2	Low-moderate. These species were not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offers marginal habitat to some of these species, although many	Bionet (10km buffer)	-
Gull-billed Tern (*Gelochelidon nilotica*)		M		0	15		Bionet (10km buffer)	-
Caspian Tern (*Hydroprogne caspia*)		M		0	48		Bionet (10km buffer)	-

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Sooty Tern (*Onychoprion fuscata*)	V			0	6	preferred habitat features are absent.	Bionet (10km buffer)	Species
Common Tern (*Sterna hirundo*)		M		0	40		Bionet (10km buffer)	-
White Tern (*Gygis alba*)	V			0	1		Bionet (10km buffer)	Species
Little Tern (*Sternula albifrons*)	E			0	9		Bionet (10 km buffer), EPBC Protected Matters search	Species/ Ecosystem
Sooty Tern (*Sterna fuscata*)	V			0	6		Bionet (10km buffer)	-
Fairy Tern (Australian) (*Sternula nereis nereis*)		V		0	0		EPBC Protected Matters search	Species
Shorebirds and waders								

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Common Sandpiper (*Actitis hypoleucos*)		M	Found along all coastlines of Australia and in many areas inland. Occurs in a wide range of coastal wetlands and some inland wetlands, with varying levels of salinity. It is mostly encountered along muddy margins or rocky shores and rarely on mudflats. It has been recorded in estuaries and deltas of streams, banks farther upstream; around lakes, pools, billabongs, reservoirs, dams and claypans, and occasionally piers and jetties (DAWE, 2020b).	0	31	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search	-
Ruddy Turnstone (*Arenaria interpres*)		M	In Australasia, the Ruddy Turnstone is mainly found on coastal regions with exposed rock coast lines or coral reefs. It also lives near platforms and shelves, often with shallow tidal pools and rocky, shingle or gravel beaches. Sometimes in estuaries, harbours, bays and coastal lagoons, among low saltmarsh or on exposed beds of seagrass, around sewage ponds and on mudflats (DAWE, 2020b).	0	18	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-

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Sharp-tailed Sandpiper (*Calidris acuminata*)		M	In Australia, mostly found in the south-east. Prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation. They use intertidal mudflats in sheltered bays, inlets, estuaries or seashores, and also swamps and creeks lined with mangroves (DAWE, 2020b).	0	602	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-
Sanderling (*Calidris alba*)	V	M	A regular summer migrant from Siberia and other Arctic breeding grounds to most of the Australian coastline. Often found in coastal areas on low beaches of firm sand, near reefs and inlets, along tidal mudflats and bare open coastal lagoons; individuals are rarely recorded in near-coastal wetlands.	0	8	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Red Knot (*Calidris canutus*)		E	In Australasia, they mainly inhabit intertidal mudflats, sandflats and sandy beaches of sheltered coasts, in estuaries, bays, inlets, lagoons and harbours; sometimes on sandy ocean beaches or shallow pools on exposed wave-cut rock platforms or coral reefs. Sometimes seen in terrestrial saline wetlands near the coast. They rarely use inland lakes or swamps (DAWE, 2020b).	0	36	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer), EPBC Protected Matters search	Species/ Ecosystem
Curlew Sandpiper (*Calidris ferruginea*)	E	CE	Occurs along the entire coast of NSW. In New South Wales is mainly found in intertidal mudflats of sheltered coasts, but also in non-tidal swamps, lakes and lagoons.	0	344	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer), EPBC Protected Matters search	Species/ Ecosystem

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Pectoral Sandpiper (*Calidris melanotos*)		M	The species is found at coastal lagoons, estuaries, bays, swamps, lakes, inundated grasslands, saltmarshes, river pools, creeks, floodplains and artificial wetlands in coastal or near coastal habitat but occasionally further inland. It prefers wetlands that have open fringing mudflats and low, emergent or fringing vegetation, such as grass or samphire (DAWE, 2020b).	0	34	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-
Red-necked Stint (*Calidris ruficollis*)		M	In Australasia, the Red-necked Stint is mostly found in coastal areas, including in sheltered inlets, bays, lagoons and estuaries with intertidal mudflats, often near spits, islets and banks and, sometimes, on protected sandy or coralline shores (DAWE, 2020b).	0	43	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-

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Great Knot (*Calidris tenuirostris*)	V	CE	In NSW, the species has been recorded at scattered sites along the coast down to about Narooma. Found within sheltered, coastal habitats containing large, intertidal mudflats or sandflats, including inlets, bays, harbours, estuaries and lagoons, sandy beaches with mudflats nearby, sandy spits and islets and sometimes on exposed reefs or rock platforms.	0	6	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer), EPBC Protected Matters search	Species/ Ecosystem
Double-banded Plover (*Charadrius bicinctus*)		M	The Double-banded Plover is found on littoral, estuarine and fresh or saline terrestrial wetlands and also saltmarsh, grasslands and pasture. It occurs on muddy, sandy, shingled or sometimes rocky beaches, bays and inlets, harbours and margins of fresh or saline terrestrial wetlands such as lakes, lagoons and swamps, shallow estuaries and rivers (DAWE, 2020b).	0	0	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Greater Sand Plover (*Charadrius leschenaultii*)	V	V	Almost entirely restricted to coastal areas in NSW, occurring mainly on sheltered sandy, shelly or muddy beaches or estuaries with large intertidal mudflats or sandbanks.	0	3	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Species/ Ecosystem
Lesser Sand Plover (*Charadrius mongolus*)	V	E	Almost entirely coastal in NSW, favouring the beaches of sheltered bays, harbours and estuaries with large intertidal sandflats or mudflats; occasionally occurs on sandy beaches, coral reefs and rock platforms.	0	2	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer), EPBC Protected Matters search	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Black-necked Stork (*Ephippiorhynchus asiaticus*)	E		Widespread in coastal and subcoastal northern and eastern Australia; in NSW, the species becomes increasingly uncommon south of the Northern Rivers region. Rarely occurs south of Sydney. Found in association with wetlands, swamps, billabongs, estuaries and surrounding vegetation.	0	1	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Ecosystem
Beach Stone-curlew (*Esacus magnirostris*)	CE		In NSW, the species occurs regularly to about the Manning River, and the small population of north-eastern NSW is at the limit of the normal range of the species in Australia. Found exclusively along the coast, on a wide range of beaches, islands, reefs and in estuaries, and may often be seen at the edges of or near mangroves.	0	2	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Oriental Plover (*Charadrius veredus*)		M	Immediately after arriving in non-breeding grounds in northern Australia, Oriental Plovers spend a few weeks in coastal habitats such as estuarine mudflats and sandbanks, on sandy or rocky ocean beaches or nearby reefs, or in near-coastal grasslands, before dispersing further inland (DAWE, 2020b)	0	3	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offers marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	-
Latham's Snipe (*Gallinago hardwickii*)		M	In Australia, the range extends inland over the eastern tablelands in south-eastern Queensland and to west of the Great Dividing Range in New South Wales. Usually inhabit open, freshwater wetlands with low, dense vegetation. Can also inhabit areas with saline or brackish water, in modified or artificial habitats, and in habitats located close to humans or human activity (DAWE, 2020b).	0	103	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-

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Sooty Oystercatcher *(Haematopus fuliginosus*)	V		Sooty Oystercatchers are found around the entire Australian coast. Favours rocky headlands, rocky shelves, exposed reefs with rock pools, beaches and muddy estuaries.	0	28	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Species
Pied Oystercatcher (*Haematopus longirostris*)	E		In NSW the species is thinly scattered along the entire coast. Favours intertidal flats of inlets and bays, open beaches and sandbanks.	0	9	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Species

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Broad-billed Sandpiper (*Limicola falcinellus*)	V		The Broad Billed Sandpiper breeds in northern Siberia before migrating southwards in winter to Australia. During winter, the species inhabits sheltered parts of the coast such as estuarine sandflats and mudflats, harbours, embayments, lagoons, saltmarshes and reefs as feeding and roosting habitat.	0	2	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Species/ Ecosystem
Bar-tailed Godwit (*Limosa lapponica*)		M	The species has been recorded in the coastal areas of all Australian states. Found mainly in coastal habitats such as large intertidal sandflats, banks, mudflats, estuaries, inlets, harbours, coastal lagoons and bays (DAWE, 2020b).	0	865	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Bar-tailed Godwit (baueri) (*Limosa lapponica baueri*)		V	The bar-tailed godwit (western Alaskan) occurs mainly in coastal habitats such as large intertidal sandflats, banks, mudflats, estuaries, inlets, harbours, coastal lagoons and bays. It has also been recorded in coastal sewage farms and saltworks, salt lakes and brackish wetlands near coasts, sandy ocean beaches, rock platforms, and coral reef-flats (DAWE, 2020b).	0	0	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	EPBC Protected Matters search	Species/ Ecosystem
Black-tailed Godwit (*Limosa limosa*)	V		Breeds in Mongolia and Eastern Siberia (Palaearctic). In NSW, it is most frequently recorded at Kooragang Island, with occasional records elsewhere along the north and south coast, and inland. Primarily a coastal species. Usually found in sheltered bays, estuaries and lagoons with large intertidal mudflats and/or sandflats. Roosts and loafs on low banks of mud, sand and shell bars.	0	13	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Eastern Curlew (*Numenius madagascariensis*)		CE	Within Australia, the Eastern Curlew has a primarily coastal distribution. In New South Wales is mainly found in intertidal mudflats and sometimes saltmarsh of sheltered coasts. Occasionally, found on ocean beaches (often near estuaries), and coral reefs, rock platforms, or rocky islets.	0	22	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer), EPBC Protected Matters search	Species/ Ecosystem
Little Curlew (*Numenius minutus)*		M	In NSW most records are scattered east of the Great Dividing Range, from Casino, south to Greenwell Point with a few scattered records west of the Great Dividing Range. Most often found in short, dry grassland and sedgeland, including dry floodplains and blacksoil plains, which have scattered, shallow freshwater pools or areas seasonally inundated (DAWE, 2020b).	0	5	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer), EPBC Protected Matters search	

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Whimbrel (*Numenius phaeopus*)		M	Primarily has a coastal distribution. Often found on the intertidal mudflats of sheltered coasts. It is also found in harbours, lagoons, estuaries and river deltas, often those with mangroves, but also open, unvegetated mudflats. It is occasionally found on sandy or rocky beaches, on coral or rocky islets, or on intertidal reefs and platforms (DAWE, 2020b).	0	2	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-
Ruff (Reeve) (*Philomachus pugnax*)		M	In Australia the Ruff is found on generally fresh, brackish of saline wetlands with exposed mudflats at the edges. It is found in terrestrial wetlands including lakes, swamps, pools, lagoons, tidal rivers, swampy fields and floodlands. They are occasionally seen on sheltered coasts, in harbours, estuaries, seashores and are known to visit sewage farms and saltworks (DAWE, 2020b).	0	2	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Pacific Golden Plover (*Pluvialis fulva*)		M	In non-breeding grounds in Australia this species usually inhabits coastal habitats, though it occasionally occurs around inland wetlands. Usually found on beaches, mudflats and sandflats (sometimes in vegetation such as mangroves, low saltmarsh such as Sarcocornia, or beds of seagrass) in sheltered areas including harbours, estuaries and lagoons, and also in evaporation ponds in saltworks. (DAWE, 2020b).	0	300	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-
Grey Plover (*Pluvialis squatarola*)		M	In non-breeding grounds in Australia, Grey Plovers occur almost entirely in coastal areas, where they usually inhabit sheltered embayments, estuaries and lagoons with mudflats and sandflats, and occasionally on rocky coasts with wave-cut platforms or reef-flats, reefs within muddy lagoons, around terrestrial wetlands such as near-coastal lakes and swamps, or salt-lakes. (DAWE, 2020b).	0	16	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species.	Bionet (10km buffer)	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Hooded Plover (*Thinornis rubricollis rubricollis*)	CE	V	In south-eastern Australia Hooded Plovers prefer sandy ocean beaches, especially those that are broad and flat, with a wide wave-wash zone for feeding, much beachcast seaweed, and backed by sparsely vegetated sand-dunes for shelter and nesting. Occasionally Hooded Plovers are found on tidal bays and estuaries, rock platforms and rocky or sand-covered reefs near sandy beaches, and small beaches in lines of cliffs. They regularly use near-coastal saline and freshwater lakes and lagoons, often with saltmarsh (DAWE, 2020b).	0	0	Low. The species was not identified during field surveys and they have not been recorded within 10 km of the subject land. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species.	EPBC Protected Matters search	Species/ Ecosystem
Grey-tailed Tattler (*Tringa brevipes*)		M	Grey-tailed Tattlers breed in Siberia. In Australia, more commonly found in the north. Usually seen in small flocks on sheltered coasts with reefs and rock platforms or with intertidal mudflats. They are also found in intertidal rocky, coral or stony reefs, platforms and islets that are exposed at high tide, also shores of rock, shingle, gravel and shells and on intertidal mudflats in embayments, estuaries and coastal lagoons, especially those fringed with mangroves. (DAWE, 2020b).	0	10	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Wood Sandpiper (*Tringa glareola*)		M	In NSW there are records east of the Great Divide, from Stratheden and Casino, south to Nowra and elsewhere, mostly from the Riverina, but also from the Upper and Lower Western Regions. Usually found in uses well-vegetated, shallow, freshwater wetlands, such as swamps, billabongs, lakes, pools and waterholes. (DAWE, 2020b).	0	3	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	-
Wandering Tattler (*Tringa incana*)		M	The Wandering Tattler is generally found on rocky coasts with reefs and platforms, points, spits, piers, offshore islands and shingle beaches or beds. It is occasionally seen on coral reefs or beaches and tends to avoid mudflats. (DAWE, 2020b).	0	6	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Common Greenshank (*Tringa nebularia*)		M	The species has been recorded in most coastal regions. It is widespread west of the Great Dividing Range, especially between the Lachlan and Murray Rivers and the Darling River drainage basin, including the Macquarie Marshes, and north-west regions. It occurs in sheltered coastal habitats, typically with large mudflats and saltmarsh, mangroves or seagrass and a wide variety of inland wetlands and sheltered coastal habitats of varying salinity (DAWE, 2020b).	0	35	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-
Marsh Sandpiper (*Tringa stagnatilis*)		M	The Marsh Sandpiper lives in permanent or ephemeral wetlands of varying salinity, including swamps, lagoons, billabongs, saltpans, saltmarshes, estuaries, pools on inundated floodplains, and intertidal mudflats and also regularly at sewage farms and saltworks (DAWE, 2020b).	0	28	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10 km buffer), EPBC Protected Matters search	-

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Terek Sandpiper (*Xenus cinereus*)	V		A rare migrant to the eastern and southern Australian coasts. The two main sites for the species in NSW are the Richmond River estuary and the Hunter River estuary. Recorded on coastal mudflats, lagoons, creeks and estuaries.	0	3	Low. The species was not identified during field surveys. Small areas of highly modified intertidal mudflats and sandflats offer marginal habitat to the species, although many preferred habitat features are absent.	Bionet (10km buffer)	Species/ Ecosystem
Mammals								
Rufous Bettong (*Aepyprymnus rufescens*)	V		In NSW it has largely vanished from inland areas but there are sporadic, unconfirmed records from the Pilliga and Torrington districts. Inhabit a variety of forests from tall, moist eucalypt forest to open woodland, with a tussock grass understorey.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Eastern Pygmy-possum (*Cercartetus nanus*)	V		Found in a broad range of habitats from rainforest through to sclerophyll forest and woodland to heath, but in most areas woodlands and heath appear to be preferred. Feeds largely on nectar and pollen collected from banksias, eucalypts and bottlebrushes. Shelters in tree hollows, rotten stumps, holes in the ground, abandoned bird-nests, Ringtail Possum dreys or thickets of vegetation. Frequently spends time in torpor especially in winter.	30	918	High. The species has been recently recorded in the Wakehurst Parkway East construction support site (BL13) and in two locations 70m and 80m east of the subject land at Wakehurst Parkway. Open forest, woodland and heath PCTs mapped next to Wakehurst Parkway offer potential foraging and sheltering habitat to this species. These vegetated habitats support preferred foraging resources, due to the presence of a variety of banksia, eucalypt and bottlebrush species.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Large-eared Pied Bat (*Chalinolobus dwyeri*)	V	V	Found mainly in areas with extensive cliffs and caves, from Rockhampton in Queensland south to Bungonia in the NSW Southern Highlands. Roosts in caves (near their entrances), crevices in cliffs, old mine workings and in the disused, mud nests of the Fairy Martin (*Petrochelidon ariel*), frequenting low to mid-elevation dry open forest and woodland close to these features.	5	25	High. This species was recorded 125 metres south-east of the Wakehurst Parkway east construction support site (BL13) during targeted surveys. There are recent Bionet records of the species in the Wakehurst Parkway east construction support site (BL13) and approximately 800 metres east of the Wakehurst Parkway in 2018.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species
Spotted-Tailed Quoll (*Dasyurus maculatus*)	V	E	Recorded across a range of habitat types, including rainforest, open forest, woodland, coastal heath and inland riparian forest, from the sub-alpine zone to the coastline. Individual animals use hollow-bearing trees, fallen logs, small caves, rock outcrops and rocky-cliff faces as den sites.	1	33	Moderate. The species was not identified during field surveys. Large tracts of native vegetation in and adjoining the northern extent of the subject land offer potential habitat to the species.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Eastern False Pipistrelle (*Falsistrellus tasmaniensis*)	V		Occurs along the east coast of NSW, where it inhabits tall moist forests. Roosts in hollows of eucalypts, occasionally under loose bark on trees or in buildings.	0	14	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species, as tall moist forests are absent from the subject land.	Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Southern Brown Bandicoot (*Isoodon obesulus obesulus*)	E	E	The Southern Brown Bandicoot is generally only found in heath or open forest with a heathy understorey on sandy or friable soils. Nest during the day in a shallow depression in the ground covered by leaf litter, grass or other plant material. Nests may be located under Grass trees Xanthorrhoea spp., blackberry bushes and other shrubs, or in rabbit burrows.	1	151	High. The species was not identified during field surveys. Large tracts of native vegetation in and adjoining the northern extent of the subject land offer potential habitat for the species.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Golden-tipped Bat (*Phoniscus papuensis*)	V		Distributed along the east coast of Australia in scattered locations from Cape York Peninsula in Queensland to south of Eden in southern NSW. Found in rainforest and adjacent wet and dry sclerophyll forest up to 1000m, tall open forest, *Casuarina*-dominated riparian forest and coastal *Melaleuca* forests.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species	BAM calculator outputs	Ecosystem
Parma Wallaby (*Macropus parma*)	V		Their range is now confined to the coast and ranges of central and northern NSW from the Gosford district to the Queensland border. Prefers moist eucalypt forest with thick, shrubby understorey, often with nearby grassy areas, rainforest margins and occasionally drier eucalypt forest.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Little Bent-winged Bat (*Miniopterus australis*)	V		The Little Bent-winged Bat is found in moist eucalypt forest, rainforest, vine thicket, wet and dry sclerophyll forest, Melaleuca swamps, dense coastal forests and banksia scrub. Generally found in well-timbered areas. Little Bent-winged Bats roost in caves, tunnels, tree hollows, abandoned mines, stormwater drains, culverts, bridges and sometimes buildings. Maternity colonies form in spring and birthing occurs in early summer. Only five nursery sites /maternity colonies are known in Australia.	13	117	High. The subject land does not support a maternity cave. Culverts and bridges within the subject land offer potential artificial roosting habitat. This species was recorded during Anabat surveys carried out in Flat Rock Drive construction support site (BL2).	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem
Large Bent-winged Bat (*Miniopterus orianae oceanensis*)	V		The Large Bent-winged Bat forage in forested areas. Caves are the primary roosting habitat, but they also use derelict mines, storm-water tunnels, buildings and other man-made structures. They form discrete populations centred on a maternity cave that is used annually in spring and summer for the birth and rearing of young. Populations disperse within about 300 km range of maternity caves.	46	479	High. The subject land does not support a maternity cave. Culverts and bridges within the subject land offer potential artificial roosting habitat. This species was recorded during Anabat surveys carried out in Flat Rock Drive construction support site (BL2).	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Eastern Coastal Free-tailed Bat (*Micronomus norfolkensis*)	V		The Eastern Coastal Free-tailed Bat is found along the east coast from south Queensland to southern NSW. Occur in dry sclerophyll forest and woodland east of the Great Dividing Range. Roost mainly in tree hollows but will also roost under bark or in man-made structures.	1	56	High. The species was not identified during field surveys. Two hollow-bearing trees identified near Wakehurst Parkway and culverts and bridges within the subject land offer potential roosting habitat to the species. Native vegetation throughout the subject land, particularly larger continuous tracts of native vegetation in the northern extent of the subject land, offers potential foraging habitat to the species.	Bionet (1.5km buffer), Bionet (10km buffer), BAM calculator outputs	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Southern Myotis (*Myotis macropus*)	V		Southern Myotis generally roost in groups of 10 - 15 close to water in caves, mine shafts, hollow-bearing trees, storm water channels, buildings, under bridges and in dense foliage. They forage over streams and pools catching insects and small fish by raking their feet across the water surface.	19	160	High. The species was not identified during field surveys. A scientific study carried out on the distribution and key foraging habitat of the Southern Myotis found the species to have a moderately high level of activity along small portions of Middle Harbour. Sheltered bays within and near the subject land (eg Sandy Bay, Shell Cove) that can provide calmer water surfaces are more suited to the trawling foraging strategy that bats employ (Gonsalves and Law, 2017b).	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Species
Long-nosed Bandicoot, North Head endangered population (*Perameles nasuta*)	EP		Restricted to North Head in the Manly local government area.	0	2310	Low. The species was not identified during field surveys. The subject land does not encompass Manly.	Bionet (10km buffer), BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Greater Glider (*Petauroides volans*)		V	The Greater Glider has restricted distribution in eastern Australia, from the Windsor Tableland in north Queensland to central Victoria, with an elevated range from sea level to 1200 metres above sea level. The species is largely restricted to eucalypt forests and woodlands. It is found in abundance in montane eucalypt forest with relatively old trees and an abundance of hollows and with a diversity of eucalypts (DAWE, 2020b).	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer), EPBC Protected Matters search	Species
Yellow-bellied Glider (*Petaurus australis*)	V		The Yellow-bellied Glider is found along the eastern coast to the western slopes of the Great Dividing Range, from southern Queensland to Victoria. Occur in tall mature eucalypt forest generally in areas with high rainfall and nutrient rich soils.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Squirrel Glider (*Petaurus norfolcensis*)	V		Inhabits mature or old growth Box, Box-Ironbark woodlands and River Red Gum forest west of the Great Dividing Range and Blackbutt-Bloodwood forest with heath understorey in coastal areas. Prefers mixed species stands with a shrub or Acacia mid-storey. Requires abundant tree hollows for refuge and nest sites.	0	6	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Squirrel Glider on Barrenjoey Peninsula, north of Bushrangers Hill (*Petaurus norfolcensis*- endangered population)	EP		Occur only on Barrenjoey Peninsula.	0	0	Low. The species was not identified during field surveys. The subject land does not encompass the Barrenjoey Peninsula.	BAM calculator outputs	Species
Brush-tailed Rock-wallaby (*Petrogale penicillata*)	E	V	In NSW they occur from the Queensland border in the north to the Shoalhaven in the south, with the population in the Warrumbungle Ranges being the western limit. Occupy rocky escarpments, outcrops and cliffs with a preference for complex structures with fissures, caves and ledges, often facing north.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	EPBC Protected Matters search	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Koala (*Phascolarctos cinereus*)	V	V	In New South Wales, koala populations are found on the central and north coasts, southern highlands, southern and northern tablelands, Blue Mountains, southern coastal forests, with some smaller populations on the plains west of the Great Dividing Range. Inhabit eucalypt woodlands and forests.	4	34	Low. The species was not identified during targeted field surveys by WSP or Arcadis. Subject land unlikely to support resident Koala population. Could occur as a vagrant. Large tracts of native vegetation within and adjoining the northern extent of the subject land offer potential habitat to the species.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species/ Ecosystem
Koala in the Pittwater Local Government Area (*Phascolarctos cinereus*)	EP		Has a fragmented distribution throughout eastern Australia, from north-east Queensland to the Eyre Peninsula in South Australia, extending west of the Great Dividing Range where it mostly occurs along inland rivers. The endangered population occurs within the Pittwater Local Government Area, with most recent records occurring on the Barrenjoey Peninsula.	0	0	Low. The species was not identified during field surveys. The subject land does not encompass the Pittwater local government area.	BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Long-nosed Potoroo (SE mainland) (*Potorous tridactylus tridactylus*)	V	V	In NSW it is generally restricted to coastal heaths and forests east of the Great Dividing Range, with an annual rainfall exceeding 760 mm. Inhabits coastal heaths and dry and wet sclerophyll forests with a dense understorey.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	BAM calculator outputs	Species
New Holland Mouse (*Pseudomys novaehollandiae*)		V	Distribution is patchy in time and space. Known to inhabit open heathlands, woodlands and forests with a heathland understorey and vegetated sand dunes.	0	7	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search	Ecosystem
Grey-headed Flying-fox (*Pteropus poliocephalus*)	V	V	Occurs in subtropical and temperate rainforests, tall sclerophyll forest and woodlands, heaths and swamps as well as urban gardens and cultivated fruit crops. Roosting camps are generally located within 20 km of a regular food source and are commonly found in gullies, close to water, in vegetation with a dense canopy.	291	3926	Known. Species was recorded in a number of locations within the subject land. A camp at Burnt Bridge Creek in Balgowlah is located in close proximity to the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species/ Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Yellow-bellied Sheathtail-bat (*Saccolaimus flaviventris*)	V		Occurs throughout tropical and south-east of Australia, excluding Tasmania. Found in a variety of habitat types including wet and dry sclerophyll forest, open woodland, Acacia shrubland, mallee, grassland and desert. Forages for insects above the tree canopy. Roost in tree hollows, abandoned sugar glider nests or animals burrows.	1	19	Low-moderate. The species was not identified during field surveys. Large tracts of native vegetation within and adjoining the northern extent of the subject land offer potential foraging and roosting habitat to the species.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem
Greater Broad-nosed Bat (*Scoteanax rueppellii*)	V		In NSW it is widespread on the New England Tablelands. Utilises a variety of habitats from woodland through to moist and dry eucalypt forest and rainforest, though it is most commonly found in tall wet forest.	1	13	Low. The species was not identified during field surveys. Large tracts of native vegetation within and adjoining the northern extent of the subject land offer habitat to the species, although preferred habitat of tall wet forest is absent from the subject land.	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Eastern Cave Bat (*Vespadelus troughtoni*)	V		Very little is known about the biology of this uncommon species. A cave-roosting species that is usually found in dry open forest and woodland, near cliffs or rocky overhangs; has been recorded roosting in disused mine workings, occasionally in colonies of up to 500 individuals. Occasionally found along cliff-lines in wet eucalypt forest and rainforest.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Species
Invertebrates								
Maroubra Woodland Snail (*Meridolum maryae*)	E		Found in the leaf litter of coastal vegetation communities, most commonly in heathland on foredunes. A large number of specimens have also been collected from areas of podsolised dunes/sand plains that support taller heath communities including Eastern Suburbs Banksia Scrub. The species has also occasionally been recorded in sandstone and clay heathland communities on headlands.	0	0	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Giant Dragonfly (*Petalura gigantea*)	E		The Giant Dragonfly is found along the east coast of NSW from the Victorian border to northern NSW. Live in permanent swamps and bogs with some free water and open vegetation.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10km buffer)	Species
Dural Land Snail (*Pommerhelix duralensis*)	E	E	The species is a shale-influenced-habitat specialist, which occurs in low densities along the western and northwest fringes of the Cumberland IBRA subregion on shale-sandstone transitional landscapes. The species has a strong affinity for communities in the interface region between shale-derived and sandstone-derived soils, with forested habitats that have good native cover and woody debris. It favours sheltering under rocks or inside curled-up bark.	0	1	Low. The species was not identified during field surveys. The subject land does not support preferred habitat for the species.	Bionet (10 km buffer), EPBC Protected Matters search, BAM calculator outputs	Species

Common Name (Scientific Name)	BC Act[1]	EPBC Act[2]	Habitat requirements	No. of records within 1.5km of subject land (since 1990) (BC Act)	No. of records within 10km of subject land	Likelihood of occurrence	Source[3]	Ecosystem or species credit species?
Reptiles								
Broad-headed Snake (*Hoplocephalus bungaroides*)	E	V	The Broad-headed Snake is largely confined to Triassic and Permian sandstones. Shelters in rock crevices and under flat sandstone rocks on exposed cliff edges during autumn, winter and spring.	0	0	Low. Rocky features such as sandstone rocks and slabs near Wakehurst Parkway in the northern extent of the subject land offer marginal habitat to the species, although exposed sandstone outcrops are absent. The closest record of this species in the Bionet atlas is about 35 kilometres south-west of the area of potential habitat in the subject land.	EPBC Protected Matters search, BAM calculator outputs	Species/ Ecosystem
Rosenberg's Goanna (*Varanus rosenbergi*)	V		Found in heath, open forest and woodland. Associated with termites, the mounds of which this species nests in; termite mounds are a critical habitat component. It shelters in burrows, hollow logs and rock crevices.	12	176	Known. This species was recorded along Wakehurst Parkway by WSP (2018).	Bionet (1.5km buffer), Bionet (10 km buffer), BAM calculator outputs	Ecosystem

1. Listed on the BC Act as V= Vulnerable, E=Endangered species, CE= Critically Endangered, E4= presumed extinct
2. Listed on the EPBC Act as M= Migratory, VM= Vulnerable and Migratory, EM= Endangered and Migratory, V= Vulnerable, Endangered, CE= Critically Endangered, X= Extinct

Data source: EPBC Search= database search using the Protected Matters Search Tool on the Department of Agriculture, Water and the Environment web site, BioNet= search of the Department of Planning Industry and Environment atlas database

Annexure B – EPBC Act Protected Matters Search Tool Results

EPBC Act Protected Matters Report

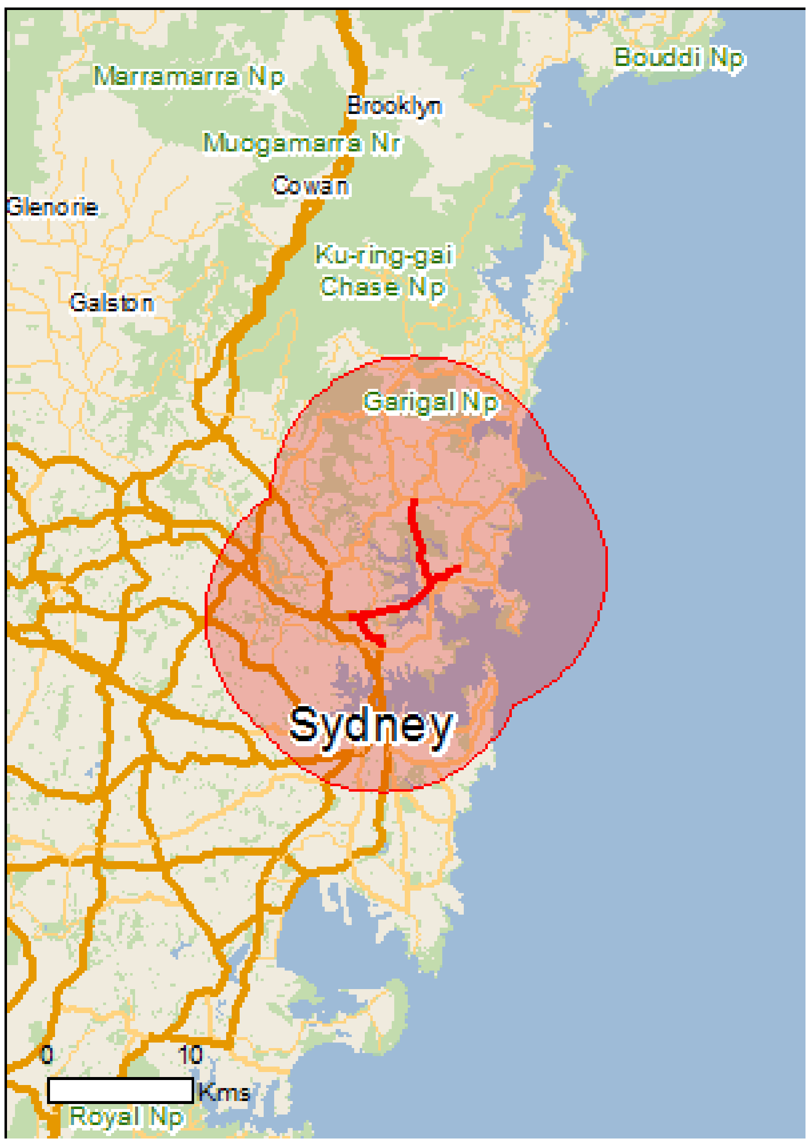
This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

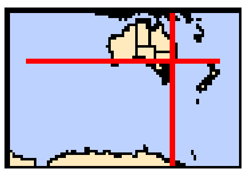
Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 11/10/21 15:17:29

Summary
Details
- Matters of NES
- Other Matters Protected by the EPBC Act
- Extra Information
Caveat
Acknowledgements



Coordinates
Buffer: 10.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	6
National Heritage Places:	12
Wetlands of International Importance:	1
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	13
Listed Threatened Species:	101
Listed Migratory Species:	75

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	59
Commonwealth Heritage Places:	71
Listed Marine Species:	96
Whales and Other Cetaceans:	16
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Australian Marine Parks:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	9
Regional Forest Agreements:	None
Invasive Species:	49
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

World Heritage Properties
[Resource Information]

Name	State	Status
Australian Convict Sites (Cockatoo Island Convict Site Buffer Zone)	NSW	Buffer zone
Australian Convict Sites (Hyde Park Barracks Buffer Zone)	NSW	Buffer zone
Sydney Opera House - Buffer Zone	NSW	Buffer zone
Australian Convict Sites (Cockatoo Island Convict Site)	NSW	Declared property
Australian Convict Sites (Hyde Park Barracks)	NSW	Declared property
Sydney Opera House	NSW	Declared property

National Heritage Properties
[Resource Information]

Name	State	Status
Natural		
Ku-ring-gai Chase National Park, Lion, Long and Spectacle Island Nature Reserves	NSW	Listed place
Indigenous		
Cyprus Hellene Club - Australian Hall	NSW	Listed place
Historic		
Bondi Beach	NSW	Listed place
Centennial Park	NSW	Listed place
Cockatoo Island	NSW	Listed place
First Government House Site	NSW	Listed place
Governors' Domain and Civic Precinct	NSW	Listed place
Hyde Park Barracks	NSW	Listed place
North Head - Sydney	NSW	Listed place
Sydney Harbour Bridge	NSW	Listed place
Sydney Opera House	NSW	Listed place
Bondi Surf Pavilion	NSW	Within listed place

Wetlands of International Importance (Ramsar)
[Resource Information]

Name	Proximity
Towra point nature reserve	Within 10km of Ramsar

Listed Threatened Ecological Communities
[Resource Information]

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Name	Status	Type of Presence
Blue Gum High Forest of the Sydney Basin Bioregion	Critically Endangered	Community likely to occur within area
Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion	Endangered	Community may occur within area
Coastal Swamp Oak (Casuarina glauca) Forest of New South Wales and South East Queensland ecological community	Endangered	Community likely to occur within area
Coastal Upland Swamps in the Sydney Basin Bioregion	Endangered	Community likely to occur within area
Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion	Critically Endangered	Community may occur within area
Eastern Suburbs Banksia Scrub of the Sydney Region	Endangered	Community known to occur within area
Littoral Rainforest and Coastal Vine Thickets of Eastern Australia	Critically Endangered	Community likely to occur within area
Posidonia australis seagrass meadows of the Manning-Hawkesbury ecoregion	Endangered	Community likely to occur within area
River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria	Critically Endangered	Community likely to occur within area
Shale Sandstone Transition Forest of the Sydney	Critically Endangered	Community may occur

Name	Status	Type of Presence
Basin Bioregion		within area
Subtropical and Temperate Coastal Saltmarsh	Vulnerable	Community likely to occur within area
Turpentine-Ironbark Forest of the Sydney Basin Bioregion	Critically Endangered	Community likely to occur within area
Western Sydney Dry Rainforest and Moist Woodland on Shale	Critically Endangered	Community likely to occur within area

Listed Threatened Species [Resource Information]

Name	Status	Type of Presence
Birds		
Anthochaera phrygia		
Regent Honeyeater [82338]	Critically Endangered	Species or species habitat known to occur within area
Botaurus poiciloptilus		
Australasian Bittern [1001]	Endangered	Species or species habitat known to occur within area
Calidris canutus		
Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea		
Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris tenuirostris		
Great Knot [862]	Critically Endangered	Foraging, feeding or related behaviour known to occur within area
Charadrius mongolus		
Lesser Sand Plover, Mongolian Plover [879]	Endangered	Foraging, feeding or related behaviour known to occur within area
Diomedea antipodensis		
Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea antipodensis gibsoni		
Gibson's Albatross [82270]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea epomophora		
Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans		
Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi		
Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Falco hypoleucos		
Grey Falcon [929]	Vulnerable	Species or species habitat may occur within area
Fregetta grallaria grallaria		
White-bellied Storm-Petrel (Tasman Sea), White-bellied Storm-Petrel (Australasian) [64438]	Vulnerable	Species or species habitat likely to occur within area
Grantiella picta		
Painted Honeyeater [470]	Vulnerable	Species or species habitat known to occur within area
Hirundapus caudacutus		
White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Lathamus discolor		
Swift Parrot [744]	Critically Endangered	Species or species

Name	Status	Type of Presence
		habitat known to occur within area
Limosa lapponica baueri Nunivak Bar-tailed Godwit, Western Alaskan Bar-tailed Godwit [86380]	Vulnerable	Species or species habitat known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Neophema chrysogaster Orange-bellied Parrot [747]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Pachyptila turtur subantarctica Fairy Prion (southern) [64445]	Vulnerable	Species or species habitat known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pterodroma leucoptera leucoptera Gould's Petrel, Australian Gould's Petrel [26033]	Endangered	Species or species habitat may occur within area
Pterodroma neglecta neglecta Kermadec Petrel (western) [64450]	Vulnerable	Foraging, feeding or related behaviour may occur within area
Rostratula australis Australian Painted Snipe [77037]	Endangered	Species or species habitat known to occur within area
Sternula nereis nereis Australian Fairy Tern [82950]	Vulnerable	Species or species habitat known to occur within area
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche bulleri platei Northern Buller's Albatross, Pacific Albatross [82273]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely

Name	Status	Type of Presence
		to occur within area
Thalassarche steadi		
White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thinornis cucullatus cucullatus		
Eastern Hooded Plover, Eastern Hooded Plover [90381]	Vulnerable	Species or species habitat known to occur within area
Fish		
Epinephelus daemelii		
Black Rockcod, Black Cod, Saddled Rockcod [68449]	Vulnerable	Species or species habitat likely to occur within area
Hippocampus whitei		
White's Seahorse, Crowned Seahorse, Sydney Seahorse [66240]	Endangered	Species or species habitat known to occur within area
Macquaria australasica		
Macquarie Perch [66632]	Endangered	Species or species habitat may occur within area
Prototroctes maraena		
Australian Grayling [26179]	Vulnerable	Species or species habitat likely to occur within area
Frogs		
Heleioporus australiacus		
Giant Burrowing Frog [1973]	Vulnerable	Species or species habitat known to occur within area
Litoria aurea		
Green and Golden Bell Frog [1870]	Vulnerable	Species or species habitat known to occur within area
Mixophyes balbus		
Stuttering Frog, Southern Barred Frog (in Victoria) [1942]	Vulnerable	Species or species habitat likely to occur within area
Mammals		
Balaenoptera borealis		
Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera musculus		
Blue Whale [36]	Endangered	Species or species habitat may occur within area
Balaenoptera physalus		
Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Chalinolobus dwyeri		
Large-eared Pied Bat, Large Pied Bat [183]	Vulnerable	Species or species habitat known to occur within area
Dasyurus maculatus maculatus (SE mainland population)		
Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll (southeastern mainland population) [75184]	Endangered	Species or species habitat known to occur within area
Eubalaena australis		
Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area
Isoodon obesulus obesulus		
Southern Brown Bandicoot (eastern), Southern Brown Bandicoot (south-eastern) [68050]	Endangered	Species or species habitat known to occur within area
Megaptera novaeangliae		
Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area

Name	Status	Type of Presence
Petauroides volans Greater Glider [254]	Vulnerable	Species or species habitat likely to occur within area
Petrogale penicillata Brush-tailed Rock-wallaby [225]	Vulnerable	Species or species habitat likely to occur within area
Phascolarctos cinereus (combined populations of Qld, NSW and the ACT) Koala (combined populations of Queensland, New South Wales and the Australian Capital Territory) [85104]	Vulnerable	Species or species habitat known to occur within area
Pseudomys novaehollandiae New Holland Mouse, Pookila [96]	Vulnerable	Species or species habitat known to occur within area
Pteropus poliocephalus Grey-headed Flying-fox [186]	Vulnerable	Roosting known to occur within area
Other		
Dendronephthya australis Cauliflower Soft Coral [90325]	Endangered	Species or species habitat known to occur within area
Pommerhelix duralensis Dural Land Snail [85268]	Endangered	Species or species habitat likely to occur within area
Plants		
Acacia bynoeana Bynoe's Wattle, Tiny Wattle [8575]	Vulnerable	Species or species habitat known to occur within area
Acacia pubescens Downy Wattle, Hairy Stemmed Wattle [18800]	Vulnerable	Species or species habitat known to occur within area
Acacia terminalis subsp. terminalis MS Sunshine Wattle (Sydney region) [88882]	Endangered	Species or species habitat known to occur within area
Allocasuarina glareicola [21932]	Endangered	Species or species habitat may occur within area
Allocasuarina portuensis Nielsen Park She-oak [21937]	Endangered	Species or species habitat known to occur within area
Asterolasia elegans [56780]	Endangered	Species or species habitat likely to occur within area
Caladenia tessellata Thick-lipped Spider-orchid, Daddy Long-legs [2119]	Vulnerable	Species or species habitat likely to occur within area
Cryptostylis hunteriana Leafless Tongue-orchid [19533]	Vulnerable	Species or species habitat likely to occur within area
Cynanchum elegans White-flowered Wax Plant [12533]	Endangered	Species or species habitat likely to occur within area
Darwinia biflora [14619]	Vulnerable	Species or species habitat known to occur within area
Deyeuxia appressa [7438]	Endangered	Species or species habitat likely to occur within area

Name	Status	Type of Presence
Eucalyptus camfieldii Camfield's Stringybark [15460]	Vulnerable	Species or species habitat known to occur within area
Genoplesium baueri Yellow Gnat-orchid, Bauer's Midge Orchid, Brittle Midge Orchid [7528]	Endangered	Species or species habitat known to occur within area
Grevillea caleyi Caley's Grevillea [9683]	Critically Endangered	Species or species habitat known to occur within area
Grevillea shiressii [19186]	Vulnerable	Species or species habitat likely to occur within area
Haloragodendron lucasii Hal [6480]	Endangered	Species or species habitat known to occur within area
Kunzea rupestris [8798]	Vulnerable	Species or species habitat likely to occur within area
Lasiopetalum joyceae [20311]	Vulnerable	Species or species habitat known to occur within area
Leptospermum deanei Deane's Tea-tree [21777]	Vulnerable	Species or species habitat known to occur within area
Melaleuca biconvexa Biconvex Paperbark [5583]	Vulnerable	Species or species habitat may occur within area
Melaleuca deanei Deane's Melaleuca [5818]	Vulnerable	Species or species habitat known to occur within area
Microtis angusii Angus's Onion Orchid [64530]	Endangered	Species or species habitat known to occur within area
Persicaria elatior Knotweed, Tall Knotweed [5831]	Vulnerable	Species or species habitat likely to occur within area
Persoonia hirsuta Hairy Geebung, Hairy Persoonia [19006]	Endangered	Species or species habitat known to occur within area
Persoonia mollis subsp. maxima [56075]	Endangered	Species or species habitat may occur within area
Pimelea curviflora var. curviflora [4182]	Vulnerable	Species or species habitat known to occur within area
Pimelea spicata Spiked Rice-flower [20834]	Endangered	Species or species habitat may occur within area
Prostanthera junonis Somersby Mintbush [64960]	Endangered	Species or species habitat known to occur within area
Prostanthera marifolia Seaforth Mintbush [7555]	Critically Endangered	Species or species habitat known to occur within area

Name	Status	Type of Presence
Rhizanthella slateri Eastern Underground Orchid [11768]	Endangered	Species or species habitat may occur within area
Rhodamnia rubescens Scrub Turpentine, Brown Malletwood [15763]	Critically Endangered	Species or species habitat known to occur within area
Rhodomyrtus psidioides Native Guava [19162]	Critically Endangered	Species or species habitat may occur within area
Syzygium paniculatum Magenta Lilly Pilly, Magenta Cherry, Daguba, Scrub Cherry, Creek Lilly Pilly, Brush Cherry [20307]	Vulnerable	Species or species habitat known to occur within area
Thesium australe Austral Toadflax, Toadflax [15202]	Vulnerable	Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Hoplocephalus bungaroides Broad-headed Snake [1182]	Vulnerable	Species or species habitat likely to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Sharks		
Carcharias taurus (east coast population) Grey Nurse Shark (east coast population) [68751]	Critically Endangered	Species or species habitat known to occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area

Listed Migratory Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Migratory Marine Birds		
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area

Name	Threatened	Type of Presence
Ardenna carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [82404]		Foraging, feeding or related behaviour likely to occur within area
Ardenna grisea Sooty Shearwater [82651]		Species or species habitat likely to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Sternula albifrons Little Tern [82849]		Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area

Name	Threatened	Type of Presence
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Migratory Marine Species		
Balaena glacialis australis Southern Right Whale [75529]	Endangered*	Species or species habitat known to occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area
Carcharhinus longimanus Oceanic Whitetip Shark [84108]		Species or species habitat may occur within area
Carcharodon carcharias White Shark, Great White Shark [64470]	Vulnerable	Species or species habitat known to occur within area
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Dugong dugon Dugong [28]		Species or species habitat may occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat may occur within area
Lamna nasus Porbeagle, Mackerel Shark [83288]		Species or species habitat likely to occur within area
Manta alfredi Reef Manta Ray, Coastal Manta Ray, Inshore Manta Ray, Prince Alfred's Ray, Resident Manta Ray [84994]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Manta birostris Giant Manta Ray, Chevron Manta Ray, Pacific Manta Ray, Pelagic Manta Ray, Oceanic Manta Ray [84995]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat likely to occur within area
Rhincodon typus Whale Shark [66680]	Vulnerable	Species or species habitat may occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Cuculus optatus Oriental Cuckoo, Horsfield's Cuckoo [86651]		Species or species habitat known to occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Migratory Wetlands Species		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Arenaria interpres Ruddy Turnstone [872]		Foraging, feeding or related behaviour known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Foraging, feeding or related behaviour known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur within area
Calidris ruficollis Red-necked Stint [860]		Foraging, feeding or related behaviour known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Foraging, feeding or related behaviour known to occur within area
Charadrius bicinctus Double-banded Plover [895]		Foraging, feeding or related behaviour known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Foraging, feeding or related behaviour known to occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Foraging, feeding or related behaviour likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Foraging, feeding or related behaviour likely to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Foraging, feeding or related behaviour known to occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Foraging, feeding or related behaviour likely to occur within area
Numenius phaeopus Whimbrel [849]		Foraging, feeding or related behaviour known to occur within area
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Foraging, feeding or related behaviour known to occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Foraging, feeding or related behaviour known to occur within area
Tringa brevipes Grey-tailed Tattler [851]		Foraging, feeding or related behaviour known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Foraging, feeding or related behaviour known to occur within area

Other Matters Protected by the EPBC Act

Commonwealth Land [Resource Information]

The Commonwealth area listed below may indicate the presence of Commonwealth land in this vicinity. Due to the unreliability of the data source, all proposals should be checked as to whether it impacts on a Commonwealth area, before making a definitive decision. Contact the State or Territory government land department for further information.

Name
Commonwealth Land -
Commonwealth Land - Airservices Australia
Commonwealth Land - Australian & Overseas Telecommunications Corporation
Commonwealth Land - Australian Broadcasting Commission
Commonwealth Land - Australian Broadcasting Corporation
Commonwealth Land - Australian National University
Commonwealth Land - Australian Postal Commission
Commonwealth Land - Australian Postal Corporation
Commonwealth Land - Australian Telecommunications Commission
Commonwealth Land - Australian Telecommunications Corporation
Commonwealth Land - Commonwealth Bank of Australia
Commonwealth Land - Commonwealth Scientific & Industrial Research Organisation
Commonwealth Land - Commonwealth Trading Bank of Australia
Commonwealth Land - Defence Housing Authority
Commonwealth Land - Defence Service Homes Corporation
Commonwealth Land - Director of Defence Service Homes
Commonwealth Land - Director of War Service Homes
Commonwealth Land - Reserve Bank of Australia
Commonwealth Land - Telstra Corporation Limited
Defence - 21 CONST REGT - HABERFIELD DEPOT
Defence - COCKATOO ISLAND DOCKYARD
Defence - DEE WHY DEPOT
Defence - DEFENCE PLAZA SYDNEY
Defence - DEGAUSSING RANGE
Defence - DSTO PYRMONT - (SEE SITE 1177)
Defence - FLEET BASE WHARVES
Defence - FOREST LODGE (SYDNEY) TRG DEP
Defence - GARDEN ISLAND
Defence - GLADESVILLE TRAINING DEPOT
Defence - HMAS KUTTABUL (AC 30/5 Lot4 DP218946)
Defence - HMAS PENGUIN
Defence - HMAS PLATYPUS - SPDU FOR DISPOSAL
Defence - HMAS WATERHEN
Defence - HMAS WATSON
Defence - JENNER BUILDING
Defence - KENSINGTON DEPOT
Defence - KISMET/HMAS KUTTABUL-POTTS PT
Defence - LADY GOWRIE HOUSE
Defence - LEICHHARDT STORES DEPOT

Name
Defence - MARITIME COMD CTRE-POTTS POINT ; BOMERAH/TARANA
Defence - MARITIME HEADQUARTERS
Defence - MATERIAL RESEARCH LAB
Defence - MILLER'S POINT TRAINING DEPOT
Defence - NFI CHOWDER BAY (fuel depot)
Defence - NORTH SYDNEY - HYDRO OFFICE
Defence - OXFORD ST SYDNEY
Defence - PARKVIEW BUILDING - SYDNEY
Defence - PYMBLE MULTI-USER DEPOT
Defence - RANDWICK (CARRINGTON RD)
Defence - RANDWICK FRENCHMANS TRG
Defence - SPECTACLE ISLAND
Defence - SYDNEY UNIVERSITY REGIMENT - DARLINGTON
Defence - TRAINING SHIP CONDAMINE
Defence - TRESCO
Defence - VAUCLUSE TRAINING DEPOT
Defence - VICTORIA BARRACKS - PADDINGTON
Defence - WILLOUGHBY TRG DEP
Defence - WOOLLOOMOOLOO CARPARK
Defence - ZETLAND NAVY SUPPLY CENTRE

Commonwealth Heritage Places

[Resource Information]

Name	State	Status
Historic		
Admiralty House Garden and Fortifications	NSW	Listed place
Admiralty House and Lodge	NSW	Listed place
Army Cottage with return verandah	NSW	Listed place
Barracks Block	NSW	Listed place
Barracks Group HMAS Watson	NSW	Listed place
Batteries A83 and C9A	NSW	Listed place
Battery B42	NSW	Listed place
Battery for Five Guns	NSW	Listed place
Biloela Group	NSW	Listed place
Bondi Beach Post Office	NSW	Listed place
Building VB1 and Parade Ground	NSW	Listed place
Building VB2 Guard House	NSW	Listed place
Buildings 31 and 32	NSW	Listed place
Buildings MQVB16 and VB56	NSW	Listed place
Buildings VB13, 15, 16 & 17	NSW	Listed place
Buildings VB41, 45 & 53	NSW	Listed place
Buildings VB60 and VB62	NSW	Listed place
Buildings VB69, 75 & 76 including Garden	NSW	Listed place
Buildings VB83, 84, 85, 87 & 89	NSW	Listed place
Buildings VB90, 91, 91A & 92	NSW	Listed place
Chain and Anchor Store (former)	NSW	Listed place
Chowder Bay Barracks Group	NSW	Listed place
Cliff House	NSW	Listed place
Cockatoo Island Industrial Conservation Area	NSW	Listed place
Commonwealth Avenue Defence Housing	NSW	Listed place
Cottage at Macquarie Lighthouse	NSW	Listed place
Customs Marine Centre	NSW	Listed place
Defence site - Georges Heights and Middle Head	NSW	Listed place
Factory	NSW	Listed place
Fitzroy Dock	NSW	Listed place
Garden Island Precinct	NSW	Listed place
Gazebo	NSW	Listed place
General Post Office	NSW	Listed place
Golf Clubhouse (former)	NSW	Listed place
HMAS Penguin	NSW	Listed place
Headquarters 8th Brigade Precinct	NSW	Listed place
Headquarters Training Command Precinct	NSW	Listed place
Kirribilli House	NSW	Listed place
Kirribilli House Garden & Grounds	NSW	Listed place
Macquarie Lighthouse	NSW	Listed place
Macquarie Lighthouse Group	NSW	Listed place
Macquarie Lighthouse Surrounding Wall	NSW	Listed place

Name	State	Status
Marine Biological Station (former)	NSW	Listed place
Mess Hall (former)	NSW	Listed place
Military Guard Room	NSW	Listed place
Military Road Framework - Defence Land	NSW	Listed place
Naval Store	NSW	Listed place
Navy Refuelling Depot and Caretakers House	NSW	Listed place
North Head Artillery Barracks	NSW	Listed place
North Sydney Post Office	NSW	Listed place
Office Building	NSW	Listed place
Officers Mess, HQ Training Command	NSW	Listed place
Paddington Post Office	NSW	Listed place
Power House / Pump House	NSW	Listed place
Prison Barracks Precinct	NSW	Listed place
Pyrmont Post Office	NSW	Listed place
Reserve Bank	NSW	Listed place
Residences Group	NSW	Listed place
Rigging Shed and Chapel	NSW	Listed place
Shark Point Battery	NSW	Listed place
Snapper Island	NSW	Listed place
Spectacle Island Explosives Complex	NSW	Listed place
Sutherland Dock	NSW	Listed place
Sydney Customs House (former)	NSW	Listed place
Ten Terminal Regiment Headquarters and AusAid Training Centre	NSW	Listed place
Thirty Terminal Squadron Precinct	NSW	Listed place
Underground Grain Silos	NSW	Listed place
Victoria Barracks Perimeter Wall and Gates	NSW	Listed place
Victoria Barracks Precinct	NSW	Listed place
Victoria Barracks Squash Courts	NSW	Listed place
Woolwich Dock	NSW	Listed place

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Actitis hypoleucos Common Sandpiper [59309]		Species or species habitat known to occur within area
Anous stolidus Common Noddy [825]		Species or species habitat likely to occur within area
Apus pacificus Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea ibis Cattle Egret [59542]		Species or species habitat may occur within area
Arenaria interpres Ruddy Turnstone [872]		Foraging, feeding or related behaviour known to occur within area
Calidris acuminata Sharp-tailed Sandpiper [874]		Foraging, feeding or related behaviour known to occur within area
Calidris canutus Red Knot, Knot [855]	Endangered	Species or species habitat known to occur within area
Calidris ferruginea Curlew Sandpiper [856]	Critically Endangered	Species or species habitat known to occur within area
Calidris melanotos Pectoral Sandpiper [858]		Species or species habitat known to occur

Name	Threatened	Type of Presence
		within area
Calidris ruficollis Red-necked Stint [860]		Foraging, feeding or related behaviour known to occur within area
Calidris tenuirostris Great Knot [862]	Critically Endangered	Foraging, feeding or related behaviour known to occur within area
Calonectris leucomelas Streaked Shearwater [1077]		Species or species habitat known to occur within area
Catharacta skua Great Skua [59472]		Species or species habitat may occur within area
Charadrius bicinctus Double-banded Plover [895]		Foraging, feeding or related behaviour known to occur within area
Charadrius mongolus Lesser Sand Plover, Mongolian Plover [879]	Endangered	Foraging, feeding or related behaviour known to occur within area
Charadrius ruficapillus Red-capped Plover [881]		Foraging, feeding or related behaviour known to occur within area
Diomedea antipodensis Antipodean Albatross [64458]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea epomophora Southern Royal Albatross [89221]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea exulans Wandering Albatross [89223]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Diomedea gibsoni Gibson's Albatross [64466]	Vulnerable*	Foraging, feeding or related behaviour likely to occur within area
Diomedea sanfordi Northern Royal Albatross [64456]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Fregata ariel Lesser Frigatebird, Least Frigatebird [1012]		Species or species habitat known to occur within area
Fregata minor Great Frigatebird, Greater Frigatebird [1013]		Species or species habitat may occur within area
Gallinago hardwickii Latham's Snipe, Japanese Snipe [863]		Species or species habitat known to occur within area
Gallinago megala Swinhoe's Snipe [864]		Foraging, feeding or related behaviour likely to occur within area
Gallinago stenura Pin-tailed Snipe [841]		Foraging, feeding or related behaviour likely to occur within area
Haliaeetus leucogaster White-bellied Sea-Eagle [943]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Heteroscelus brevipes Grey-tailed Tattler [59311]		Foraging, feeding or related behaviour known to occur within area
Himantopus himantopus Pied Stilt, Black-winged Stilt [870]		Foraging, feeding or related behaviour known to occur within area
Hirundapus caudacutus White-throated Needletail [682]	Vulnerable	Species or species habitat known to occur within area
Lathamus discolor Swift Parrot [744]	Critically Endangered	Species or species habitat known to occur within area
Limosa lapponica Bar-tailed Godwit [844]		Species or species habitat known to occur within area
Limosa limosa Black-tailed Godwit [845]		Foraging, feeding or related behaviour known to occur within area
Macronectes giganteus Southern Giant-Petrel, Southern Giant Petrel [1060]	Endangered	Species or species habitat may occur within area
Macronectes halli Northern Giant Petrel [1061]	Vulnerable	Species or species habitat may occur within area
Merops ornatus Rainbow Bee-eater [670]		Species or species habitat may occur within area
Monarcha melanopsis Black-faced Monarch [609]		Species or species habitat known to occur within area
Monarcha trivirgatus Spectacled Monarch [610]		Species or species habitat known to occur within area
Motacilla flava Yellow Wagtail [644]		Species or species habitat known to occur within area
Myiagra cyanoleuca Satin Flycatcher [612]		Species or species habitat known to occur within area
Neophema chrysogaster Orange-bellied Parrot [747]	Critically Endangered	Species or species habitat may occur within area
Numenius madagascariensis Eastern Curlew, Far Eastern Curlew [847]	Critically Endangered	Species or species habitat known to occur within area
Numenius minutus Little Curlew, Little Whimbrel [848]		Foraging, feeding or related behaviour likely to occur within area
Numenius phaeopus Whimbrel [849]		Foraging, feeding or related behaviour known to occur within area
Pachyptila turtur Fairy Prion [1066]		Species or species habitat known to occur within area

Name	Threatened	Type of Presence
Pandion haliaetus Osprey [952]		Species or species habitat known to occur within area
Philomachus pugnax Ruff (Reeve) [850]		Foraging, feeding or related behaviour known to occur within area
Phoebetria fusca Sooty Albatross [1075]	Vulnerable	Species or species habitat may occur within area
Pluvialis fulva Pacific Golden Plover [25545]		Foraging, feeding or related behaviour known to occur within area
Puffinus carneipes Flesh-footed Shearwater, Fleshy-footed Shearwater [1043]		Foraging, feeding or related behaviour likely to occur within area
Puffinus griseus Sooty Shearwater [1024]		Species or species habitat likely to occur within area
Recurvirostra novaehollandiae Red-necked Avocet [871]		Foraging, feeding or related behaviour known to occur within area
Rhipidura rufifrons Rufous Fantail [592]		Species or species habitat known to occur within area
Rostratula benghalensis (sensu lato) Painted Snipe [889]	Endangered*	Species or species habitat known to occur within area
Sterna albifrons Little Tern [813]		Species or species habitat may occur within area
Thalassarche bulleri Buller's Albatross, Pacific Albatross [64460]	Vulnerable	Species or species habitat may occur within area
Thalassarche cauta Shy Albatross [89224]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche eremita Chatham Albatross [64457]	Endangered	Foraging, feeding or related behaviour likely to occur within area
Thalassarche impavida Campbell Albatross, Campbell Black-browed Albatross [64459]	Vulnerable	Species or species habitat may occur within area
Thalassarche melanophris Black-browed Albatross [66472]	Vulnerable	Species or species habitat may occur within area
Thalassarche salvini Salvin's Albatross [64463]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Thalassarche sp. nov. Pacific Albatross [66511]	Vulnerable*	Species or species habitat may occur within area
Thalassarche steadi White-capped Albatross [64462]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area

Name	Threatened	Type of Presence
Thinornis rubricollis rubricollis Hooded Plover (eastern) [66726]	Vulnerable*	Species or species habitat known to occur within area
Tringa nebularia Common Greenshank, Greenshank [832]		Species or species habitat known to occur within area
Tringa stagnatilis Marsh Sandpiper, Little Greenshank [833]		Foraging, feeding or related behaviour known to occur within area
Fish		
Acentronura tentaculata Shortpouch Pygmy Pipehorse [66187]		Species or species habitat may occur within area
Festucalex cinctus Girdled Pipefish [66214]		Species or species habitat may occur within area
Filicampus tigris Tiger Pipefish [66217]		Species or species habitat may occur within area
Heraldia nocturna Upside-down Pipefish, Eastern Upside-down Pipefish, Eastern Upside-down Pipefish [66227]		Species or species habitat may occur within area
Hippichthys penicillus Beady Pipefish, Steep-nosed Pipefish [66231]		Species or species habitat may occur within area
Hippocampus abdominalis Big-belly Seahorse, Eastern Potbelly Seahorse, New Zealand Potbelly Seahorse [66233]		Species or species habitat may occur within area
Hippocampus whitei White's Seahorse, Crowned Seahorse, Sydney Seahorse [66240]	Endangered	Species or species habitat known to occur within area
Histiogamphelus briggsii Crested Pipefish, Briggs' Crested Pipefish, Briggs' Pipefish [66242]		Species or species habitat may occur within area
Lissocampus runa Javelin Pipefish [66251]		Species or species habitat may occur within area
Maroubra perserrata Sawtooth Pipefish [66252]		Species or species habitat may occur within area
Notiocampus ruber Red Pipefish [66265]		Species or species habitat may occur within area
Phyllopteryx taeniolatus Common Seadragon, Weedy Seadragon [66268]		Species or species habitat may occur within area
Solegnathus spinosissimus Spiny Pipehorse, Australian Spiny Pipehorse [66275]		Species or species habitat may occur within area
Solenostomus cyanopterus Robust Ghostpipefish, Blue-finned Ghost Pipefish, [66183]		Species or species habitat may occur within area
Solenostomus paradoxus Ornate Ghostpipefish, Harlequin Ghost Pipefish, Ornate Ghost Pipefish [66184]		Species or species habitat may occur within area

Name	Threatened	Type of Presence
Stigmatopora argus Spotted Pipefish, Gulf Pipefish, Peacock Pipefish [66276]		Species or species habitat may occur within area
Stigmatopora nigra Widebody Pipefish, Wide-bodied Pipefish, Black Pipefish [66277]		Species or species habitat may occur within area
Syngnathoides biaculeatus Double-end Pipehorse, Double-ended Pipehorse, Alligator Pipefish [66279]		Species or species habitat may occur within area
Trachyrhamphus bicoarctatus Bentstick Pipefish, Bend Stick Pipefish, Short-tailed Pipefish [66280]		Species or species habitat may occur within area
Urocampus carinirostris Hairy Pipefish [66282]		Species or species habitat may occur within area
Vanacampus margaritifer Mother-of-pearl Pipefish [66283]		Species or species habitat may occur within area
Mammals		
Arctocephalus forsteri Long-nosed Fur-seal, New Zealand Fur-seal [20]		Species or species habitat may occur within area
Arctocephalus pusillus Australian Fur-seal, Australo-African Fur-seal [21]		Species or species habitat may occur within area
Dugong dugon Dugong [28]		Species or species habitat may occur within area
Reptiles		
Caretta caretta Loggerhead Turtle [1763]	Endangered	Species or species habitat known to occur within area
Chelonia mydas Green Turtle [1765]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Dermochelys coriacea Leatherback Turtle, Leathery Turtle, Luth [1768]	Endangered	Foraging, feeding or related behaviour known to occur within area
Eretmochelys imbricata Hawksbill Turtle [1766]	Vulnerable	Species or species habitat known to occur within area
Natator depressus Flatback Turtle [59257]	Vulnerable	Foraging, feeding or related behaviour known to occur within area
Pelamis platurus Yellow-bellied Seasnake [1091]		Species or species habitat may occur within area

Whales and other Cetaceans [Resource Information]

Name	Status	Type of Presence
Mammals		
Balaenoptera acutorostrata Minke Whale [33]		Species or species habitat may occur within area
Balaenoptera borealis Sei Whale [34]	Vulnerable	Foraging, feeding or related behaviour likely

Name	Status	Type of Presence
		to occur within area
Balaenoptera edeni Bryde's Whale [35]		Species or species habitat may occur within area
Balaenoptera musculus Blue Whale [36]	Endangered	Species or species habitat may occur within area
Balaenoptera physalus Fin Whale [37]	Vulnerable	Foraging, feeding or related behaviour likely to occur within area
Caperea marginata Pygmy Right Whale [39]		Foraging, feeding or related behaviour may occur within area
Delphinus delphis Common Dolphin, Short-beaked Common Dolphin [60]		Species or species habitat may occur within area
Eubalaena australis Southern Right Whale [40]	Endangered	Species or species habitat known to occur within area
Grampus griseus Risso's Dolphin, Grampus [64]		Species or species habitat may occur within area
Lagenorhynchus obscurus Dusky Dolphin [43]		Species or species habitat may occur within area
Megaptera novaeangliae Humpback Whale [38]	Vulnerable	Species or species habitat known to occur within area
Orcinus orca Killer Whale, Orca [46]		Species or species habitat likely to occur within area
Sousa chinensis Indo-Pacific Humpback Dolphin [50]		Species or species habitat likely to occur within area
Stenella attenuata Spotted Dolphin, Pantropical Spotted Dolphin [51]		Species or species habitat may occur within area
Tursiops aduncus Indian Ocean Bottlenose Dolphin, Spotted Bottlenose Dolphin [68418]		Species or species habitat likely to occur within area
Tursiops truncatus s. str. Bottlenose Dolphin [68417]		Species or species habitat may occur within area

Extra Information

State and Territory Reserves	[Resource Information]
Name	State
102 Rosedale Road	NSW
Dalrymple-Hay	NSW
Garigal	NSW
Ku-ring-gai Chase	NSW
Lane Cove	NSW
North Head	NSW
Parramatta River	NSW
Sydney Harbour	NSW
Wallumatta	NSW

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Acridotheres tristis Common Myna, Indian Myna [387]		Species or species habitat likely to occur within area
Alauda arvensis Skylark [656]		Species or species habitat likely to occur within area
Anas platyrhynchos Mallard [974]		Species or species habitat likely to occur within area
Carduelis carduelis European Goldfinch [403]		Species or species habitat likely to occur within area
Carduelis chloris European Greenfinch [404]		Species or species habitat likely to occur within area
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Lonchura punctulata Nutmeg Mannikin [399]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Passer montanus Eurasian Tree Sparrow [406]		Species or species habitat likely to occur within area
Pycnonotus jocosus Red-whiskered Bulbul [631]		Species or species habitat likely to occur within area
Streptopelia chinensis Spotted Turtle-Dove [780]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area

Name	Status	Type of Presence
Turdus merula Common Blackbird, Eurasian Blackbird [596]		Species or species habitat likely to occur within area
Frogs		
Rhinella marina Cane Toad [83218]		Species or species habitat known to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Canis lupus familiaris Domestic Dog [82654]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Feral deer Feral deer species in Australia [85733]		Species or species habitat likely to occur within area
Lepus capensis Brown Hare [127]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Rattus norvegicus Brown Rat, Norway Rat [83]		Species or species habitat likely to occur within area
Rattus rattus Black Rat, Ship Rat [84]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Alternanthera philoxeroides Alligator Weed [11620]		Species or species habitat likely to occur within area
Anredera cordifolia Madeira Vine, Jalap, Lamb's-tail, Mignonette Vine, Anredera, Gulf Madeiravine, Heartleaf Madeiravine, Potato Vine [2643]		Species or species habitat likely to occur within area
Asparagus aethiopicus Asparagus Fern, Ground Asparagus, Basket Fern, Sprengi's Fern, Bushy Asparagus, Emerald Asparagus [62425]		Species or species habitat likely to occur within area
Asparagus asparagoides Bridal Creeper, Bridal Veil Creeper, Smilax, Florist's Smilax, Smilax Asparagus [22473]		Species or species habitat likely to occur within area
Asparagus plumosus Climbing Asparagus-fern [48993]		Species or species habitat likely to occur within area
Asparagus scandens Asparagus Fern, Climbing Asparagus Fern		Species or species

Name	Status	Type of Presence
[23255]		habitat likely to occur within area
Cabomba caroliniana		
Cabomba, Fanwort, Carolina Watershield, Fish Grass, Washington Grass, Watershield, Carolina Fanwort, Common Cabomba [5171]		Species or species habitat likely to occur within area
Chrysanthemoides monilifera		
Bitou Bush, Boneseed [18983]		Species or species habitat may occur within area
Chrysanthemoides monilifera subsp. monilifera		
Boneseed [16905]		Species or species habitat likely to occur within area
Chrysanthemoides monilifera subsp. rotundata		
Bitou Bush [16332]		Species or species habitat likely to occur within area
Cytisus scoparius		
Broom, English Broom, Scotch Broom, Common Broom, Scottish Broom, Spanish Broom [5934]		Species or species habitat likely to occur within area
Dolichandra unguis-cati		
Cat's Claw Vine, Yellow Trumpet Vine, Cat's Claw Creeper, Funnel Creeper [85119]		Species or species habitat likely to occur within area
Eichhornia crassipes		
Water Hyacinth, Water Orchid, Nile Lily [13466]		Species or species habitat likely to occur within area
Genista linifolia		
Flax-leaved Broom, Mediterranean Broom, Flax Broom [2800]		Species or species habitat likely to occur within area
Genista monspessulana		
Montpellier Broom, Cape Broom, Canary Broom, Common Broom, French Broom, Soft Broom [20126]		Species or species habitat likely to occur within area
Genista sp. X Genista monspessulana		
Broom [67538]		Species or species habitat may occur within area
Lantana camara		
Lantana, Common Lantana, Kamara Lantana, Large-leaf Lantana, Pink Flowered Lantana, Red Flowered Lantana, Red-Flowered Sage, White Sage, Wild Sage [10892]		Species or species habitat likely to occur within area
Lycium ferocissimum		
African Boxthorn, Boxthorn [19235]		Species or species habitat likely to occur within area
Opuntia spp.		
Prickly Pears [82753]		Species or species habitat likely to occur within area
Pinus radiata		
Radiata Pine Monterey Pine, Insignis Pine, Wilding Pine [20780]		Species or species habitat may occur within area
Rubus fruticosus aggregate		
Blackberry, European Blackberry [68406]		Species or species habitat likely to occur within area
Sagittaria platyphylla		
Delta Arrowhead, Arrowhead, Slender Arrowhead [68483]		Species or species habitat likely to occur within area
Salix spp. except S.babylonica, S.x calodendron & S.x reichardtii		
Willows except Weeping Willow, Pussy Willow and Sterile Pussy Willow [68497]		Species or species habitat likely to occur within area
Salvinia molesta		
Salvinia, Giant Salvinia, Aquarium Watermoss,		Species or species

Name	Status	Type of Presence
Kariba Weed [13665]		habitat likely to occur within area
Senecio madagascariensis		
Fireweed, Madagascar Ragwort, Madagascar Groundsel [2624]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

Threatened, migratory and marine species distributions have been derived through a variety of methods. Where distributions are well known and if time permits, maps are derived using either thematic spatial data (i.e. vegetation, soils, geology, elevation, aspect, terrain, etc) together with point locations and described habitat; or environmental modelling (MAXENT or BIOCLIM habitat modelling) using point locations and environmental data layers.

Where very little information is available for species or large number of maps are required in a short time-frame, maps are derived either from 0.04 or 0.02 decimal degree cells; by an automated process using polygon capture techniques (static two kilometre grid cells, alpha-hull and convex hull); or captured manually or by using topographic features (national park boundaries, islands, etc). In the early stages of the distribution mapping process (1999-early 2000s) distributions were defined by degree blocks, 100K or 250K map sheets to rapidly create distribution maps. More reliable distribution mapping methods are used to update these distributions as time permits.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-33.829733 151.213999,-33.828806 151.213999,-33.827238 151.213569,-33.825669 151.212969,-33.824742 151.211681,-33.824243 151.210394,-33.824029 151.20902,-33.823459 151.207561,-33.82296 151.206703,-33.822247 151.205587,-33.821534 151.204815,-33.820179 151.203699,-33.818824 151.202497,-33.816471 151.201296,-33.815544 151.201296,-33.81426 151.201896,-33.813547 151.202583,-33.81262 151.203527,-33.811978 151.204815,-33.812549 151.193399,-33.811978 151.204815,-33.808341 151.2291,-33.803563 151.23743,-33.799854 151.242409,-33.799283 151.243009,-33.798285 151.243353,-33.797357 151.243782,-33.796145 151.244383,-33.795432 151.244726,-33.794576 151.245498,-33.793506 151.248073,-33.793006 151.249704,-33.792578 151.252537,-33.792293 151.253824,-33.791722 151.254768,-33.789797 151.256571,-33.789083 151.257601,-33.788584 151.259489,-33.788655 151.261806,-33.788798 151.264639,-33.788584 151.259489,-33.788941 151.257772,-33.791081 151.255197,-33.791794 151.254511,-33.792293 151.253481,-33.792792 151.250734,-33.793434 151.248073,-33.794504 151.245584,-33.795788 151.244468,-33.796858 151.244039,-33.793862 151.243782,-33.791009 151.242323,-33.78944 151.241379,-33.7873 151.240349,-33.782092 151.23786,-33.78088 151.23786,-33.779167 151.238374,-33.777027 151.238374,-33.774316 151.237173,-33.762615 151.232366,-33.760973 151.232366,-33.752196 151.234598

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Department of Land and Resource Management, Northern Territory
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Australian Tropical Herbarium, Cairns
- -eBird Australia
- -Australian Government – Australian Antarctic Data Centre
- -Museum and Art Gallery of the Northern Territory
- -Australian Government National Environmental Science Program
- -Australian Institute of Marine Science
- -Reef Life Survey Australia
- -American Museum of Natural History
- -Queen Victoria Museum and Art Gallery, Inveresk, Tasmania
- -Tasmanian Museum and Art Gallery, Hobart, Tasmania
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

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Annexure C – Species recorded

Flora species recorded in vegetation plots (WSP, 2018; Arcadis)

* indicates exotic species

Family	Scientific name	Common name	Per cent cover in vegetation plots																						
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Pteridophytes																									
Aspleniaceae	*Asplenium australasicum f. australasicum*	Birds-nest Fern								1															
Blechnaceae	*Doodia aspera*	Prickly Rasp Fern						0.5																	
Cyatheaceae	*Cyathea cooperi*	Straw Tree-fern		3		1	1	10																	
Davalliaceae	*Nephrolepis cordifolia*	Fishbone Fern	*				1																		
Dennstaedtiaceae	*Histiopteris incisa*	Batswing Fern		5																					
Dennstaedtiaceae	*Pteridium esculentum*	Bracken		5		2		10		1	4			5					3						
Dicksoniaceae	*Calochlaena dubia*	Rainbow Fern								0.4															
Gleicheniaceae	*Gleichenia dicarpa*	Pouched Coral-fern						0.2																	
Gleicheniaceae	*Sticherus flabellatus*	Umbrella Fern						4																	
Lindsaeaceae	*Lindsaea linearis*	Screw Fern									0.5	0.4		0.4			0.3		0.5						
Lindsaeaceae	*Lindsaea microphylla*	Lacy Wedge-fern						0.1	0.1			0.2		0.4			0.5	0.2							

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Pteridaceae	*Adiantum aethiopicum*	Common Maidenhair Fern								0.4	2													
Angiosperms - Dicotyledons																								
Acanthaceae	*Brunoniella australis*	Blue Trumpet												0.5										
Acanthaceae	*Pseuderanthemum variabile*	Pastel Flower								10									0.1					
Alliaceae	*Nothoscordum gracile*	Onion Weed	*				0.4														0.2	0.1		
Apiaceae	*Actinotus minor*	Lesser Flannel Flower							0.1				0.1			0.3	0.4	0.3	0.6				0.1	0.2
Apiaceae	*Centella asiatica*	Indian Pennywort																	0.4					
Apiaceae	*Cyclospermum leptophyllum*	Slender Celery	*			0.1											0.1				0.1	0.1		
Apiaceae	*Hydrocotyle bonariensis*	Beach Pennywort	*	0.1		0.2																		
Apiaceae	*Hydrocotyle laxiflora*	Stinking Pennywort				0.1																		
Apiaceae	*Hydrocotyle sibthorpioides*	Pennywort				0.1																		
Apiaceae	*Platysace linearifolia*							0.3	0.2				0.2	1	0.6		0.7	1						
Apiaceae	*Xanthosia pilosa*							0.1										0.1					0.1	
Apiaceae	*Xanthosia tridentata*	Rock Xanthosia							0.1		0.4							0.1	0.4					

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Apocynaceae	*Araujia sericifera*	Moth Vine	*		0.1			0.1																
Apocynaceae	*Parsonsia straminea*	Common Silkpod																	0.2					
Araliaceae	*Polyscias sambucifolia*	Elderberry Panax								1														
Asteraceae	*Ageratina adenophora*	Crofton Weed	*	0.2																				
Asteraceae	*Ageratina riparia*	Mistflower	*	0.1		0.1																		
Asteraceae	*Bidens pilosa*	Cobblers Pegs	*		0.1		0.4														0.2			
Asteraceae	*Conyza bonariensis*	Flaxleaf Fleabane	*	0.1	0.1	0.1																		
Asteraceae	*Cymbonotus lawsonianus*	Bear's-ear						0.1																
Asteraceae	*Delairea odorata*	Cape Ivy	*	0.1	0.1																			
Asteraceae	*Galinsoga parviflora*	Potato Weed	*				0.4																	
Asteraceae	*Gamochaeta americana*	Cudweed	*																		0.1			
Asteraceae	*Lactuca serriola*	Prickly Lettuce	*																		0.1			
Asteraceae	*Ozothamnus diosmifolius*	White Dogwood																			0.1			
Asteraceae	*Sonchus oleraceus*	Common Sow-thistle	*				0.4														0.1			
Basellaceae	*Anredera cordifolia*	Madeira Vine	*	0.4	5																			

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Bignoniaceae	*Pandorea pandorana*	Wonga Vine								0.2									0.1					
Brassicaceae	*Cardamine hirsuta*	Common Bittercress	*				0.4	0.1																
Cannabaceae	*Celtis sinensis*	Japanese Hackberry	*				1														0.1			
Caryophyllaceae	*Stellaria media*	Common Chickweed	*				0.4																	
Casuarinaceae	*Allocasuarina distyla*												15		40								20	2
Casuarinaceae	*Allocasuarina littoralis*	Black She-Oak						5	3		30	40		2		30	2	3	30	30	1	0.1	10	30
Casuarinaceae	*Allocasuarina torulosa*	Forest She-oak								1														
Casuarinaceae	*Casuarina cunninghamiana*	River Oak,		5	8	12																		
Convolvulaceae	*Dichondra repens*	Kidney-weed		0.2						1														
Convolvulaceae	*Ipomoea indica*	Blue Morning Glory	*	0.2	7																			
Cunoniaceae	*Callicoma serratifolia*	Blackwattle		2		2	1	10																
Cunoniaceae	*Ceratopetalum gummiferum*	NSW Christmas Bush						3		3	5			15					2					
Cupressaceae	*Cupressus sp.*		*				5																	
Dilleniaceae	*Hibbertia aspera*	Rough Guinea-flower						0.2	0.9		0.5		0.1	0.9				0.5	0.7				0.1	

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Dilleniaceae	*Hibbertia scandens*	Twining Guinea-flower		0.1																	0.1			
Elaeocarpaceae	*Elaeocarpus reticulatus*	Blueberry Ash								18	0.2	1						0.4		0.2				
Elaeocarpaceae	*Tetratheca ericifolia*	Pink Bells											0.1											
Ericaceae Styphelioideae	*Epacris microphylla*	Coral Heath							0.2							0.5								
Ericaceae Styphelioideae	*Epacris pulchella*	Wallum Heath												1		0.1	0.6	0.2						0.1
Ericaceae Styphelioideae	*Leucopogon ericoides*	Beard-heath											0.1				0.1							
Ericaceae Styphelioideae	*Leucopogon juniperinus*	Long-flowered Beard-heath									1									0.1				
Ericaceae Styphelioideae	*Leucopogon microphyllus*												0.1			0.2	0.1							
Ericaceae Styphelioideae	*Styphelia triflora*	Pink Fivecorners																0.1						
Ericaceae Styphelioideae	*Styphelia tubiflora*	Pink Fivecorners														0.2								
Ericaceae Styphelioideae	*Woollsia pungens*	Woollsia										0.7	2		0.5									
Euphorbiaceae	*Euphorbia peplus*	Petty Spurge	*			0.1	0.4			0.4											0.1	0.1		
Euphorbiaceae	*Homalanthus populifolius*	Bleeding heart		0.5	1	2	5			5											5	0.1		
Euphorbiaceae	*Ricinus communis*	Castor Oil Plant	*		0.1																			

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Fabaceae Caesalpinioideae	*Senna pendula var. glabrata*	Easter Cassia	*					0.2		0.1	0.7								0.7					
Fabaceae Faboideae	*Bossiaea ensata*	Sword Bossiaea											0.1		0.3									
Fabaceae Faboideae	*Bossiaea heterophylla*	Variable Bossiaea														0.5	0.1	0.4						0.1
Fabaceae Faboideae	*Bossiaea obcordata*	Spiny Bossiaea									0			1					0.5					
Fabaceae Faboideae	*Desmodium varians*	Slender Tick-trefoil																				0.1		
Fabaceae Faboideae	*Erythrina X sykesii*	Coral Tree	*	15																				
Fabaceae Faboideae	*Glycine tabacina*																				0.1			
Fabaceae Faboideae	*Gompholobium grandiflorum*	Large Wedge Pea																				0.1		
Fabaceae Faboideae	*Hardenbergia violacea*	Purple Coral Pea					0.4															0.2		
Fabaceae Faboideae	*Hovea linearis*	Narrow-leaf Hovea							0.1							0.3	0.2	0.9					0.1	0.1
Fabaceae Faboideae	*Indigofera australis*	Native Indigo					0.4			2												0.1		
Fabaceae Faboideae	*Kennedia rubicunda*	Dusky Coral Pea					0.4															0.1		
Fabaceae Faboideae	*Medicago polymorpha*	Burr Medic	*																		10			
Fabaceae Faboideae	*Mirbelia rubiifolia*	Heathy Mirbelia											0.1											

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Fabaceae Faboideae	*Phyllota phylicoides*	Common Phyllota							0.1						0.6									
Fabaceae Faboideae	*Platylobium formosum*	Handsome Flat-pea						5		1				2										
Fabaceae Faboideae	*Pultenaea daphnoides*	Large-leaf Bush-pea						1						0.9			0.6							
Fabaceae Faboideae	*Pultenaea microphylla*	Spreading Bush-pea							0.1															
Fabaceae Faboideae	*Pultenaea rosmarinifolia*													0.3										
Fabaceae Faboideae	*Pultenaea sp.*								0.2													0.1		
Fabaceae Faboideae	*Pultenaea tuberculata*													0.4										
Fabaceae Faboideae	*Trifolium repens*	White Clover	*			0.1	0.4														0.1			
Fabaceae Faboideae	*Vicia sativa*		*																		1	0.2		
Fabaceae Faboideae	*Viminaria juncea*	Golden Spray																						
Fabaceae Mimosoideae	*Acacia brownii*	Golden Prickly Moses						0.1							0.5	0.7				0.1	0.1			
Fabaceae Mimosoideae	*Acacia floribunda*	White Sally						2																
Fabaceae Mimosoideae	*Acacia linearifolia*									0.4				2										
Fabaceae Mimosoideae	*Acacia linifolia*	Flax-leaved Wattle					4	1									0.6					10		0.1

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Fabaceae Mimosoideae	*Acacia longifolia*	Sydney Golden Wattle			1	1	2						1					1		0.1	1			
Fabaceae Mimosoideae	*Acacia myrtifolia*	Red-stemmed Wattle															0.5	0.2				0.1		0.1
Fabaceae Mimosoideae	*Acacia parramattensis*	Parramatta Green Wattle						2				2										0.2		
Fabaceae Mimosoideae	*Acacia spp.*	Wattle			0.1																	0.1		
Fabaceae Mimosoideae	*Acacia suaveolens*	Sweet Wattle							2							0.3		0.9				0.1		0.1
Geraniaceae	*Geranium homeanum*	Rainforest Cranesbill		0.1	0.1	0.1				0.4											0.5			
Goodeniaceae	*Dampiera stricta*	Blue Dampiera							0.2				0.1			0.4	0.1							
Goodeniaceae	*Goodenia ovata*	Hop Goodenia		0.1		0.2																		
Haloragaceae	*Gonocarpus micranthus*	Creeping Raspwort														0.2								
Haloragaceae	*Gonocarpus teucrioides*							0.5			0.6			0.2		0.6			0.4					
Lamiaceae	*Hemigenia purpurea*																0.2							
Lamiaceae	*Plectranthus parviflorus*	Cockspur Flower					0.4																	
Lamiaceae	*Prostanthera denticulata*	Rough Mintbush												1										
Lamiaceae	*Stachys arvensis*	Stagger Weed	*																		0.2	0.2		
Lauraceae	*Cassytha glabella*								0.2					0.4				0.9	0.5					

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Lauraceae	*Cassytha pubescens*	Devil's Twine															0.5							0.1
Lauraceae	*Cinnamomum camphora*	Camphor-laurel	*							0.4														
Lobeliaceae	*Pratia purpurascens*	Whiteroot								0.4														
Loganiaceae	*Logania albiflora*	Narrowleaf Logania						0.1																
Malaceae	*Cotoneaster glaucophyllus*		*				0.4					0.1												
Malvaceae	*Abutilon spp.*				0.1																			
Malvaceae	*Malva parviflora*	Small-flowered Mallow	*																		1			
Malvaceae	*Modiola caroliniana*	Red-flowered Mallow	*				0.4																	
Malvaceae	*Pavonia hastata*		*	0.1																				
Malvaceae	*Sida rhombifolia*	Paddy's Lucerne	*		0.5		0.4																	
Meliaceae	*Melia azedarach*	White Cedar								2											0.2			
Moraceae	*Ficus coronata*	Creek Sandpaper Fig		0.1		0.2																		
Myrsinaceae	*Lysimachia arvensis*	Pimpernel	*																		0.2			
Myrsinaceae	*Myrsine variabilis*	Muttonwood								1														
Myrtaceae	*Angophora costata*	Smooth-barked Apple		2	0.5	2	15	10			25			15					20		4			

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Myrtaceae	*Angophora hispida*	Dwarf Apple											1			0.3								
Myrtaceae	*Baeckea brevifolia*	Short-leaved Heath-myrtle											0.1							0.1				
Myrtaceae	*Callistemon citrinus*	Scarlet Bottlebrush				2																		
Myrtaceae	*Callistemon linearifolius*	Bottlebrush		0.1	0.1																			
Myrtaceae	*Callistemon linearis*	Narrow-leaved Bottlebrush		0.2		0.1	3	1			1		0.2			2			1		2		0.2	
Myrtaceae	*Callistemon rigidus*	Stiff Bottlebrush									0.9								1					
Myrtaceae	*Callistemon salignus*	White Bottlebrush, Pink-tips				1	1															0.1		
Myrtaceae	*Callistemon viminalis*	Weeping Bottlebrush																			1			
Myrtaceae	*Calytrix tetragona*	Common Fringe-myrtle																					0.1	0.2
Myrtaceae	*Corymbia gummifera*	Red Bloodwood							10		15	20	5	15	15	15	30	20	10					1
Myrtaceae	*Darwinia fascicularis* subsp. *fascicularis*												4		0.9	0.7								
Myrtaceae	*Eucalyptus agglomerata*	Blue-leaved Stringybark							2															
Myrtaceae	*Eucalyptus capitellata*	Brown Stringybark							5		20						15			5				

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Myrtaceae	*Eucalyptus haemastoma*	Broad-leaved Scribbly Gum							4			10	2			15	5	7		3				
Myrtaceae	*Eucalyptus pilularis*	Blackbutt					10																	
Myrtaceae	*Eucalyptus piperita*	Sydney Peppermint						10													8			
Myrtaceae	*Eucalyptus punctata*	Grey Gum			3										2							1	0.1	
Myrtaceae	*Eucalyptus robusta*	Swamp Mahogany		15	0.5																			
Myrtaceae	*Eucalyptus saligna*	Sydney Blue Gum								15												20		
Myrtaceae	*Eucalyptus sieberi*	Silvertop Ash												10						10				
Myrtaceae	*Eucalyptus spp.*										2													
Myrtaceae	*Kunzea ambigua*	Tick-bush		2		0.2	0.4	1		1		0.9			1	2		0.4		0.2	0.1	0.1	15	
Myrtaceae	*Kunzea capitata*	Pink Kunzea									0.4			0.9			1							
Myrtaceae	*Leptospermum polygalifolium*	Tantoon				0.1		5						1		5								
Myrtaceae	*Leptospermum squarrosum*	Peach-flowered Tea-tree							5			1	1		1	2								
Myrtaceae	*Leptospermum trinervium*	Slender Tea-tree		1					4			2	4		4	3	3	4			0.1		0.2	2
Myrtaceae	*Melaleuca hypericifolia*	Hillock Bush				0.1						2												
Myrtaceae	*Melaleuca linariifolia*	Flax-leaved Paperbark																			0.1			

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Myrtaceae	*Melaleuca thymifolia*	Thyme Honey-myrtle																			0.1			
Myrtaceae	*Syncarpia glomulifera*	Turpentine				10				30											0.1			
Myrtaceae	*Syzygium paniculatum*	Magenta Brush Cherry		0.1																				
Myrtaceae	*Tristaniopsis laurina*	Water Gum					15																	
Nandinaceae	*Nandina domestica*	Sacred Bamboo	*																0.5					
Ochnaceae	*Ochna serrulata*	Mickey Mouse Plant	*					0.2		0.4	0.1	0.1		0.2					0.1					
Oleaceae	*Ligustrum lucidum*	Broad-leaved Privet	*	0.1			0.4			0.1	0.6													
Oleaceae	*Ligustrum sinense*	Small-Leaved Privet	*	0.1	0.1	0.1	0.4	0.3			0.5								0.2					
Oleaceae	*Notelaea longifolia*	Mock-olive								5	1													
Oleaceae	*Olea europaea* subsp. *cuspidata*	African Olive	*																		0.1			
Oxalidaceae	*Oxalis corniculata*		*																	0.1				
Oxalidaceae	*Oxalis debilis var. corymbosa*		*																		0.1			
Oxalidaceae	*Oxalis latifolia*		*			0.1																		
Oxalidaceae	*Oxalis spp.*									0.2	0.4													
Papaveraceae	*Fumaria muralis*	Wall Fumitory	*				0.4														0.1	0.1		

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Passifloraceae	*Passiflora edulis*	Passionfruit	*																					
Phyllanthaceae	*Breynia oblongifolia*	Coffee Bush			4	0.5	0.4			3											0.1	1		
Phyllanthaceae	*Glochidion ferdinandi*	Cheese Tree		0.5	0.5		1			20	0.5							0.4		0.2	1	0.1		
Phyllanthaceae	*Phyllanthus hirtellus*	Thyme Spurge										0.2					0.1	0.4	0.9				0.1	0.1
Phyllanthaceae	*Phyllanthus sp.*						0.4																	
Phyllanthaceae	*Phyllanthus tenellus*		*	0.1						10														
Picrodendraceae	*Micrantheum ericoides*								0.5		0.1	0.2	0.2	0.7			3	0.4	0.5	0.2			0.1	
Pittosporaceae	*Billardiera scandens*	Hairy Apple Berry						0.1	0.1		0.8	0.1	0.1	0.2				0.1	0.5				0.1	0.1
Pittosporaceae	*Bursaria spinosa*	Blackthorn								0.4	1													
Pittosporaceae	*Pittosporum revolutum*	Yellow Pittosporum								0.4														
Pittosporaceae	*Pittosporum undulatum*	Pittosporum		2	5	1	5	0.8		15	2	0.1							1	1	1	0.2		
Plantaginaceae	*Plantago lanceolata*	Plantain	*				0.4																	
Podocarpaceae	*Podocarpus spinulosus*				0.1																			
Polygonaceae	*Acetosa sagittata*	Turkey Rhubarb	*			0.1															0.1			
Polygonaceae	*Persicaria decipiens*	Slender Knotweed					0.4																	

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Polygonaceae	*Persicaria hydropiper*	Water Pepper					0.4																	
Polygonaceae	*Rumex crispus*	Curled Dock	*				0.4																	
Proteaceae	*Banksia ericifolia*	Heath-leaved Banksia		0.1			5		7			0.2	25	2	2	30	5	3			0.5	0.1	5	
Proteaceae	*Banksia integrifolia*	Coast Banksia			0.6	2																		
Proteaceae	*Banksia oblongifolia*	Fern-leaved Banksia																						0.5
Proteaceae	*Banksia serrata*	Old Man Banksia				1		5	3				2		1	2	1	0.5	1			0.1		
Proteaceae	*Banksia spinulosa*	Hairpin Banksia							4		1	2		1			3	3	1			0.1		
Proteaceae	*Conospermum longifolium*	Long-leaf Coneseeds															0.2	0.1						
Proteaceae	*Grevillea buxifolia*	Grey Spider-flower							2				0.5			0.4	0.5	0.3						0.2
Proteaceae	*Grevillea linearifolia*					0.1		0.5						2			1	0.6						0.1
Proteaceae	*Grevillea longifolia*										0.2													
Proteaceae	*Grevillea speciosa*	Red Spider-flower							0.2			0.5			0.2	0.5								
Proteaceae	*Hakea dactyloides*	Finger Hakea					0.4		5				1				2		1		1			
Proteaceae	*Hakea gibbosa*	Needlebush							3		0.1	2	0.5		1		1	3					1	2
Proteaceae	*Hakea salicifolia*	Willow Hakea			1																			

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Proteaceae	*Hakea sericea*	Needlebush				0.2	0.4		2	1				2							0.5	0.2		
Proteaceae	*Hakea teretifolia*	Needlebush							0.3							0.4	1	3						
Proteaceae	*Isopogon anethifolius*	Narrow-leaf Drumsticks										1									0.1			
Proteaceae	*Lambertia formosa*	Mountain Devil							3			1	0.4				1	5	1				0.1	2
Proteaceae	*Lomatia fraseri*	Silky Lomatia							0.4															
Proteaceae	*Lomatia silaifolia*	Crinkle Bush						3				0.6		0.7			0.6	0.7	0.3					1
Proteaceae	*Persoonia lanceolata*	Geebung																		0.1				
Proteaceae	*Persoonia laurina*	Laurel Geebung									1			1										
Proteaceae	*Persoonia levis*	Broad-leaved Geebung						0.4				0.9		1			2	1	1					
Proteaceae	*Persoonia linearis*	Narrow-leaved Geebung																						5
Proteaceae	*Persoonia pinifolia*	Pineleaf Geebung										2								1				
Proteaceae	*Petrophile pulchella*	Conesticks							5			1				1	2	0.2					0.1	0.1
Ranunculaceae	*Clematis aristata*	Old Man's Beard																				0.1		
Ranunculaceae	*Ranunculus repens*	Creeping Buttercup	*			0.1																		
Rhamnaceae	*Pomaderris sp.*																					0.5		
Rubiaceae	*Galium aparine*	Goosegrass	*				0.4														2			

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			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Rubiaceae	*Opercularia diphylla*	Stinkweed									0.5								0.3					
Rutaceae	*Boronia ledifolia*	Sydney Boronia													0.6	0.6	1							
Rutaceae	*Boronia pinnata*	Pinnate Boronia							0.5															
Rutaceae	*Crowea saligna*												0.1											
Rutaceae	*Leionema dentatum*							4																
Rutaceae	*Murraya paniculata*	Jasmine-orange	*	0.1						0.1														
Rutaceae	*Phebalium squamulosum*	Scaly Phebalium											1		3									
Rutaceae	*Philotheca buxifolia* subsp. *obovata*												0.1											
Rutaceae	*Zieria laevigata*														0.2									
Rutaceae	*Zieria smithii*	Sandfly Zieria			0.4					0.2												0.1		
Sapindaceae	*Diploglottis australis*	Native Tamarind			0.1																			
Sapindaceae	*Dodonaea triquetra*	Hopbush			0.6	0.4		0.2	1		1	0.6					0.2	0.7		0.2	0.2	0.1		
Scrophulariaceae	*Veronica plebeia*	Trailing Speedwell					0.4																	
Solanaceae	*Solanum mauritianum*	Tree Tobacco	*	0.1																				
Solanaceae	*Solanum nigrum*	Blackberry Nightshade	*	0.1		0.1				0.4														

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
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Sterculiaceae	*Lasiopetalum ferrugineum var. ferrugineum*								0.5		0.3	0.3		1						0.1				0.1
Ulmaceae	*Trema tomentosa*	Poison Peach		0.1	0.2																			
Urticaceae	*Parietaria judaica*	Wall Pellitory	*	0.1		0.1	0.4														0.1			
Verbenaceae	*Lantana camara*	Lantana	*		0.2			0.2		0.4	1	0.2							2	0.2				0.1
Verbenaceae	*Verbena officinalis*	Common Verbena	*				0.4																	
Violaceae	*Viola hederacea*	Native Violet						0.1						0.5										
Vitaceae	*Cayratia clematidea*	Slender Grape			0.2		0.4			1											0.1			
Vitaceae	*Cissus antarctica*	Kangaroo Vine								0.4														
Angioserms - Dicotyledons																								
Alstroemeriaceae	*Alstroemeria psittacina*	Parrot Lily	*	10		0.5																		
Araceae	*Alocasia brisbanensis*	Cunjevoi Lily						0.4																
Arecaceae	*Archontophoenix cunninghamiana*	Bangalow Palm				0.1																		
Arecaceae	*Phoenix canariensis*	Canary Island Date	*	0.5	0.1																			
Asparagaceae	*Asparagus aethiopicus*	Asparagus Fern	*		0.3		3	0.1		0.1											0.2			
Asteliaceae	*Cordyline australis*	New Zealand Cabbage Tree	*							0.2														

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
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Commelinaceae	*Commelina cyanea*	Blue Spiderwort		5	0.1	0.2	1			5												0.2		
Commelinaceae	*Tradescantia fluminensis*	Wandering Jew	*	30	20	5				0.4														
Cyperaceae	*Baumea rubiginosa*	Soft Twig-rush														0.5								
Cyperaceae	*Carex appressa*	Tall Sedge																			0.1			
Cyperaceae	*Caustis flexuosa*	Old-man's Whiskers												6	0.7	1	20	10						
Cyperaceae	*Caustis pentandra*												5		3									
Cyperaceae	*Cyathochaeta diandra*																			0.2			0.2	5
Cyperaceae	*Cyperus eragrostis*	Drain Flat-sedge	*																		1			
Cyperaceae	*Gahnia aspera*	Rough-leaved Saw-sedge		0.4																				
Cyperaceae	*Gahnia clarkei*	Tall Saw-sedge						2		1											0.1			
Cyperaceae	*Gahnia erythrocarpa*							4											30					
Cyperaceae	*Gahnia radula*	Thatch Saw-sedge									40			10										
Cyperaceae	*Lepidosperma laterale*	Variable Sword-sedge							3				0.2	30	1	2	2	4	0.8	0.2			0.5	0.2
Cyperaceae	*Ptilothrix deusta*																		0.7					

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
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Cyperaceae	*Schoenus melanostachys*	Black Bog-rush														8								
Cyperaceae	*Tetraria capillaris*	Hair-sedge											0.1							0.1				
Cyperaceae	*Tricostularia pauciflora*														0.2									
Iridaceae	*Crocosmia x crocosmiiflora*	Montbretia	*			0.1																		
Iridaceae	*Dietes spp.*	Butterfly Iris	*									2												
Iridaceae	*Patersonia glabrata*	Native Iris											0.2											
Iridaceae	*Patersonia sericea*	Native Iris									1				1	0.5	0.5	5	0.3				0.1	
Juncaceae	*Juncus usitatus*	Common Rush																			0.1			
Liliaceae	*Lilium longiflorum*	November Lily	*													0.1								
Lomandraceae	*Lomandra confertifolia*																2							
Lomandraceae	*Lomandra filiformis*	Wattle Mat-rush									1													
Lomandraceae	*Lomandra glauca*	Pale Mat-rush													0.6		0.4	1		0.2				0.1
Lomandraceae	*Lomandra gracilis*															0.4								
Lomandraceae	*Lomandra longifolia*	Spiny-headed Mat-rush		2	4	1	1	2		1	2					2		2	1	0.5	0.5	0.2		0.2
Lomandraceae	*Lomandra multiflora*	Many-flowered Mat-rush												0.5					0.2					

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
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Lomandraceae	*Lomandra obliqua*								0.8		1			1			0.5	1	1					
Lomandraceae	*Lomandra spp.*									0.1														
Luzuriagaceae	*Eustrephus latifolius*	Wombat Berry					0.4			1											0.1			
Orchidaceae	*Cryptostylis erecta*	Tartan Tongue Orchid						0.1					0.1											
Orchidaceae	*Cryptostylis spp.*																			0.1				
Orchidaceae	*Cryptostylis subulata*	Large Tongue-orchid									0.2			0.1			0.3		0.4					
Phormiaceae	*Dianella caerulea*	Blue Flax-lily			0.2	1	1	1	0.2	1										0.2	1	0.5	0.1	0.1
Phormiaceae	*Dianella caerulea var. producta*			0.5							0.5	0.2	0.2	1		0.3		0.4	1					
Phormiaceae	*Dianella prunina*	Big Blue Flax-lily															0.5	0.5						
Phormiaceae	*Dianella revoluta*	Blueberry Lily																						0.1
Poaceae	*Andropogon virginicus*	Whisky Grass	*													0.2								
Poaceae	*Austrostipa pubescens*	Speargrass															0.1	10						
Poaceae	*Avena sp.*		*																		5			
Poaceae	*Bromus catharticus*	Prairie Grass	*																		5			
Poaceae	*Cymbopogon refractus*	Barbed Wire Grass																			0.2			

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Poaceae	*Cynodon dactylon*	Couch					0.4														0.5			
Poaceae	*Ehrharta erecta*	Panic Veldtgrass	*	10	5	10	1			0.4											10	2		
Poaceae	*Entolasia marginata*	Bordered Panic				4		5						20		15			30	2				
Poaceae	*Entolasia stricta*	Wiry Panic							2	1	6		0.9	15	0.9	4	4	20	2	2			2	2
Poaceae	*Eragrostis curvula*	African Lovegrass	*																				0.1	0.1
Poaceae	*Imperata cylindrica*	Blady Grass			5					1		0.7	0.1			0.9		0.5			5			
Poaceae	*Lolium perenne*	Perennial Ryegrass	*																		5			
Poaceae	*Microlaena stipoides*	Weeping Grass		5		5	1			1	0.2								0.4	0.5	0.1	0.5		
Poaceae	*Oplismenus aemulus*	Broad-leaved Basket Grass		5	0.1	4	0.4	0.1		0.2														
Poaceae	*Oplismenus imbecillis*	Narrow-leaved Basket Grass								1									0.2					
Poaceae	*Panicum simile*	Two-colour Panic									0.1	0.1												
Poaceae	*Paspalum dilatatum*	Paspalum	*				0.4																	
Poaceae	*Paspalum quadrifarium*		*																					0.1
Poaceae	*Poa annua*	Winter Grass	*				0.4																	
Poaceae	*Themeda triandra*	Kangaroo Grass				0.4	1			0.1											5			

Family	Scientific name	Common name	Per cent cover in vegetation plots																					
			Exotic	BB5	BB6	BB7	BB10	BB13	BB14	BB19	P17	P18	P19	P20	P22	P23	P24	P25	P26	A01	A02	A03	A04	A05
Restionaceae	*Chordifex dimorphus*															0.4								
Restionaceae	*Empodisma minus*	Tanglefoot						0.5																
Restionaceae	*Lepyrodia scariosa*											0.2	0.8	0.6		10	5			0.1			0.1	
Smilacaceae	*Smilax australis*	Lawyer Vine																				0.5		
Smilacaceae	*Smilax glyciphylla*	Sweet Sarsaparilla						0.4	0.1	1	0.6	0.4		0.5				0.5	0.2					
Uvulariaceae	*Schelhammera undulata*	Lilac Lily								0.4														
Xanthorrhoeaceae	*Xanthorrhoea arborea*	Forest Grass-tree						2											1					
Xanthorrhoeaceae	*Xanthorrhoea media*	Grass Tree							5		0.2	1	0.3	0.6	1	1	1	3					0.2	0.2

BAM plot data: location, patch size and composition data

Plot	PCT	Area	Patch size	Condition class	Zone	Easting	Northing	Bearing	Number of native species					
									Tree	Shrub	Grass	Forb	Fern	Other
BB5	1250	0.40	600	Mod_Good_Mod	56	338590	6259751	212	4	12	4	4	2	2
BB6	1841	1.37	600	Mod_Good	56	338473	6259604	210	7	11	3	4	0	1
BB7	1250	0.40	600	Mod_Good_Mod	56	338339	6259484	278	5	16	5	5	1	2
BB10	1841	1.37	600	Mod_Good	56	334015	6257090	16	4	14	4	6	0	5

Plot	PCT	Area	Patch size	Condition class	Zone	Easting	Northing	Bearing	Number of native species					
									Tree	Shrub	Grass	Forb	Fern	Other
BB13	1250	0.20	600	Mod_Good_Good	56	336352	6263077	192	6	18	6	7	5	4
BB14	1786	1.01	600	Mod_Good_Good	56	336368	6263196	12	6	24	3	5	1	4
BB19	1841	1.37	600	Mod_Good	56	332500	6257110	62	8	13	9	8	3	6
P17	1845	0.39	600	Mod_Good	56	336368	6263458	11	8	16	7	7	3	3
P18	1783	4.23	600	Mod_Good	56	336899	6261029	131	4	21	3	2	2	3
P19	1824	6.18	600	Mod_Good	56	336928	6261200	230	4	24	6	5	0	2
P20	1786	1.01	600	Mod_Good_Good	56	336428	6263519	190	6	20	8	5	3	4
P22	1824	6.18	600	Mod_Good	56	336699	6261574	320	3	16	7	1	0	1
P23	1824	6.18	600	Mod_Good	56	336306	6262643	164	5	19	11	7	0	1
P24	1783	4.23	600	Mod_Good	56	336323	6262900	180	5	27	8	6	2	2
P25	1783	4.23	600	Mod_Good	56	336282	6262891	181	5	25	8	7	1	4
P26	1845	0.39	600	Mod_Good	56	336349	6263328	12	5	12	10	10	2	6
A01	1786	0.37	600	Mod_Good_Mod	56	336893	6260940	190	7	10	9	2	0	0
A02	1841	1.29	70	Reveg	56	333914	6257130	56	7	16	8	2	0	4
A03	1841	1.29	70	Reveg	56	333891	6257220	56	6	18	2	2	0	5
A04	1824	6.18	600	Mod_Good	56	337012	6261110	287	2	12	4	5	0	2
A05	1783	4.23	600	Mod_Good	56	337037	6261040	132	2	18	5	4	0	3

BAM plot data: structure and function data

Plot	Percent cover					Large trees	Hollow trees	Litter cover	Fallen logs	Tree stem size (diameter in centimetres)					Tree regeneration	High threat exotic cover
	Tree	Shrub	Grass	Forb	Fern					5-9	10-19	20-29	30-49	50-79		
BB5	22.5	8.3	12.4	5.8	10	0	0	55	11	1	1	1	0	0	1	56.2
BB6	13.2	13.5	9.1	0.5	0	0	0	66	4	1	1	1	1	1	1	37.9
BB7	27	11.1	14.4	1.5	2	4	0	60	0	1	1	1	1	0	1	15.5
BB10	41	28.4	3.4	3.6	0	0	0	40	33	0	1	1	1	0	0	5.6
BB13	35	35.6	13.6	2.3	14.8	3	1	66	30	1	1	1	1	0	1	1.1
BB14	27	47.1	5.8	0.7	0.1	0	0	52	5	1	1	1	1	0	1	0
BB19	76.4	49	6.4	18.4	2.4	2	0	40	39.5	1	0	1	1	1	1	2.3
P17	98.5	10.7	50.3	3.6	6.5	1	2	42	17	1	1	1	1	1	1	2.9
P18	72	20.2	1	0.2	0.6	1	0	91	3	1	1	1	0	0	1	0.4
P19	10	56.9	7.1	0.7	0	0	0	70	3	0	1	1	0	0	1	0
P20	59	21.8	83.1	2.3	5.8	0	0	45	12	1	1	1	1	0	1	0.2
P22	18	56.4	6.4	1	0	0	0	69	6	1	1	1	0	0	1	0
P23	62.3	50.1	44.3	2.6	0	0	0	58	8	1	1	1	0	0	1	0.2
P24	53	31.1	34	2	0.8	0	0	76.8	8	1	1	1	0	0	1	0
P25	30.9	30.5	48.5	7.3	0.2	0	0	56	5	1	1	1	1	0	1	0
P26	63	9.9	66.3	3.9	3.5	0	0	58	20	1	1	1	1	1	1	3
A01	48.2	3.4	5.8	0.3	0	7	1	100	6	0	1	0	0	0	0	0.2

Plot	Percent cover					Large trees	Hollow trees	Litter cover	Fallen logs	Tree stem size (diameter in centimetres)					Tree regeneration	High threat exotic cover
	Tree	Shrub	Grass	Forb	Fern					5-9	10-19	20-29	30-49	50-79		
A02	15.3	12	11.1	1.5	0	1	0	57	57	1	1	1	1	1	0	11.6
A03	21.5	13.2	0.7	0.7	0	5	0	90	17.5	1	1	1	1	1	1	2
A04	10.1	42	2.8	0.5	0	0	0	96.6	2	1	1	1	0	0	1	0.1
A05	31	15.8	7.5	0.5	0	0	0	100	12	1	1	0	1	0	1	0.3

Fauna species recorded (WSP, 2018; Arcadis, 2018; Arcadis, 2021)

Fauna group	Common Name	Scientific name	Status		Ecosystem or species credit species?
			BC Act	EPBC Act	
Amphibian	*Crinia signifera*	Common Eastern Froglet			
Amphibian	*Limnodynastes peronii*	Brown-striped Frog			
Amphibian	*Litoria dentata*	Bleating Tree Frog			
Amphibian	*Litoria fallax*	Eastern Dwarf Tree Frog			
Amphibian	*Litoria peronii*	Peron's Tree Frog			
Bird	*Acanthiza pusilla*	Brown Thornbill			
Bird	*Acanthorhynchus tenuirostris*	Eastern Spinebill			
Bird	*Accipiter cirrhocephalus*	Collared Sparrowhawk			
Bird	*Accipiter novaehollandiae*	Grey Goshawk			
Bird	*Alectura lathami*	Australian Brush-turkey			
Bird	*Anas superciliosa*	Pacific Black Duck			
Bird	*Anhinga melanogaster*	Darter			
Bird	*Anthochaera carunculata*	Red Wattlebird			
Bird	*Anthochaera chrysoptera*	Little Wattlebird			
Bird	*Cacatua galerita*	Sulphur-crested Cockatoo			
Bird	*Cacomantis flabelliformis*	Fan-tailed Cuckoo			
Bird	*Calyptorhynchus funereus*	Yellow-tailed Black-Cockatoo			
Bird	*Colluricincla harmonica*	Grey Shrike-thrush			
Bird	*Columba livia*	Rock Dove			
Bird	*Coracina novaehollandiae*	Black-faced Cuckoo-shrike			
Bird	*Corvus coronoides*	Australian Raven			
Bird	*Cracticus tibicen*	Australian Magpie			
Bird	*Cracticus torquatus*	Grey Butcherbird			
Bird	*Dacelo novaeguineae*	Laughing Kookaburra			
Bird	*Egretta novaehollandiae*	White-faced Heron			
Bird	*Eopsaltria australis*	Eastern Yellow Robin			
Bird	*Geopelia striata*	Peaceful Dove			
Bird	*Glossopsitta concinna*	Musk Lorikeet			
Bird	*Grallina cyanoleuca*	Magpie Lark			
Bird	*Haliaeetus leucogaster*	White-bellied Sea-Eagle	V		Species credit species
Bird	*Hirundo neoxena*	Welcome Swallow			
Bird	*Hirundo nigricans*	Tree Martin			
Bird	*Larus novaehollandiae*	Silver Gull			
Bird	*Malurus cyaneus*	Superb Fairy-wren			
Bird	*Malurus lamberti*	Variegated Fairy-wren			

Fauna group	Common Name	Scientific name	Status		Ecosystem or species credit species?
			BC Act	EPBC Act	
Bird	*Manorina melanocephala*	Noisy Miner			
Bird	*Neochmia temporalis*	Red-browed Finch			
Bird	*Ninox strenua*	Powerful Owl	V		Ecosystem credit species
Bird	*Ocyphaps lophotes*	Crested Pigeon			
Bird	*Pachycephala pectoralis*	Golden Whistler			
Bird	*Pardalotus punctatus*	Spotted Pardalote			
Bird	*Pardalotus striatus*	Striated Pardalote			
Bird	*Pelecanus conspicillatus*	Australian Pelican			
Bird	*Phalacrocorax melanoleucos*	Little Pied Cormorant			
Bird	*Phalacrocorax sulcirostris*	Little Black Cormorant			
Bird	*Phalacrocorax varius*	Pied Cormorant			
Bird	*Phylidonyris novaehollandiae*	New Holland Honeyeater			
Bird	*Podargus strigoides*	Tawny Frogmouth			
Bird	*Psophodes olivaceus*	Eastern Whipbird			
Bird	*Rhipidura fuliginosa*	Grey Fantail			
Bird	*Rhipidura leucophrys*	Willie Wagtail			
Bird	*Sericornis frontalis*	White-browed Scrubwren			
Bird	*Strepera graculina*	Pied Currawong			
Bird	*Streptopelia chinensis*	Spotted Turtle-Dove			
Bird	*Trichoglossus chlorolepidotus*	Scaly-breasted Lorikeet			
Bird	*Trichoglossus haematodus*	Rainbow Lorikeet			
Bird	*Vanellus miles*	Masked Lapwing			
Bird	*Zosterops lateralis*	Silvereye			
Mammal	*Antechinus stuartii*	Brown Antechinus			
Mammal	*Canis lupus familiaris*	Domestic Dog			
Mammal	*Cercartetus nanus*	Eastern Pygmy-possum	V		Species credit species
Mammal	*Chalinolobus gouldii*	Gould's Wattled Bat			
Mammal	*Miniopterus australis*	Little Bent-winged Bat			
Mammal	*Miniopterus orianae oceanensis orianae*	Large Bent-winged Bat			
Mammal	*Mormopterus ridei*	Little Freetail Bat, Eastern Free-tailed Bat			
Mammal	*Nyctophilus sp.*	Long-eared Bat sp.			
Mammal	*Oryctolagus cuniculus*	Rabbit			

Fauna group	Common Name	Scientific name	Status		Ecosystem or species credit species?
			BC Act	EPBC Act	
Mammal	*Perameles nasuta*	Long-nosed Bandicoot			
Mammal	*Petaurus breviceps*	Sugar Glider			
Mammal	*Pseudocheirus peregrinus*	Common Ringtail Possum			
Mammal	*Pteropus poliocephalus*	Grey-headed Flying-fox	V	V	Species credit species (for breeding habitat)
Mammal	*Rattus fuscipes*	Bush Rat			
Mammal	*Rattus rattus*	Black Rat			
Mammal	*Trichosurus vulpecula*	Common Brushtail Possum			
Mammals	*Chalinolobus dwyeri*	Large-eared Pied Bat	V	V	Species credit species (for breeding habitat)
Mammal	*Vulpes*	European Red Fox			
Mammal	*Wallabia bicolor*	Swamp Wallaby			
Reptile	*Egernia cunninghami*	Cunningham's Skink			
Reptile	*Eulamprus quoyii*	Eastern Water Skink			
Reptile	*Intellagama lesueurii*	Australian Water Dragon			
Reptile	*Lampropholis delicata*	Delicate Garden Skink			
Reptile	*Lampropholis guichenoti*	Common Garden Skink			
Reptile	*Phyllurus platurus*	Southern Leaf-tailed Gecko			
Reptile	*Saproscincus mustelinus*	Weasel Skink			
Reptile	*Varanus rosenbergi*	Rosenberg’s Goanna	V		Ecosystem credit species

Annexure D – Freshwater ecology impact assessment

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Freshwater ecology impact assessment

October 2021

Prepared for

Transport for NSW

Prepared by

Cardno (NSW/ACT) Pty Ltd

Note to reader:

Beaches Link and Gore Hill Freeway Connection: Freshwater Ecology Impact Assessment was prepared in conjunction with the *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) to support the environmental impact statement for the Beaches Link and Gore Hill Freeway Connection project. This was provided as Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report) of the environmental impact statement.

Following exhibition of the environmental impact statement, Transport for NSW has prepared a submissions report and preferred infrastructure report for the project. In addition, an updated biodiversity assessment to synthesise the updated and supplementary information provided in the submissions report, with *Beaches Link and Gore Hill Freeway Connection Technical working paper: Biodiversity development assessment report* (Arcadis, 2020a) has also been prepared (provided as Appendix F5 of the submissions report).

As a result of feedback received from government agencies and the community regarding the level of groundwater baseflow reductions predicted in Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, Transport for NSW also carried out further investigations and groundwater modelling to support a focused assessment of the potential environmental impacts to these creek systems. The further investigations and groundwater modelling is documented in Annexure G of the updated biodiversity assessment. As part of these investigations, a detailed report on the impacts to freshwater ecology resulting from revised groundwater modelling was also prepared and is included as Attachment A of Annexure G of the updated biodiversity assessment.

This version of the Freshwater Ecology Impact Assessment has been provided with the updated biodiversity assessment for completeness. However, apart from adjustments to the project description consistent with the submissions report and preferred infrastructure report, minor formatting corrections and amending errors identified in Table A5-13 of the submissions (ie Figure 2-1 and Figure 2-2), this version of Annexure D has not been updated to include new or revised information following exhibition of the environmental impact statement. The table below identifies where new or revised information included in the submissions report updates or supplements this report.

Annexure D section	Description	Where this information has been updated and/or supplemented
Section 2.3.1	Reference to construction phase water quality criteria.	Table 4.2 and Section 5.4.5.2 of the updated biodiversity assessment
Section 2.3.2	Reference to operational phase water quality criteria.	Table 4.2 and Section 5.4.5.2 of the updated biodiversity assessment
Section 3	Descriptions of Flat Rock Creek, Burnt Bridge Creek and Balgowlah Golf Course dam.	Section 3.7.3 and Section 3 of Attachment A of Annexure G of the updated biodiversity assessment
Section 4.1.3	Description of decommissioning the Balgowlah Golf Course dam.	Section 5.4.5.2 of the updated biodiversity assessment
Section 4.4	Description of impacts from groundwater drawdown on freshwater ecology.	Section 5.4.5.2 and sections 4.1 and 4.2 of Attachment A of Annexure G of the updated biodiversity assessment
Table 5-1	Reference to construction and operational phase water quality criteria.	Table 4.2 and Section 5.4.5.2 of the updated biodiversity assessment
Section 5.1	Consideration of offset requirements	Section 3.7.3 and Section 7.2 of the updated biodiversity assessment

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1 Introduction

1.1 Background

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

> 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 Western Harbour Tunnel, the Warringah Freeway and the Gore Hill Freeway to Balgowlah and Killarney Heights and including the surface upgrade of the Wakehurst Parkway from Seaforth to Frenchs Forest and upgrade and integration works to connect to the Gore Hill Freeway at Artarmon.

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

1.2 The project

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

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

An environmental impact statement for the project was prepared and was placed on public exhibition on 9 December 2020, with an exhibition closing date of 1 March 2021. Public exhibition of the environmental impact statement provided the community, interested parties and key stakeholders (including government agencies and councils) with an understanding of the project and the opportunity to comment on the environmental impact statement.

Following the end of exhibition, the Secretary of the Department of Planning, Industry and Environment requested Transport for NSW on 11 March 2021 respond to the issues raised in the submissions in a submissions report. In addition, Department of Planning, Industry and Environment also requested Transport for NSW on 14 May 2021 prepare a preferred infrastructure report, in addition to a submissions report, providing further assessment and information on some key issues. The environmental impact statement, submissions report and preferred infrastructure report are available on the Department of Planning, Industry and Environment website www.planningportal.nsw.gov.au/majorprojects/project/10456.

1.3 Project location

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

Commencing at the Warringah Freeway at Cammeray, the mainline tunnels would pass under Naremburn and Northbridge, then cross Middle Harbour between Northbridge and Seaforth. The mainline tunnels would then split under Seaforth into two ramp tunnels and continue north to the Wakehurst Parkway at Killarney Heights and north-east to Balgowlah, linking directly to the Burnt Bridge Creek Deviation to the south of the existing Kitchener Street bridge.

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

The project would also be located within the Newcastle local government area during construction. During further design development and construction planning in 2021, Transport for NSW identified a preferred location for a loadout facility at the Port of Newcastle for sediment from Middle Harbour that is not suitable for offshore disposal (refer to Section 5 (Treatment and loadout of dredged and excavated material not suitable for offshore disposal) of the preferred infrastructure report for further details). However, given there is no freshwater habitat at this location, further consideration of this facility is not provided in this report.

For key features of the project refer and a summary of key construction activities refer to Section 1 of the updated biodiversity assessment.

1.4 Avoid and minimise impact through design

Under the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (Roads and Traffic Authority (RTA), 2011) the management of biodiversity should aim to:

1. Avoid and minimise impacts first
2. Mitigate impacts where avoidance is not possible
3. Offset where residual impacts cannot be avoided (Section 5.1).

Similarly, the NSW Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) (formerly NSW Department of Primary Industries (DPI) (Fisheries)) requires that proponents should, as a first priority, aim to avoid impacts to key fish habitat (KFH) as a general principle. Where avoidance is impossible or impractical, proponents should then aim to minimise impacts. Any remaining impacts should then be offset with compensatory works (see Section 5.1). Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) assesses activity and development proposals in relation to general policies with consideration for the ‘sensitivity’ (Type) and ‘function’ (Class) of the affected fish habitat detailed in Section 3.2 of the *Policy and Guidelines for Fish Habitat Conservation and Management* (NSW DPI, 2013) (the Policy). Environmental management measures to minimise impacts on freshwater biodiversity would be implemented and maintained in accordance with the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011) and Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) Policy.

The Secretary’s environmental assessment requirements issued for the project identified the following key issue and desired performance outcome in relation to aquatic biodiversity:

"6. Biodiversity

The project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity.”

Requirement 6(8) of the Secretary’s environmental assessment requirements states:

“Impacts on biodiversity values that cannot be assessed using the Biodiversity Assessment Method (BAM) must also be otherwise assessed”

The project has been designed to avoid and minimise potential impacts to freshwater ecology under the hierarchy of ‘avoid, minimise, mitigate and offset if required’. The construction footprint, and the management of discharges to waterways from the project during construction and operation, have been reduced as far as practicable to reduce the risk of impacts to nearby waterways. Environmental management measures should be implemented for the project to minimise potential impacts to freshwater ecology and associated geomorphology including:

> Consideration of industry recognised design requirements for water quality and spill containment

> Site-specific design and maintenance considerations to avoid/minimise water quality and/or geomorphology impacts in accordance with the *Blue Book* (Landcom, 2004)

> Design of wastewater treatment plants to ensure discharges meet the relevant physical and chemical stressors set out in of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000), the Australian and New Zealand Guidelines (ANZG) species protection levels (ANZG, 2018), and the draft ANZG default values for iron (in fresh and marine water) and zinc (in marine water)

> Culvert, drainage infrastructure and realignment designs to be in accordance with *Why do fish cross the road?: Fish Passage requirements for waterway crossings* (Fairfull & Witheridge, 2003) and developed in consultation with Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) to ensure fish passage is maintained during low flows and a 'no net loss' of fish habitat

> Scour protection in the proposed localised adjustment of Burnt Bridge Creek to consider the susceptibility of the creek to scour from increased flow and runoff. The extension to the existing culvert would be designed with low gradient and scour protection to minimise impacts to geomorphology. Where required, grade controls and bank stabilisation works would be implemented to manage anticipated high velocity conditions.

These are detailed in Appendix O (Technical working paper: Surface water quality and hydrology) and would be refined during further design development.

1.5 Legislative context

NSW and Commonwealth legislation with relevance to this assessment are:

> *Environmental Planning and Assessment Act 1979* (EP&A Act) (NSW)

> *Fisheries Management Act 1994* (FM Act) (NSW)

> *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (Cwlth).

1.5.1 Environmental Planning and Assessment Act 1979 (EP&A Act)

All projects assessed as State significant infrastructure under Part 5, Division 5.2 of the EP&A Act require an environmental impact statement to address the Secretary's environmental assessment requirements. The environmental impact statement must assess biodiversity impacts. Freshwater biodiversity matters have been assessed in accordance with the Policy.

1.5.2 Fisheries Management Act 1994 (FM Act)

The FM Act contains provisions for the conservation of fish stocks, key fish habitat (KFH), biodiversity, threatened species, populations and ecological communities. The FM Act regulates the conservation of fish, aquatic vegetation and some aquatic macroinvertebrates and the development and sharing of fishery resources of NSW for present and future generations. Part 7 of the FM Act identifies requirements for the protection of aquatic habitats while Part 7A of the FM Act lists threatened species, populations and ecological communities and key threatening processes (KTPs) for species, populations and ecological communities in NSW waters. Section 220ZZ of the FM Act outlines significant impact considerations to threatened species, populations and ecological communities listed under the FM Act.

1.5.3 Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act protects nationally and internationally important flora, fauna, ecological communities and heritage places, which are defined in the EPBC Act as 'matters of national environmental significance' (MNES). The significance of impacts on MNES is determined in accordance with the *Significant Impact Guidelines 1.1 – Matters of National Environmental Significance* (Department of the Environment (DoE), 2013). Where an action is likely to have a significant impact on a MNES, the action is referred to the Australian Minister for the Environment for approval. The referral process involves a decision on whether or not the action is a ‘controlled action’. When an action is declared a controlled action, approval from the Minister is required.

1.6 Definitions

The following definitions are used in this assessment:

> The project: refers to that described in Section 1.2

> Construction footprint: refers to the area to be directly impacted by the project

> Construction support sites: parcels of land on which construction-related activities would be carried out and with each site having a unique identifier

> Construction sites: other parcels of land on which the project would be constructed

> Study area: refers to an area encompassing the construction footprint and areas adjacent (about 500 metres around the construction footprint)

> The Policy: The NSW Government’s *Policy and Guidelines for Fish Habitat Conservation and Management* (NSW DPI, 2013).

2 The freshwater ecology assessment approach

The main sources of information used in this assessment included:

> An initial aquatic habitat assessment (Jacobs, 2018)
> Field surveys by Cardno (27 March 2020)
> Appendix M (Technical working paper: Contamination)
> Appendix N (Technical working paper: Groundwater)
> Appendix O (Technical working paper: Surface water quality and hydrology).

No fish or macroinvertebrate sampling was carried out and occurrences of species have been predicted based on the availability of suitable habitat.

2.1 Personnel

This assessment was prepared by the following personnel:

> Dr Craig Blount (BSc (Hons), PhD, Grad Dip) – Technical Lead
> Dilys Zhang (BSc (Hons)) – Senior Environmental Scientist (Aquatic Ecologist).

2.2 Aims

The aims of this assessment was to:

> Identify the location, extent and condition of freshwater waterways with potential to be impacted by the project
> Identify any KTPs listed under the FM Act and EPBC Act relevant to the project and their potential to be triggered
> Assess impacts to freshwater ecology, including threatened species and ecological communities, and associated geomorphology as a result of construction and operation of the project
> Recommend mitigation measures to address impacts to freshwater ecology in accordance with NSW Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) and Transport for NSW's 'avoid, minimise, mitigate and offset' strategies
> Identify any potential ecological offsets required to compensate for any residual impacts to aquatic habitat in accordance with the Policy.

There were no Secretary's environmental assessment requirements specific to freshwater ecology however as per requirement 6(8) of the Secretary's environmental assessment requirements (refer to Section 1.4) all biodiversity values must be assessed. This assessment has been completed in accordance with:

> *Policy and Guidelines for Fish Habitat Conservation and Management* (NSW DPI, 2013)
> *Fish Passage Requirements for Waterway Crossings* (Fairfull & Witheridge, 2003)
> *Aquatic Ecology in Environmental Impact Assessment – EIA Guideline Series* (Lincoln Smith, 2003).

2.3 Components of the project relevant to freshwater ecology

2.3.1 Construction

Components of the project relevant to freshwater ecology are associated with construction support sites, and construction site activities in the vicinity of waterways. This would include locations for tunnel decline access and support, earthworks and workforce amenities.

Key components would include:

> Construction wastewater treatment plants. The wastewater treatment plants would be required to treat groundwater and surface wastewater generated/captured from tunnelling activities (including dust suppression water), and rainfall runoff captured from tunnel portals. Four wastewater treatment plants would discharge treated wastewater into a number of locations along natural waterways via the local

stormwater network. The wastewater treatment plant at Wakehurst Parkway east construction support site (BL13) would discharge via a drainage channel to be formed at the eastern section of the site which would drain towards Wakehurst Golf Course and the golf course dam (Table 2-1 and Figure 2-1). Due to the absence of a suitable reference site to develop site specific trigger value criteria for discharges from the wastewater treatment plants, the project proposes to adopt the Australian and New Zealand Environment and Conservation Council (ANZECC and ARMCANZ, 2000) default trigger values for physical and chemical stressors for estuarine and lowland river ecosystems and the ANZG (2018) 90 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 95 per cent species protection levels, and the draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) when designing wastewater treatment plants

> Instream activities associated with a localised adjustment of Burnt Bridge Creek to facilitate an extension of the existing box culvert crossing of Burnt Bridge Creek Deviation and inclusion of scour protection

> Instream activities associated with diversion of an existing aboveground constructed watercourse within Flat Rock Reserve into a multi cell box culvert and provision of scour protection (culvert may be temporary or permanent pending council/community preferences and final end use of Flat Rock Reserve)

> Construction works associated with new or modified permanent drainage infrastructure (eg at the Wakehurst Parkway).

Details of these components of the project are described in Chapter 6 (Construction work) of the environmental impact statement.

Table 2-1 Wastewater treatment plant locations, receiving environments and discharge volumes during construction

Construction support site	Receiving waterways/waterbodies	Construction discharge volumes (kilolitres per day)
Cammeray Golf Course (BL1)	Local stormwater then Willoughby Creek	296
Flat Rock Drive (BL2)	Local stormwater then Flat Rock Creek	711
Punch Street (BL3)	Local stormwater then Flat Rock Creek	308
Balgowlah Golf Course (BL10)	Local stormwater then Burnt Bridge Creek	428
Wakehurst Parkway east (BL13)	Drainage pit on the eastern boundary of the construction support site then Wakehurst Golf Course dam	10

Construction activities, including those at construction support sites, have potential to generate runoff which may enter freshwater waterways. Project activities with potential to impact the freshwater environments are detailed in sections 5 and 6 of Appendix O (Technical working paper: Surface water quality and hydrology). A summary of these activities is provided in Table 2-2.

Construction support sites would be decommissioned following completion of construction.

Table 2-2 Specific project aspects relevant to freshwater ecology and associated geomorphology (source: Jacobs, 2018b)

Project feature	Project activities	Potential impacts	Waterways potentially impacted	Project phase
Construction support sites	▪ Vegetation clearing and ground disturbance for site establishment ▪ Dredging works ▪ Stockpiling of topsoil and mulched and chipped vegetation ▪ Cut and cover and trough excavation ▪ Construction of instream structures (eg culverts and other drainage elements) ▪ Storage of chemicals ▪ Vehicle and equipment washdown ▪ Refuelling of plant ▪ Movement of plant and transport of materials and spoil ▪ Demolition works and relocation of utilities ▪ Construction of support structures and road integration works ▪ Temporary and permanent wastewater treatment plants (Table 2-1) which would discharge into natural waterways via the stormwater network.	▪ Erosion and sedimentation ▪ Contaminated runoff ▪ Increase in impervious surfaces increasing the volume and velocity of runoff ▪ Alterations to water quality and geomorphology from wastewater treatment plant discharges. ▪ Pollution from increased litter and debris being washed into waterways from storms and wind.	Willoughby Creek Flat Rock Creek Burnt Bridge Creek Manly Dam Manly Creek Trefoil Creek	Construction Operation
Drainage works and localised adjustment of existing waterways	▪ Localised adjustment of Burnt Bridge Creek to facilitate an extension of the existing box culvert crossing of Burnt Bridge Creek Deviation and inclusion of scour protection ▪ Drainage works associated with an existing aboveground watercourse within Flat Rock Reserve ▪ Backfilling and disposal of excavated material	▪ Alterations to water quality, flow and geomorphology ▪ Temporary/permanent barriers to fish passage.	Burnt Bridge Creek Downstream to Flat Rock Creek	Construction Operation

Project feature	Project activities	Potential impacts	Waterways potentially impacted	Project phase
Surface works within construction footprint	▪ Vegetation clearing and ground disturbance ▪ Increase in impervious surfaces ▪ Demolition and installation of civil structures ▪ Increase in traffic ▪ Movement of plant and transport of materials and spoil ▪ Management and haulage of spoil ▪ Dewatering	▪ Erosion and sedimentation ▪ Mobilisation of contaminants and acid sulfate soils (ASS) to waterways ▪ Increased levels of turbidity and sediment loads posing risk to sensitive receiving environments.	Willoughby Creek Flat Rock Creek Burnt Bridge Creek Manly Dam Manly Creek Trefoil Creek	Construction
Tunnel construction	▪ Tunnelling under waterways ▪ Management and haulage of materials and spoil	▪ Subsidence of waterways ▪ Mobilisation of contaminants and ASS to waterways ▪ Increased levels of turbidity and sediment loads posing risk to sensitive receiving environments ▪ Reduction in baseflows from groundwater drawdown.	Willoughby Creek Flat Rock Creek Quarry Creek Burnt Bridge Creek Manly Dam Manly Creek Trefoil Creek	Construction

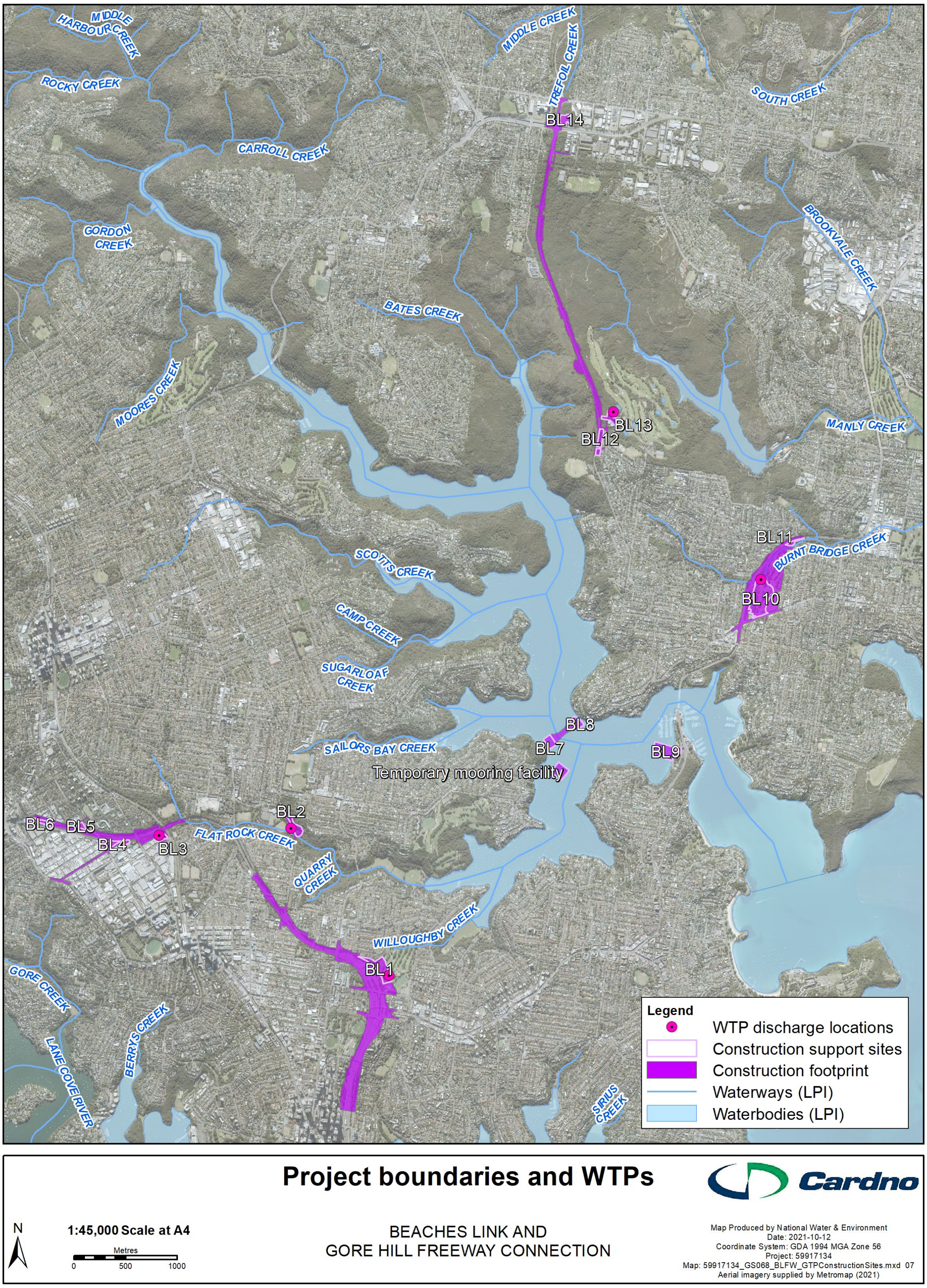


Figure 2-1 Construction footprint, relevant construction sites, wastewater treatment plant discharge locations and associated waterways

2.3.2 Operation

The key operational infrastructure relevant to freshwater ecology includes:

> New and modified drainage infrastructure along Gore Hill Freeway and along modified or new surface roads at Balgowlah, Killarney Heights and Frenchs Forest, and new water quality basins at Balgowlah and along the Wakehurst Parkway

> Localised adjustment of a small section of previously modified Burnt Bridge Creek to facilitate an extension of the existing box culvert crossing of Burnt Bridge Creek Deviation and inclusion of scour protection

> The driven tunnels for the project would be mainly drained structures, except for the driven tunnels approaching the crossing of Middle Harbour from both Northbridge and Seaforth

> The selection and sizing of new operational water quality basins would be determined during further design development

> A permanent wastewater treatment plant at the Gore Hill Freeway at Artarmon (Figure 2-1). The wastewater treatment plant would treat groundwater ingress into the tunnels, stormwater entering the tunnels, deluge water, washdown water, and spills. The wastewater treatment plant would include a tank to regulate flows at a discharge rate of 1425 kilolitres per day. Treated wastewater would be discharged to the local stormwater network and ultimately to Flat Rock Creek. Due to the absence of a suitable reference site to develop site specific trigger value criteria, the project proposes to adopt the Australian and New Zealand Environment and Conservation Council (ANZECC and ARMCANZ, 2000) default trigger values for physical and chemical stressors for estuarine and lowland river ecosystems and the ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels, and the draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) when designing the Gore Hill Freeway wastewater treatment plant.

Further discussion on water quality basins and wastewater treatment plants is provided in Appendix O (Technical working paper: Surface water quality and hydrology).

2.4 Field survey locations

The field survey was completed at ten locations across five waterways, and associated tributaries, and two waterbodies. Site names and location details are provided in Table 2-3. The sites included about 100 metre reach of waterway centred at each location point illustrated in Figure 2-2.

A description of the main surface drainage features in the project area is provided in Section 3 and Appendix O (Technical working paper: Surface water quality and hydrology).

Table 2-3 Field survey sites

Site code	Site name	Site details	Surveyed by
2b	Willoughby Creek downstream	Downstream of the construction footprint	Jacobs (2018)
3a	Burnt Bridge Creek upstream	Upstream of the construction footprint	Jacobs (2018)
3b	Burnt Bridge Creek downstream	Downstream of the construction footprint at Kitchener Street	Jacobs (2018)
3c, 3d and 3e	Burnt Bridge Creek midstream	Along the stretch between the culverts at Burnt Bridge Creek Deviation and Kitchener Street	Jacobs (2018)
5a	Flat Rock Creek upstream	Upstream of the construction footprint	Jacobs (2018)
5b	Flat Rock Creek downstream	Downstream of the construction footprint, upstream of Quarry Creek	Jacobs (2018)

Site code	Site name	Site details	Surveyed by
5b(1)	Flat Rock Reserve aboveground watercourse	Along the north-eastern boundary of the Flat Rock Drive construction support site (BL2)	Cardno (2020)
5c	Flat Rock Creek downstream	Downstream of the construction footprint and site 5b	Jacobs (2018)
6b	Manly Dam mid	Downstream of the construction footprint	Jacobs (2018)
6c	Manly Dam downstream	Downstream of the construction footprint and 6b	Jacobs (2018)
7b	Manly Creek	Downstream of the construction footprint and upstream of Manly Dam	Jacobs (2018)
8b	Trefoil Creek downstream	Downstream of the construction footprint	Jacobs (2018)
9	Wakehurst Golf Course dam	Downstream of the Wakehurst Parkway east construction support site (BL13)	Cardno (2020)

The sections of waterways visited were considered representative of those that could be impacted by the project (Jacobs, 2018; Jacobs, 2020a).

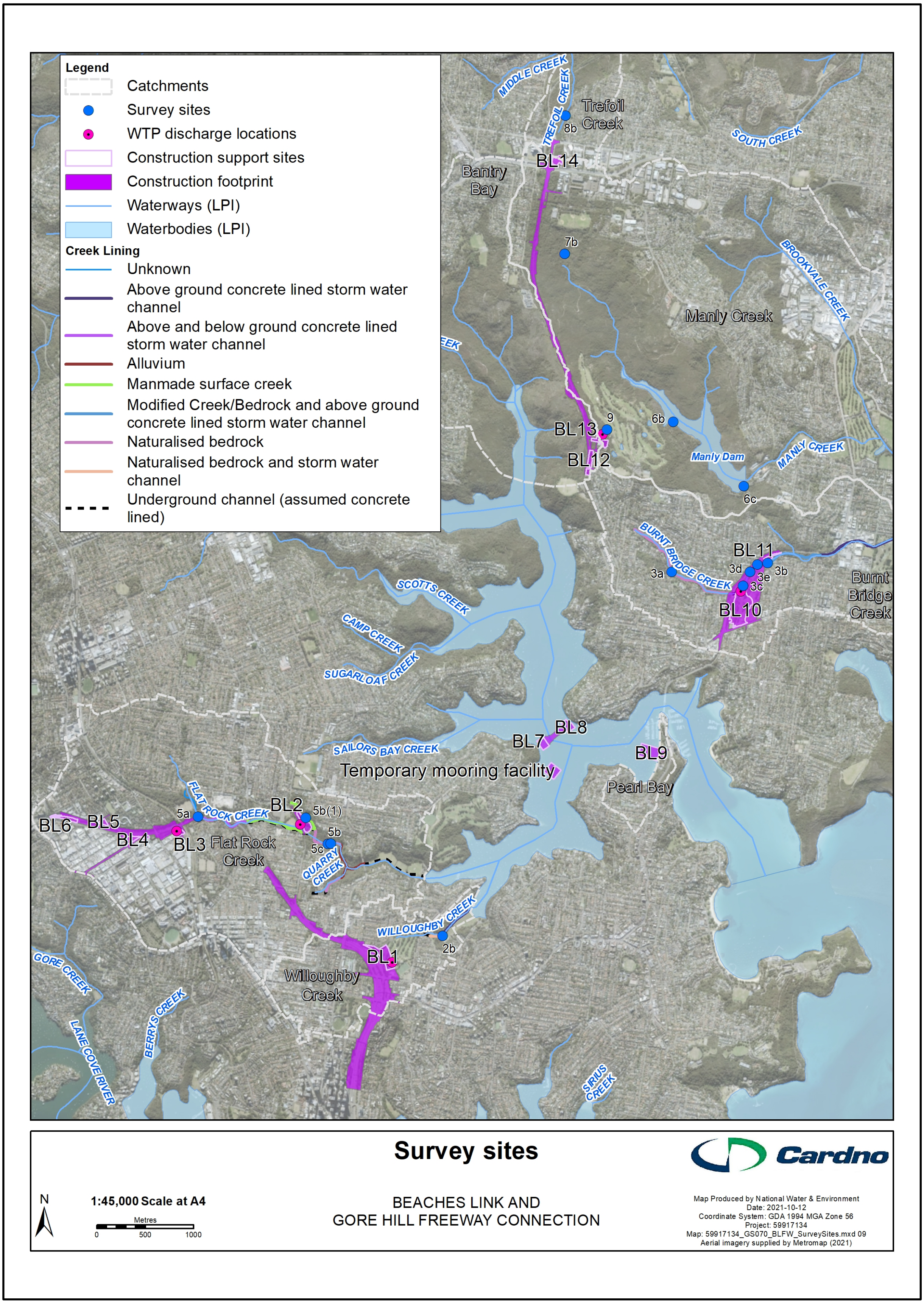


Figure 2-2 Field survey sites (source: Jacobs, 2018 and Cardno, 2020)

3 Existing environment

The study area includes the following waterways, and associated tributaries, and two waterbodies within the Willoughby, North Sydney and Northern Beaches local government areas (Figure 2-2):

> Willoughby Creek
> Burnt Bridge Creek
> Flat Rock Creek
> Manly Dam
> Manly Creek
> Trefoil Creek
> Wakehurst Golf Course dam.

3.1 Freshwater habitat and geomorphology summary

3.1.1 Willoughby Creek

Willoughby Creek is a first order waterway (Strahler, 1957) in the Willoughby Creek catchment that flows in a general easterly direction from Cammeray Golf Course to Primrose Park into Willoughby Bay at Cammeray. At one site (2b) (Table 2-3 and Figure 2-2) next to Primrose Park Tennis Courts it appeared a semi-natural waterway partially modified to accept stormwater discharge. Modifications included entrenched bedrock and a concrete-lined channel around 10 metres downstream from the survey point (site 2b). A natural bedrock/boulder waterfall and a shallow plunge pool was located around 50 metres upstream from the survey point (site 2b). Banks in the upstream section were vegetated by dense tree cover and shrubs with a groundcover consisting primarily of ferns. Walking tracks and tennis courts were present on the south-east bank and on the opposite bank the riparian vegetation corridor was around 70 metres wide and continuous. Further downstream, the riparian corridor included Primrose Park sporting fields. This riparian vegetation would provide shade and potentially, other ecological functions (eg a source of food and habitat, in the form of wood debris, for freshwater biota).

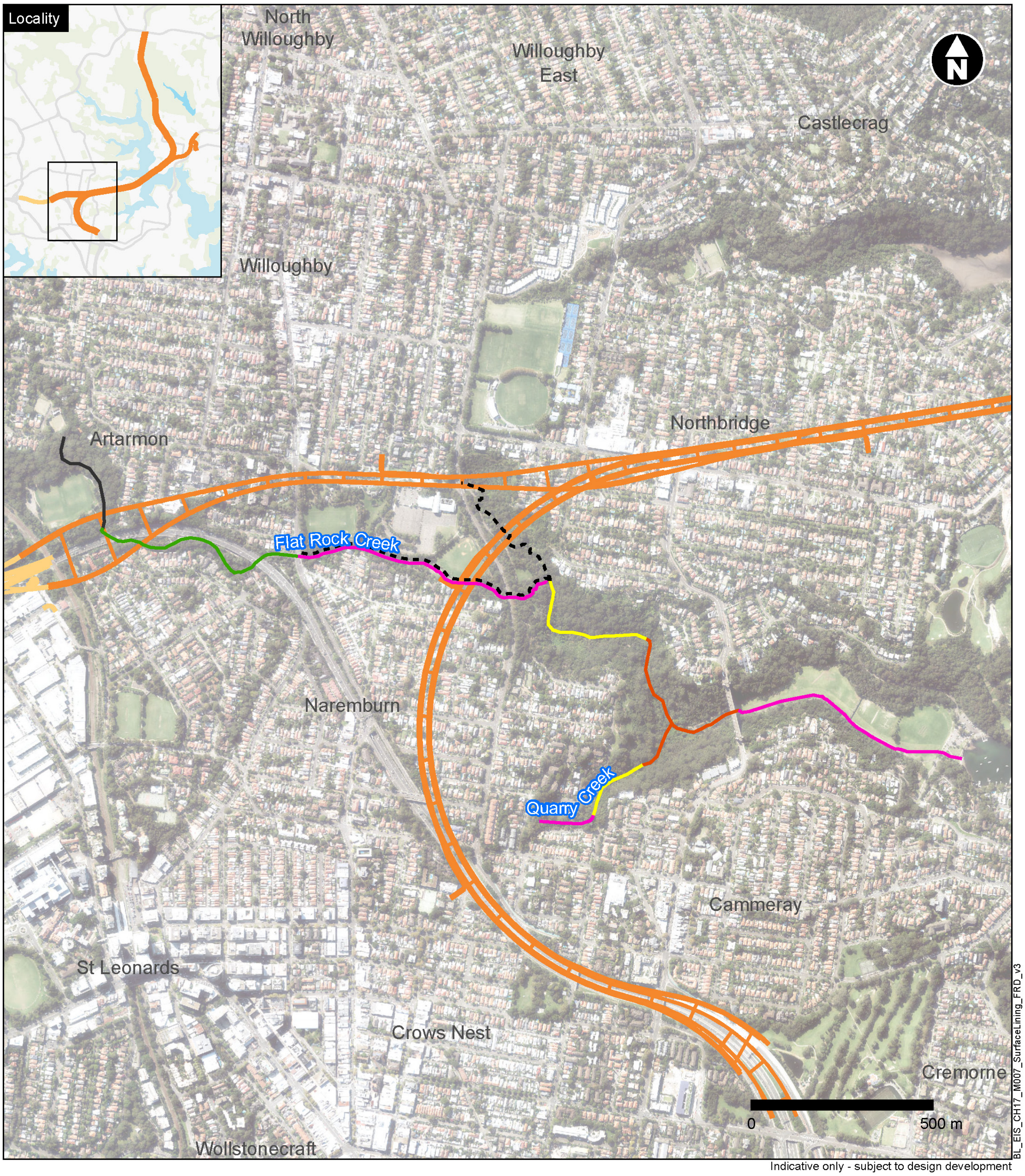
The section visited provided minimal freshwater habitat and no instream vegetation or woody debris (1.1.1). The survey reach is mapped as KFH (NSW DPI, 2016) and was considered Type 3 – minimally sensitive KFH and a Class 3 – minimal KFH for fish passage. It was the only waterway not considered to be a sensitive receiving environment (as defined in Section 4.2 of Appendix O (Technical working paper: Surface water quality and hydrology).

Figure 3-1 Willoughby Creek looking downstream (left) and upstream (right)

3.1.2 Flat Rock Creek

Flat Rock Creek is a first order waterway upstream of the Quarry Creek confluence and a second order waterway downstream (Strahler, 1957). It drains the Flat Rock Creek catchment into Middle Harbour and the Quarry Creek tributary drains the Quarry Creek catchment into Flat Rock Creek (Figure 2-2). It flows in a general easterly direction from Marlow Road at Artarmon into Middle Harbour at Tunks Park at Cammeray. The waterway was assessed at one site (Table 2-3 and Figure 2-2) at Artarmon Reserve (5a) and Flat Rock Reserve (5b(1)) and two at Flat Rock Drive at Naremburn (5b and 5c). It appeared to be freshwater upstream of its confluence with Quarry Creek (sites 5a, 5b(1) and 5b) and estuarine downstream (site 5c).

The surface lining of Flat Rock Creek varies along its course and is shown in Figure 3-2.



Legend

- Beaches Link
- Gore Hill Freeway Connection

Surface water lining

- Above and below ground concrete lined storm water channel
- Alluvium
- Constructed surface creek
- Naturalised bedrock
- Underground box culvert
- Covered concrete lined drain and vegetated floodway associated with Artarmon Reserve detention basin

Figure 3-2 Surface lining of Flat Rock Creek

The channel and banks traverse underground between Chelmsford Avenue at Naremburn and Flat Rock Gully, and along Artarmon Reserve (5a) the channel was concrete-lined and supported no instream (aquatic) vegetation and limited, landscaped riparian vegetation (Figure 3-3). This reach of Flat Rock Creek has not been mapped as KFH at a coarse scale (NSW DPI, 2016), and given the results of the field survey this reach is not considered to be KFH and not a sensitive receiving environment.

Figure 3-3 Flat Rock Creek at the upstream site looking upstream (5a) (left) and along the underground channel (right)

Existing aboveground watercourse within the northern extent of Flat Rock Reserve, parallel to Wilksch Walk joins Flat Rock Creek at a rock cascade about 50 metres south-west from the Calbina Road cul de sac. This tributary drains through a 40 centimetre underground pipe at the Small Street roundabout (northern extent of the site) but also receives catchment runoff from the escarpment which forms the north-eastern bank. This escarpment bank was steep, ranged between three and 10 metres along the tributary and was generally comprised of sandstone. The escarpment was well vegetated with a mix of native and exotic woody trees, ferns with a dense midstorey and groundcover (Figure 3-4). No instream macrophytes were recorded in the tributary however, moss was observed in some reaches. The south-western banks, that plateau to the Wilksch Walk track, ranged between two and four metres and were substantially lower. These banks were also densely vegetated with a similar vegetation assemblage as the escarpment. However, the riparian corridor along the south-western side was narrower due to the constraints of walking track and open space clearings. The Wilksch Walk intersects the tributary in a number of locations as the following features (Figure 3-6):

> Boardwalk

> Pipe culverts

> Stepping stones across a spillway.

There was little to no evidence of scouring or undercutting and along the sections likely to be exposed to higher flow velocities (eg. higher gradients), concrete or rock was laid on the channel bed. The natural channel bed was generally bedrock with a layer of sediment and detritus. The tributary width ranged between two and 10 metres albeit only some sections were flowing. Riffles and pools were observed (Figure 3-5) and where there was no flow, the channel bed was soft and damp and mostly colonised by exotic grasses and forbs, typically found in riparian corridors in Sydney metropolitan areas (eg *Tradescantia fluminensis*, *Ehrharta erecta*). This waterway had substantial canopy cover across the channel and small to medium instream logs were common, although most were not submerged at the time of survey.

This tributary is not mapped as KFH (NSW DPI, 2016) but there is an approximate one kilometre section of Coastal Sandstone Gully Forest/Sandstone Riparian Scrub/Coastal Sand Forest located in the middle reaches of Flat Rock Creek at Munro Park that is mapped by the Bureau of Meteorology (BOM) (2018) as having moderate to high potential for groundwater interaction (see Figure 3-12 of the updated biodiversity assessment).

Figure 3-4 Existing aboveground watercourse within the northern extent of Flat Rock Reserve looking downstream from the Small Street roundabout culvert

Figure 3-5 Examples of riffles and pools along the existing aboveground watercourse within the northern extent of Flat Rock Reserve

Figure 3-6 Wilksch Walk crossings along the existing aboveground watercourse

The reach immediately upstream of the Quarry Creek confluence (5b) consisted of a steep gorge with natural bedrock and large boulders. Dense riparian vegetation encroached on the channel. Riparian vegetation consisted of native, tall, woody trees, dense shrubs and groundcover. The site forms part of a popular bushwalking track connecting Bicentennial Reserve at Willoughby to Tunks Park. Instream woody debris (less than three metres long) would provide freshwater habitat along this reach albeit some were emergent at the time of survey (Figure 3-7). Bush regeneration activities by local groups were noted in some areas.

Figure 3-7 Flat Rock Creek at the downstream site looking downstream (5b) (left) and upstream (right)

Downstream of the Quarry Creek confluence (5c) Flat Rock Creek was estuarine with an alluvium bed. This reach of Flat Rock Creek was subjected to stormwater discharge with evidence of channel and bank erosion a likely result of high flow events. The south bank had dense native and exotic, overhanging riparian vegetation. Fish habitat included woody debris and some undercut banks with potential to provide refuge (Figure 3-8). Large woody debris (greater than three metres long) and dense instream common reed (*Phragmites australis*) were present in some sections about 50 metres downstream of the confluence under the current suspension bridge. The survey sites 5b and 5c contained Type 1 – highly sensitive KFH and were considered to be sensitive receiving environments. The freshwater reach (site 5b) was considered a Class 2 – moderate KFH for fish passage waterway while the estuarine reach (site 5c) was considered Class 1 – major KFH for fish passage waterway.

Figure 3-8 Flat Rock Creek at the estuarine site looking downstream (5c) (left) and looking at the right bank (right)

3.1.3 Burnt Bridge Creek

Burnt Bridge Creek is a first order waterway (Strahler, 1957) in the Burnt Bridge Creek catchment which flows in a general easterly direction from Clontarf Street at Seaforth to Manly Lagoon. This waterway was assessed at five sites (Table 2-3 and Figure 2-2) located at Baringa Avenue at Seaforth (3a), Kitchener Street at Balgowlah (3b) and three sites along the north-western boundary of Balgowlah Golf Course (3c-3e). The survey reaches appeared to be intermittent, freshwater with stormwater inflows from multiple locations. Overall, stormwater influence along this waterway has resulted in scouring of the bedrock bed, eroded mudbanks and the loss of coarse and fine-grained sediments.

The surface lining Burnt Bridge Creek varies along its course and is shown in Figure 3-9.

Figure 3-9 Surface lining of Burnt Bridge Creek

The upstream reach of Burnt Bridge Creek (3a) appeared to be a mostly natural channel with rocky outcrops and low levels of sedimentation (sandy silt) over bedrock. Modified stormwater inflows and culvert crossings were present along this reach. These crossings are potential barriers to fish passage low flows such as that observed at the time of survey where flows were restricted to partially connected pools (Figure 3-10). The exotic parrot's feather plant (*Myriophyllum aquaticum*) and native eels (*Anguilla* spp.) in the deeper pools were the only instream biota observed. Emergent woody debris along the banks have potential to provide habitat for freshwater fish and invertebrates during high flows. The channel receives substantial shading from the native riparian overstorey of sheoaks (*Casuarina* spp.). However, the width of the riparian corridor was limited by residences and landscaped gardens and exotic vegetation were prevalent in the understorey.

Figure 3-10 Burnt Bridge Creek at 3a (ie upstream of Burnt Bridge Creek Deviation) looking downstream (left) and upstream (right)

The downstream reach of Burnt Bridge Creek (3b) appeared to be a wider channel with modified bedrock and sections of concrete and boulder retaining walls. The Kitchener Street bridge spans the width of the channel along this reach with two large box culverts (Figure 3-11). These culverts were perched over bedrock and appeared to have a small culvert drop which was inundated at the time of survey. Similar to the upstream reach (3a), flows were restricted to partially connected pools (Figure 3-11). Erosion and bank undercutting was observed along this reach. The width of riparian corridor along this reach was also limited by residence and Burnt Bridge Creek Deviation. Notwithstanding, the riparian corridor provided moderate shading over the channel and small woody debris were also observed instream.

Figure 3-11 Burnt Bridge Creek at 3b (ie at Kitchener Street) looking upstream (left) and downstream (right)

The section of Burnt Bridge Creek along sites 3c-3e has been modified and realigned in the past and is known to experience hazardous flooding and flow velocities (up to eight metres per second). Channel characteristics along this reach were similar to that at 3a (Figure 3-12, Figure 3-13, Figure 3-14 and Figure 3-15) with some modifications along the banks including rock gabion banks and constructed rock walls to limit further potential for incision and controlling the overall grade of the creek (Figure 3-15 and Figure 3-16). A weir at site 3c was observed which had created a deeper pool where organic detritus have accumulated and exotic macrophytes have established (Figure 3-15). A thin corridor of native riparian vegetation bound the channel some of which overhang instream and provide shading along sections of the reach (Figure 3-12, Figure 3-13 and Figure 3-14).

All reaches of Burnt Bridge Creek were considered as Type 2 – moderately sensitive KFH and Class 2 – moderate KFH for fish passage waterway but were not sensitive receiving environments.

Figure 3-12 Burnt Bridge Creek at 3c (ie along the stretch between the culverts at Burnt Bridge Creek Deviation and Kitchener Street) looking upstream (left) and downstream (right)

Figure 3-13 Burnt Bridge Creek at 3d (along the stretch between the culverts at Burnt Bridge Creek Deviation and Kitchener Street) looking upstream (left) and downstream (right)

Figure 3-14 Burnt Bridge Creek at 3e looking upstream (left) and downstream (right)

Figure 3-15 Burnt Bridge Creek concrete weir (left) and rocky outcrop (right)

Figure 3-16 Burnt Bridge Creek rock gabion (left) and rock wall (right)

Within the eastern side of the Burnt Bridge Creek catchment is the Balgowlah Golf Course stormwater harvesting dam which was completed in 2013. The dam is a four megalitre pond/dam with a maximum nominal water depth of 2.5 metres and it is used irrigate the Balgowlah Golf Course. A key outcome of the Balgowlah Golf Course stormwater harvesting project was that the golf course no longer needed to extract water from Burnt Bridge Creek for irrigation that would have affected environmental flows. This allowed for a return to the natural conditions of flow in the creek.

Given its recent construction and disconnection with natural watercourses, the Balgowlah Golf Course stormwater harvesting dam is unlikely to provide potential habitat for native fish.

3.1.4 Manly Creek

Manly Creek, also known as Curl Curl Creek, is a first order (Strahler, 1957) freshwater waterway in the Manly Creek catchment which flows in a south-easterly direction from the northern end of Manly Dam Reserve to Manly Dam where it continues in a general eastward direction to Manly Lagoon. Manly Creek was assessed at one site (7b) located along the headwaters (ie upstream of Manly Dam) (Table 2-3 and Figure 2-2). The substratum of Manly Creek was comprised mostly of sandstone bedrock, boulders and cobbles and was inundated by a series of connected pools, runs and riffles at the time of survey (Figure 3-17). Some unconsolidated materials have accumulated in the pools (Figure 3-17). The banks along Manly Creek were low and large snags and boulders provided potential fish habitat throughout the survey reach. The riparian corridor consisted of woody vegetation. Coastal Sandstone Gully Forest groundwater dependent ecosystem (GDE) occurs within 100 metres of the waterway (see Section 3.1.5 and Figure 3-12 of the updated biodiversity assessment). This reach of Manly Creek was considered to be a Type 1 – highly sensitive KFH, Class 1 – major KFH for fish passage waterway and a sensitive receiving environment.

Figure 3-17 Manly Creek (7b) looking upstream (left) and downstream (right)

3.1.5 Manly Dam

Manly Dam is a freshwater lagoon in the Manly Creek catchment which receives water from Manly Creek and discharges via south Manly Creek into Manly Lagoon to the east. Many Dam was built in 1892 as a water supply dam for the Manly area, and at times neighbouring suburbs where It supplied drinking water up until 1933, although was briefly used in 1942 during a period of drought (NSW OEH, 2020). Manly Dam and its catchment are now used primarily for public recreation. Manly Dam was assessed at two sites (Table 2-3 and Figure 2-2) located mid-dam adjacent to Wakehurst Golf Course (6b) and at the dam wall (6c). The Manly Dam catchment is characterised by sandstone slopes, rock platforms, gullies and some areas of shale over a steep terrain. This lagoon is one of the largest freshwater lakes in Sydney. Large areas of emergent, native/exotic freshwater macrophytes occur throughout the lagoon including the native *Eleocharis* sp. and the exotic yellow waterlily (*Nymphaea mexicana*). Manly Dam supports an extensive wetland community (Figure 3-18) and Manly Dam Reserve is mapped by the Bureau of Meteorology (BOM) (2018) as having moderate to high potential for groundwater interaction. Coastal Sandstone Gully Forest and Coastal Sandstone Plateau Heath GDEs are mapped in close proximity to the subject land (see Figure 3-12 of the updated biodiversity assessment). Although Manly Dam is not a waterway, the Policy classification was used to assist with the impact assessment to follow. These characteristics categorise these reaches of the waterbody as Type 1 – highly sensitive KFH, Class 1 – major KFH for fish passage and a sensitive receiving environment.

Figure 3-18 Many Dam mid-dam (6b) (left) and at the dam wall (6c) (right)

3.1.6 Trefoil Creek

Trefoil Creek is a first order freshwater waterway (Strahler, 1957) in the Trefoil Creek catchment which flows north from Frenchs Forest Road at Frenchs Forest into Middle Creek along Peppercorn Drive at Frenchs Forest. This waterway crosses underneath Wakehurst Parkway before discharging into Middle Creek which flows into Narrabeen Lagoon to the north-east. Trefoil Creek was assessed at one site (8b) (Table 2-3 and Figure 2-2) located adjacent to the Ausgrid easement along the headwaters. Trefoil Creek is a narrow (less than one metre wide), natural, ephemeral channel located within a steep gully. The survey reach at the time of survey was characterised by small, disconnected pools with a sandy silt substratum overlaying bedrock. Accumulations of detritus and log jams were common along the reach and likely to be mobilised during high flows (Figure 3-19). The riparian corridor consisted of dense, overhanging native and exotic vegetation bordered by residences on the east bank. This reach of the waterway was considered a sensitive receiving environment, a Type 2 – moderately sensitive KFH and a Class 3 – minimal KFH for fish passage waterway.

Figure 3-19 Trefoil Creek along the survey reach (8b)

3.1.7 Wakehurst Golf Course dam

Wakehurst Golf Course dam is a freshwater lagoon in the Manly Creek catchment on the western boundary of the Wakehurst Golf Club. It is nested within the bushland reserve between Wakehurst Parkway and Wakehurst Golf Club and is about 100 metres north-east of the Sydney Water water storage facility at Killarney Heights. The dam is about 50 by 20 metres with a two metre levee/bank on the golf course side and an eight to 10 metre natural escarpment on the reserve side. The riparian vegetation around the dam comprised mostly of dense, native vegetation with some exotic understorey. The riparian corridor on the reserve side was more extensive (greater than 50 metres) than the golf course side (about two to eight metres). The depth of the dam was not determined at the time of survey however, it appeared to be shallow enough for macrophytes (*Eleocharis* spp.) to colonise the northern and southern areas. Filamentous green algae were also recorded on the sediment close to the banks. Eastern Gambusia (*Gambusia holbrooki*) and a turtle (Family Chelidae) were also observed from the banks at the time of survey. The bed and the banks of the dam were mostly comprised of unconsolidated sediment and detritus, although little were suspended in the water column at the time of survey (Figure 3-20).

Figure 3-20 Instream condition of the Wakehurst Golf Course dam looking south-west from the northern end.

The dam did not appear to spill/discharge into any aboveground waterways. It appeared to receive water from the escarpment to the west. Wakehurst Parkway forms a ridge where runoff from the road is likely to drain to the west to Bantry Bay and to the east to Wakehurst Golf Course. A vegetated drainage line originated from a 40 centimetre pipe, flowed into the dam down the escarpment on the western side of the dam (Figure 3-21). This drainage line was about one metre wide at the pipe becoming wider towards its approach to the dam. There was little flow from the pipe and no water reached the dam at the time of inspection. Sand and small boulders were observed at the discharge location of the drainage line while the channel bed along the upstream sections was vegetated with shrubs, ferns, grasses and forbs or layered with detritus. There were no instream macrophytes, but moss was observed in some channel sections. The drainage line does not meander and mostly flows in one direction to the dam. Some minor undercutting of the banks of the drainage line was observed.

The dam is not a waterway. The dam and the drainage line are not mapped as KFH (NSW DPI, 2016).

Figure 3-21 Vegetation drainage line originating from a 40 centimetre pipe on the escarpment

3.2 Existing water quality

Existing surface water quality is detailed in Appendix O (Technical working paper: Surface water quality and hydrology). In summary, the surface water quality of these five waterways and Manly Dam is likely to be substantially influenced by the surrounding urban development. Sources of contaminants, such as suspended sediments, heavy metals and persistent organic pollutants (POPs), include stormwater, wastewater overflows and leachate from contaminated lands. Some of these waterways have also undergone significant modifications to the original bedrock channel or alterations from natural channels to artificial, hard (concrete-lined) channels to accommodate higher volume and velocity flows from an increase in urban, impervious surfaces. This hydrological alteration from natural conditions would have promoted the transport of sediments and contaminants to downstream receiving environments (ie Middle Harbour and Manly Lagoon). A summary of existing water quality across these freshwater environments is outlined in Table 3-1.

Water quality data, in addition to that collected for Appendix O (Technical working paper: Surface water quality and hydrology), at the unnamed tributary of Flat Rock Creek (site 5b(1)) and the Wakehurst Golf Course dam (site 9) collected at the time of the freshwater ecology survey are detailed in Attachment A.

3.3 Freshwater fauna

The waterways in the Sydney region support a diversity of freshwater fauna due to the diversity and connectivity of aquatic habitats spanning freshwater, estuarine and marine areas. This leads to many aquatic species (up to 70 per cent) migrating across these areas during part of their lifecycles (Fairfull & Witheridge, 2003). Common native fish species found in waterways in the Sydney region include short-finned and long-finned eels (*Anguilla australis* and *A. reinhardtii*), common galaxias (*Galaxias maculatus*), Australian bass (*Macquaria novemaculeata*) and a number of gudgeon species (Nichols & McGirr, 2005). Exotic fish species are also widespread across the Sydney region (Section 3.9). Waterways in the Sydney region support an array of macroinvertebrates including the Sydney crayfish (*Euastacus australasiensis*) and the freshwater shrimp (*Paratya australiensis*) as well as smaller insects and freshwater mussels. These species depend on healthy waterways and access to diverse habitats including swamps, floodplains, wetland, streams and rivers of which the majority occur within the study area. Although no fish or macroinvertebrate sampling was carried out for this assessment, the waterways in the study area and Manly Dam are suitable for most of these species. Thus, these species are likely to occur in these freshwater environments with the natural reaches (ie Willoughby Creek, Burnt Bridge Creek, Manly Creek and some reaches of Flat Rock Creek) being more suitable.

The Manly Dam catchment, including the middle and lower reaches of Manly Creek, is home to the only confirmed population of climbing galaxias (*Galaxias brevipinnis)* in the Sydney area. Although not a threatened or protected species, the community prepared an action plan for its protection in the Manly Dam catchment (Salkavich et al., 2002). The action plan considers water pollution to be among the threats to this population.

3.4 Threatened ecological communities, species and endangered populations

It was considered unlikely that any threatened freshwater fauna, flora species or ecological communities or endangered populations listed under the FM Act and/or the EPBC Act occur within the study area. No predicted freshwater threatened species, ecological communities or endangered populations' distributions coincide with the study area. Most of the waterways within the study area have been modified and are substantially disturbed and would not provide optimal habitat for any threatened freshwater species. For information about terrestrial species potentially occurring in the study area refer to the updated biodiversity assessment.

Silver perch (*Bidyanus bidyanus*) has been historically caught in Manly Dam. This species is listed as vulnerable under the FM Act and was commercially harvested in the 1900s contributing to population declines (NSW DPI, 2017a). Silver perch naturally occurs in rivers in the Murray-Darling Basin thus, its anecdotal occurrence in Manly Dam was likely due to fish stocking for recreational fishing. The lack of verified, recent records of this species within the study area suggests that the occurrence of silver perch in Manly Dam is unlikely to be a self-sustaining population. Due to the study area being outside of the natural distribution of silver perch, the potential occurrence of the species in Manly Dam attributed to stocking and the lack of recent records within the study area, the anecdotal occurrence of this species is not considered to form part of the vulnerable listing under the FM Act. Thus, silver perch will not be considered further in this assessment.

3.5 Migratory species

No freshwater migratory species listed under the EPBC Act were considered likely to occur within the study area. Migratory species associated with the freshwater waterways and riparian corridors are addressed in the updated biodiversity assessment.

3.6 Protected species

Some species of fish or invertebrates have been formally protected because they are naturally scarce or their numbers have been substantially reduced over recent decades. These species are protected to help prevent them becoming threatened in the future. Fishing and collecting of these species without a permit will incur a penalty in accordance with Section 19 of the FM Act.

The isopod *Crenoicus harrisoni* is the only freshwater species listed as protected under the FM Act. This species is only known from Saxby's Swamp in the Barrington Tops area, about 240 kilometres north of the study area.

No protected freshwater species listed under the EPBC Act were predicted to occur within the study area.

Protected estuarine species with potential to occur within the study area are addressed in Appendix T (Technical working paper: Marine ecology).

3.7 Critical habitat

Critical habitat refers only to those areas listed in the Register of Critical Habitat maintained by Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) and the Commonwealth Department of Agriculture, Water and the Environment. There are no freshwater critical habitats listed in either register with potential to occur within the study area.

3.8 Wetlands and conservation areas

No Ramsar or coastal wetlands (*State Environmental Planning Policy (Coastal Management) 2018*) occur along the waterways within the study area. The closest Ramsar wetland is at Towra Point at Kurnell, about 24 kilometres south of the study area. The closest coastal wetland identified in the *State Environmental Planning Policy (Coastal Management) 2018* is along Burnt Bridge Creek within Manly Golf Course, located about one kilometre to the east of the study area.

3.9 Pests and diseases

A number of exotic fish species have been intentionally or unintentionally introduced into NSW waterways since European settlement. Some of these species have become problematic, widespread pests altering native community structure and interactions through competition for resources, predation and the introduction of diseases (NSW DPI, 2017b). Carp (Family Cyprinidae), redfin perch (*Perca fluviatilis*), eastern gambusia, oriental weatherloach (*Misgurnus anguillicaudatus*), banded grunter (*Amniataba percoides*) and goldfish (*Carassius auratus*) are freshwater pest fish species which have established in NSW waterways. Of these species, redfin perch, eastern gambusia and carp are the most widespread. Eastern gambusia was observed at the Wakehurst Golf Course dam.

Species of carp are native to Asia and Europe while eastern gambusia are native to the south-eastern United States of America (USA) (NSW DPI, 2017b). These two species are able to tolerate a wide range of environmental conditions contributing to a widespread distribution in NSW, including the potential to currently occur within the study area waterways. Redfin perch are native to northern Europe and prefer still or slow-flowing waters (eg lotic systems). Anecdotal evidence suggests that this species and carp have been caught in Manly Dam.

3.10 Commercial and recreational fisheries

Aquaculture or commercial fisheries have not been identified within the waterways in the study area. No aquaculture or commercial fisheries have been identified in Manly Lagoon.

Recreational fishing is a common activity in Manly Dam but is unlikely to occur in the connected waterways. Target species have historically included silver perch, European carp (*Cyprinus carpio*), redfin perch and Australian bass (*Macquaria novemaculeata*) the latter of which is stocked regularly in the dam. Other waterways within the study area are unlikely to support recreational fishing activities.

3.11 Key threatening processes

A key threatening process (KTP) is a process that threatens, or may have the capability to threaten, the survival or evolutionary development of species, populations or ecological communities. KTPs are listed under the FM Act and the EPBC Act. At present, there are eight KTPs listed under the FM Act and 21 listed under the EPBC Act. Four KTPs listed under the FM Act and three listed under the EPBC Act have potential to be associated with potential project impacts to freshwater ecology. These include:

> Degradation of native riparian vegetation along New South Wales watercourses (FM Act) from the direct removal and/or disturbance of native riparian vegetation for project construction

> Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (EPBC Act) from the disturbance of landscaped areas and the repurposing of materials containing propagules

> Human-caused climate change (FM Act) due to the generation of greenhouse gas emissions associated with the construction and operation of the project

> Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases (EPBC Act) due to the generation of greenhouse gas emissions associated with the construction and operation of the project

> Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act) such as wastewater discharges or drainage works

> Removal of large woody debris from New South Wales rivers and streams (FM Act) during instream works

> Novel biota and their impact on biodiversity (EPBC Act) from the use of contaminated equipment, plant, vehicles and foot traffic.

Potential exacerbation of these KTPs are assessed in the impact assessment (see Section 4.5).

3.12 Summary

All five creeks within the study area are first order waterways flowing into Middle Harbour or Manly Lagoon. Manly Dam is a freshwater lagoon of which Manly Creek runs through. All freshwater environments within the study area are located in highly urbanised catchments. Sections of Willoughby Creek, Flat Rock Creek and Burnt Bridge Creek have been modified to receive stormwater inflows with a section of Flat Rock Creek (5a) completely converted to a concrete-lined channel in some areas and a concrete box culvert in another area. Parts of Burnt Bridge Creek within the study area have experienced historical modifications and realignment as part of past road widening works and to address flooding behaviour. The natural sections of the waterways are mostly characterised by consolidated bedrock with some unconsolidated materials (sediments and detritus) accumulating in pools. Refer to Figure 2-2 for the location of waterways associated with the project.

Manly Dam, Manly Creek and the natural reaches of Flat Rock Creek (5b and 5c) were considered sensitive receiving environments and Type 1 – highly sensitive KFH. The Wakehurst Golf Course dam and the aboveground watercourse at Flat Rock Reserve are not KFH.

Waterways located within Sydney's urbanised catchments, such as those in the study area, can have impaired water quality (eg Preston, 1995). These freshwater environments are unlikely to provide optimal habitat for any threatened freshwater species, communities or populations due to the extent of habitat disturbance and modification. A summary of the existing environment is outlined in Table 3-1.

Table 3-1 Freshwater ecology and geomorphology summary of assessment sites (source: Jacobs, 2018a and Jacobs, 2018b)

KFH Type and Class	Sensitive receiving environment	Bank and instream geomorphology	General water quality	Riparian condition	Instream habitat
Willoughby Creek (2b)					
Type 3 – minimally sensitive KFH Class 3 – minimal KFH for fish passage	No	▪ Entrenched bedrock in the upstream reaches of the survey site modified to form a stormwater channel ▪ Concrete-lined channel approximately 10 metres downstream of the survey point.	▪ Freshwater ▪ Periodically elevated heavy metal concentrations ▪ Elevated nitrogen concentrations ▪ Low dissolved oxygen.	Dense, woody riparian corridor wider on the north-western bank (approximately 70 metres) while a thinner riparian corridor lies adjacent to cleared sporting facilities.	No instream vegetation or woody debris. The waterway was substantially shaded from woody riparian vegetation.
Burnt Bridge Creek upstream (3a)					
Type 2 – moderately sensitive KFH Class 2 – moderate KFH for fish passage	No	▪ Natural channel with patches of sandy silt over bedrock and rocky outcrops ▪ Sections of the channel comprise modified stormwater inflows and culvert crossings.	▪ Freshwater ▪ Low dissolved oxygen ▪ Elevated heavy metal concentrations ▪ Elevated nutrient concentrations.	Thin riparian corridor of native overstorey tress and an exotic understorey bound by residences and landscaped gardens.	Partially connected pools with some exotic instream vegetation, isolated occurrences of emergent snags and substantial shading from riparian vegetation.
Burnt Bridge Creek downstream (3b)					
Type 2 – moderately sensitive KFH Class 2 – moderate KFH for fish passage	No	▪ Modified bedrock channel with sections of concrete and boulder retaining walls along a wider channel than the upstream reach ▪ Erosion and bank undercutting in some reaches along the north bank ▪ Kitchener Street Bridge spans across the width of the channel with two large box culverts perches on bedrock.	▪ Freshwater ▪ Water quality was similar but slightly better than site 3a except for higher zinc concentrations.	Thin, vegetated riparian corridor bound by residences on the south bank and Burnt Bridge Deviation on the north bank.	Disconnected pools with minimal connectivity with moderate shading from riparian vegetation and small snags instream.

KFH Type and Class	Sensitive receiving environment	Bank and instream geomorphology	General water quality	Riparian condition	Instream habitat
Burnt Bridge Creek middle reach (3c-3e)					
Type 2 – moderately sensitive KFH Class 2 – moderate KFH for fish passage	No	▪ Similar to 3a with bank modifications including rock gabion and construction rock wall banks ▪ A concrete weir was located at 3c	▪ Assumed to be consistent with 3a and 3b (no data specific to this reach available).	Thin riparian corridor bound by Burnt Bridge Creek Deviation and Balgowlah Golf Course.	Pools and runs of varying depth with some instream macrophytes, overhanging native riparian vegetation and instream shading.
Flat Rock Creek upstream (5a)					
Not KFH	No	▪ Concrete-lined channel ▪ Vertical concrete slabs up the banks ▪ Concrete box culvert	▪ Freshwater ▪ Elevated heavy metal concentrations ▪ Elevated nutrient concentrations ▪ Microbiological contamination evident.	Limited, landscaped riparian vegetation.	No instream vegetation.
Flat Rock Creek downstream (5b)					
Type 1 – highly sensitive KFH Class 2 – moderate KFH for fish passage	Yes	▪ Steep banks comprising bedrock and boulders.	▪ Freshwater ▪ Elevated heavy metal concentrations ▪ Elevated nutrient concentrations.	Dense native woody and shrubby riparian vegetation some of which were encroaching instream.	Some small snags.
Flat Rock Reserve aboveground watercourse (5b(1))					
Not KFH	No	▪ Bedrock channel with a layer of sediment colonised by exotic grasses and forbs ▪ Concrete or rock was laid on channel bed in sections exposed to higher flow velocities ▪ Steep banks ▪ Little to no evidence of scouring or undercutting.	▪ Freshwater ▪ Elevated heavy metal concentrations ▪ Elevated nutrient concentrations.	Dense native and exotic riparian vegetation along both banks.	Moss, rocks and loose snags in some sections.

KFH Type and Class	Sensitive receiving environment	Bank and instream geomorphology	General water quality	Riparian condition	Instream habitat
Flat Rock Creek downstream (5c)					
Type 1 – highly sensitive KFH Class 1 – major KFH for fish passage	Yes	▪ Alluvium bed with banks prone to inundation, erosion and bank destabilisation.	▪ Estuarine ▪ Elevated heavy metal concentrations ▪ Elevated nutrient concentrations.	Dense native and exotic riparian vegetation along the south bank and some native trees along the north bank.	Large snags and dense instream, emergent vegetation in some areas.
Manly Dam (6b and 6c)					
Type 1 – highly sensitive major KFH Class 1 – sensitive KFH for fish passage	Yes	▪ Lagoon bound by sandstone slopes, rock platforms and gullies.	▪ Freshwater ▪ Seasonally fluctuating dissolved oxygen conditions ▪ Elevated nutrient concentrations. ▪ Periodically experience elevated heavy metal concentrations.	Within the densely vegetated, wide corridor of Manly Dam Reserve.	Large areas of native and exotic emergent macrophytes amongst sandy shores and wetland vegetation.
Manly Creek (7b)					
Type 1 – highly sensitive major KFH Class 1 – sensitive KFH for fish passage	Yes	▪ Substratum of mostly sandstone bedrock, boulders and cobbles ▪ Channel of connected pools, runs and riffles ▪ Pools appeared to hold some sediment.	▪ Freshwater ▪ Low dissolved oxygen ▪ Elevated heavy metal concentrations ▪ Elevated nutrient concentrations.	Within the densely vegetated, wide corridor of Manly Dam Reserve.	Large snags and instream shading from riparian vegetation.
Trefoil Creek (8b)					
Type 2 – moderately sensitive KFH Class 3 – minimal KFH for fish passage	Yes	▪ Narrow, natural channel located within a steep gully. ▪ Sandy silt substratum overlaying bedrock with occasional rocky outcrops.	▪ Freshwater ▪ Elevated heavy metal concentrations during wet weather ▪ Elevated nutrient concentrations during wet weather.	Dense, overhanging native and exotic vegetation bound by residences.	Substantial riparian shading over ephemeral disconnected pools at the time of survey.
Wakehurst Golf Course dam (9)					
Not KFH	No	▪ Dam bound by sandstone escarpment to west and levee banks to its north, east and south.	▪ Freshwater.	Within dense, native vegetation with some exotic understorey.	Some fringing areas of native emergent macrophytes.

4 Impact assessment

Construction activities and the operation of the project could potentially impact freshwater ecology or geomorphology. These activities are summarised in Section 2.3. This section determines the likelihood and magnitude of the potential impacts associated with construction and operation of the project in accordance with the approach outlined in Section 2.

Cumulative impacts from other projects considered in Section 7 of Appendix O (Technical working paper: Surface water quality and hydrology) have potential to increase pressures on maintaining water quality. Jacobs (2020a) suggests that cumulative impacts as a result of other projects are minimal on freshwater environments provided controls are implemented, maintained and monitored. Hence, cumulative impacts on freshwater ecology as a result of these projects would likely be minimal.

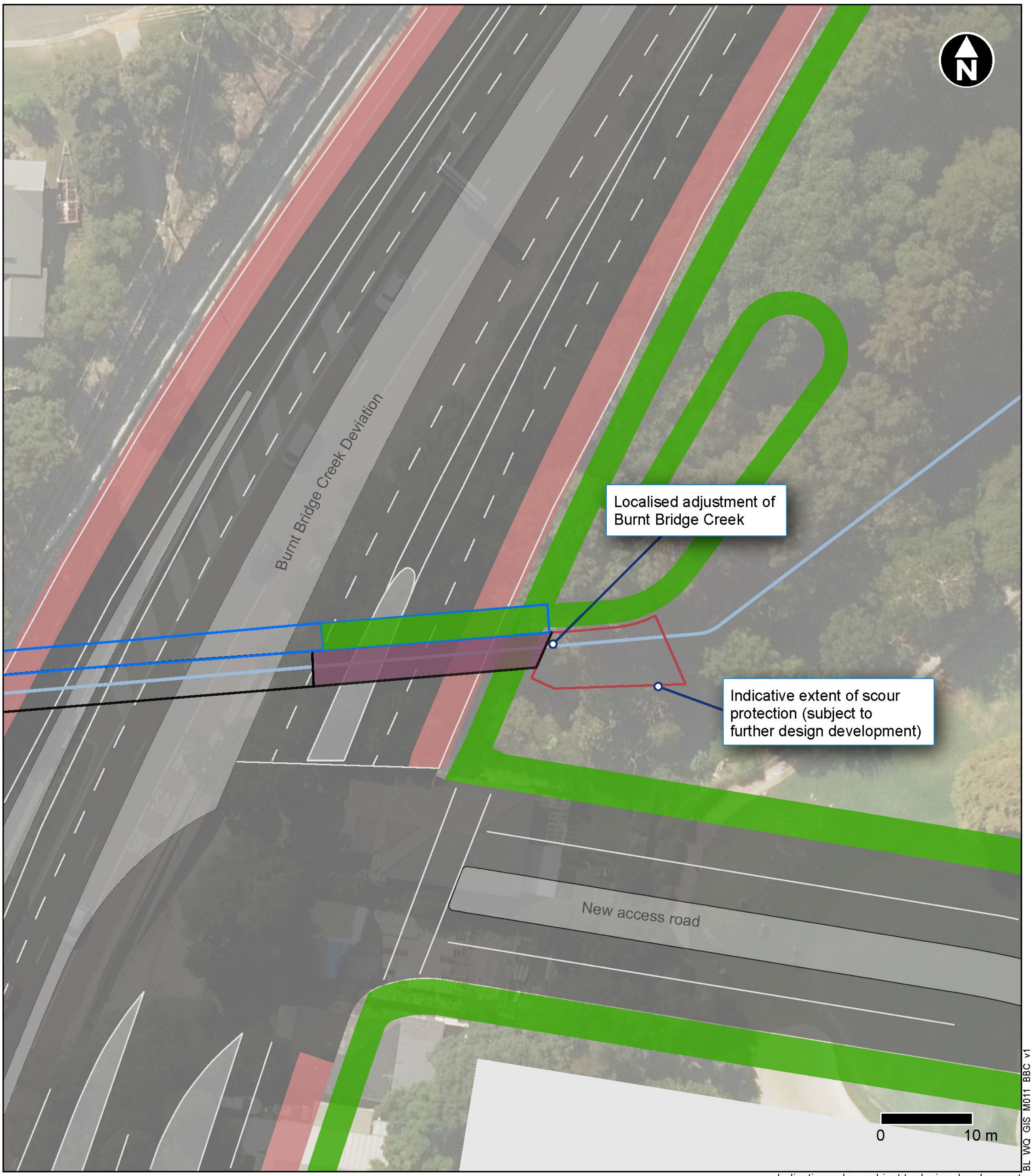
4.1 Direct construction impacts

4.1.1 Vegetation clearing

A small area of riparian vegetation would be removed for the localised adjustment and drainage works at Burnt Bridge Creek and for drainage works at the existing aboveground watercourse within the northern extent of Flat Rock Reserve (see Figure 4-1 and refer to the updated biodiversity assessment). Small areas (<0.01 hectares) of native and exotic vegetation/native plantings would also be removed for the establishment of Balgowlah Golf Course construction support site (BL10) and Kitchener Street construction support site (BL11).

Removal of riparian vegetation along these areas would have the potential to alter conditions such that exotic vegetation could establish, or to impact bank stability and surface water quality. However, within the construction footprint, modifications have been made along sections of the banks of Burnt Bridge Creek to assist in stabilising and preventing erosion or bank collapse (Section 3.1.3). The potential for impacts to water quality and/or freshwater ecology are discussed in Section 4.2.1. Bank erosion could also alter geomorphology, and flow regimes, by altering substratum and sediment transport/deposition. However, given the minor amount of riparian vegetation that would potentially be cleared the risk of these impacts occurring is considered low. Impacts of this to freshwater ecology are discussed in Section 4.1.2.

During construction when riparian vegetation is removed measures would be implemented to ensure water quality, geomorphology and flow regimes upstream and downstream of the area of impact would be protected and impacts to freshwater habitat minimised (refer to sections 1.4 and 5). An exclusion zone is proposed to be established around riparian vegetation adjoining Burnt Bridge Creek adjacent to the surface road works at Balgowlah where reasonable and feasible to minimise disturbance. Rehabilitation and revegetation of disturbed riparian vegetation would occur progressively during construction (refer to the updated biodiversity assessment). As such, the removal of riparian vegetation is considered a localised but recoverable impact to freshwater ecology.



Indicative only – subject to design development

Legend

- Surface road
- Bus lane
- Pedestrian / active transport links
- Operational facilities and ancillary infrastructure
- Burnt Bridge Creek culvert extension
- Shared user underpass extension
- Burnt Bridge Creek

Figure 4-1 Culvert extension at Burnt Bridge Creek

4.1.2 Instream works

Instream works would be required along the existing aboveground watercourse within Flat Rock Reserve and Burnt Bridge Creek.

To facilitate the establishment of the Flat Rock Drive construction support site (BL2), the existing aboveground constructed watercourse within Flat Rock Reserve would be diverted for around 100 metres through a newly constructed culvert at the north eastern perimeter of the Flat Rock Drive construction support site (BL2). The works would occur in the very upper reaches of Flat Rock Creek in the Gore Hill/Artarmon area which are in the location where the creek has been largely replaced by concrete channels from previous projects.

Burnt Bridge Creek would undergo localised adjustment to facilitate an extension of the existing box culvert crossing of the Burnt Bridge Creek Deviation further into Balgowlah Golf Course. The extension to the existing culvert would be designed with a low gradient and scour protection to minimise impacts to geomorphology. The gradient, sinuosity and channel capacity would remain consistent with upstream and downstream sections of the creek. Where required, grade controls and bank stabilisation works would be implemented to manage anticipated high velocity conditions. Based on current design, about a 15 metre length of Burnt Bridge Creek would be directly affected by the culvert extension works and/or scour protection. Assuming an average bed width of about four metres in the affected area, this equates to an estimated net loss of about 60 square metres of Type 2 moderately sensitive KFH. This section of Burnt Bridge Creek has been previously modified, however the work may result in the loss of some small invertebrates, instream macrophytes and unconsolidated sediments. Notwithstanding, the instream works are anticipated to have a minimal and localised impact to instream freshwater habitats.

Culvert and instream drainage infrastructure would also be designed in accordance with *Why do fish need to cross the road?: Fish passage requirements for waterway crossings* (Fairfull & Witheridge, 2003) and in consultation with Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) to ensure fish passage is maintained along the waterway during low flows (refer to Section 1.4). Where required, native fish and large invertebrates would be relocated downstream of the works during dewatering activities (refer to Section 5). With considerations during project design and the implementation of additional environmental management measures, impacts of culvert and drainage infrastructure installations are likely to have minimal impacts to freshwater ecology.

4.1.3 Dam dewatering

The project would impact the Balgowlah Golf Course stormwater harvesting dam as part of constructing the new access road between Sydney Road and Burnt Bridge Creek Deviation. The Balgowlah Golf Course stormwater harvesting dam would initially be retained and maintained for construction water and for irrigation of Balgowlah Oval by Northern Beaches Council. As construction progresses the stormwater harvesting dam would be dewatered and filled in.

As discussed in Section 3.1.3, the stormwater harvesting dam is unlikely to provide habitat for native fish. Notwithstanding, dewatering procedures should be implemented in the event that native aquatic fauna are encountered to ensure any potential impacts are minimised.

4.2 Indirect construction impacts

The greatest potential risk to freshwater ecology during project construction would likely be indirect impacts to water quality and flow in nearby waterways. Construction support sites located in close proximity to freshwater waterways would be those at Cammeray Golf Course (BL1), Flat Rock Drive (BL2), Punch Street (BL3), Barton Road (BL5), Gore Hill Freeway median (BL6), Balgowlah Golf Course (BL10), Kitchener Street (BL11), Wakehurst Parkway south (BL12), Wakehurst Parkway east (BL13) and Wakehurst Parkway north (BL14).

4.2.1 Water quality

Alterations to water quality can arise from the inadvertent mobilisation of sediments and contaminants offsite. This could arise if the environmental management measures outlined in Section 2.3 of Appendix O (Technical working paper: Surface water quality and hydrology) are not implemented effectively. Sediment mobilised by runoff or through site discharges and dewatering of sediment control basins has the potential to increase turbidity in receiving waters. Elevated turbidity can clog the gills and feeding apparatus of freshwater invertebrates and fish and potentially reduce photosynthesis in submerged macrophytes via light attenuation. The mobilisation of sediments could also increase sedimentation in the receiving waters which would alter the existing substratum or smother freshwater habitats (eg snags) and benthic fauna. In particular, Burnt Bridge Creek, Flat Rock Creek, downstream of the Quarry Creek confluence (5c), Manly Dam, Manly Creek and Trefoil Creek could be impacted. Sedimentation along other reaches could cover the existing hard substratum and/or smother freshwater habitat. Although only incidental observations of freshwater invertebrates and fish were made during the field survey, it would be precautionary to assume that they occur in the waterways of the study area, particularly in areas considered to be KFH (except for a section of Flat Rock Creek) (Table 3-1). The waterways in the study area are currently likely to be exposed to elevated turbidity and sedimentation intermittently from highly urbanised catchment flows, thus the biota in the waterways are likely to have developed some tolerance.

Contaminants (if present) bound to sediments and/or from accidental releases could also reach waterways. Contaminants are also likely to be present in tunnel inflows at each wastewater treatment plant catchment based on the project groundwater and soil investigations documented in Appendix N (Technical working paper: Groundwater) and Appendix M (Technical working paper: Contamination). The solubility, bioavailability and persistence of contaminants is compound specific. Common compounds which may be mobilised during construction that are within sediment, groundwater or associated with the use of construction plant, equipment and vehicles include nutrients, heavy metals, total recoverable hydrocarbons (TRH), POPs and ASS. There is currently evidence of heavy metal and nutrient contamination in all three receiving waterways (Table 3-1) thus, biota are likely to already be exposed to some of these contaminants. Freshwater biota toxicity varies between species, life stages of species and distribution. Algal blooms also have potential to affect water chemistry and clarity. Further contributions to contaminant concentrations or the introduction of new contaminants as a result of the project has potential to affect freshwater biota through toxicity (from, for example, heavy metals) and induce algal blooms (from nutrients). However, taking into account the proposed environmental management measures in Section 5 of this assessment, the likely volumes of such inflows are likely to be very small. The likelihood of occurrence of ASS within the study area was considered to be low to extremely low (refer to Appendix M (Technical working paper: Contamination)), thus, associated potential impacts to freshwater ecology are considered low.

The project construction wastewater treatment plants would treat the tunnel inflows estimated in Table 2-1 as well as other wastewater generated by tunnelling activities. Further, with the implementation of environmental management measures recommended in Section 5, the likelihood of sediments and contaminants entering the waterways as a result of the project is low and impacts to freshwater ecology are expected to be minimal.

4.2.2 Geomorphology and flow regimes

As described in Appendix N (Technical working paper: Groundwater), surface environmental water availability and flows have the potential to be reduced as a result of groundwater drawdown during construction of the project as detailed below:

- Maximum predicted drawdown at Willoughby Creek during the construction phase is up to three metres. The creek is lined in this region and therefore baseflow impacts are not expected
- The drawdown beneath Flat Rock Creek is estimated to be up to 28 metres. There would be maximum of 20 per cent reduction in baseflow at the end of construction
- The drawdown beneath Quarry Creek is estimated to be up to eight metres. There would be maximum of 23 per cent reduction in baseflow at the end of construction
- The drawdown beneath Burnt Bridge Creek is estimated to be up to five metres. There would be maximum of 79 per cent reduction in baseflow at the end of construction
- An estimated drawdown of less than one metre is expected at Manly Dam resulting in maximum baseflow reduction of two per cent
- Manly Creek and Trefoil Creek would be unaffected by changes to baseflow.

Although the predicted impact to the baseflow of Quarry Creek, Flat Rock Creek and Burnt Bridge Creek has the potential to be considerable, the predicted baseflow is a conservative (high) estimate. Further, as groundwater inflows to the tunnels would be collected, treated and discharged to local waterways (Willoughby Creek, Flat Rock Creek and Burnt Bridge Creek), this would be expected to partially offset baseflow reductions to these watercourses (see Appendix N (Technical working paper: Groundwater)).

Baseflow would not be reduced completely and given the changes to baseflows during the construction period would be expected to be within natural ranges, there would be minor impact only to aquatic ecology, other than from a temporary disturbance. It is expected that the additional creek flows from treated water from the construction wastewater treatment plants could partially feed the surrounding groundwater system (discussed in Appendix N (Technical working paper: Groundwater)). Refer to the updated biodiversity assessment for impacts of groundwater drawdown to GDEs along watercourses.

Wastewater would be treated at wastewater treatment plants and discharged to waterways within the study area during construction. Wastewater treatment plant discharges are predicted to enter Willoughby Creek, Flat Rock Creek and Burnt Bridge Creek via the local stormwater network and Wakehurst Golf Course dam via a constructed drainage line (Table 2-1). All affected waterways currently receive stormwater inflows and have modified channels which avoid erosion. Appendix O (Technical working paper: Surface water quality and hydrology) indicates that anticipated flows in the waterways from the additional discharges are minor compared to a two-year average recurrence interval (ARI) event. Appendix O (Technical working paper: Surface water quality and hydrology) concluded that the susceptibilities of the waterways to degradation as a result of increased flows is considered low based on assessment of their current stability and the relatively low level of discharges anticipated compared to existing flows. Notwithstanding this, environmental management measures to manage geomorphology impacts on Flat Rock Creek and Burnt Bridge Creek are proposed to reduce the potential for any unexpected degradation from increased flows (see Section 5). Scour protection would be considered and installed where a risk of erosion is predicted as a result of the culvert/instream drainage infrastructure. Subsidence and tunnel collapse was also considered highly unlikely based on an assessment of geological conditions (refer to Appendix O (Technical working paper: Surface water quality and hydrology)). Thus the project is unlikely to substantially modify the existing geomorphology of waterways within the study area so that the habitat of freshwater biota would be impacted.

Most of the treated water from the construction wastewater treatment plant at the Wakehurst Parkway east construction support site (BL13) would be reused at the construction support site and for construction activities associated with the Wakehurst Parkway upgrade. Surplus water (10 kilolitres per day) would be discharged to a drainage pit on the eastern boundary of the support site and subsequently flow into nearby Wakehurst Golf Course dam via overland flow, for reuse by the golf course. Stormwater also currently flows into the Wakehurst Golf Course dam along a short (about 25 metre) drainage line. The expected additional discharge volumes from Wakehurst Parkway east construction support site (BL13) (14 kilolitres per day) would not be expected to cause overtopping of the dam.

Given the discharges from wastewater treatment plants equate to only minimal, temporary changes to flow volumes during construction (refer to Appendix O (Technical working paper: Surface water quality and hydrology)), substantial impacts to freshwater ecology would be unlikely. It is possible that any increases in flows to waterways/reaches of waterways currently with low flow (eg Willoughby Creek, Burnt Bridge Creek and Flat Rock Creek) may be temporarily beneficial to freshwater ecology (ie during construction) if these are associated with greater creek connectivity in what are naturally ephemeral watercourses and greater mixing of the water column. The continual increased flows would also likely remove terrestrial mats of weeds currently covering many parts of the stream beds.

If the water level at Wakehurst Golf Course dam increases due to the increased inflow, there is some potential for emergent freshwater macrophytes to be affected. However, these plants are likely to be resilient to minor changes in water level. Even if some of these commonly occurring macrophytes were to die, they are likely to re-establish soon after flows associated with construction have ceased and water levels in the dam return to normal.

4.3 Direct operational impacts

The culvert extension at Burnt Bridge Creek Deviation would maintain habitat conditions if connectivity and optimising fish passage is carried out in accordance with the Policy as discussed in Section 5.

4.4 Indirect operational impacts

Increases in impervious surfaces and traffic and ineffective treatment of tunnel wastewater during project operation has potential to expose waterways to nutrients and contaminant-laden runoff, including litter, with subsequent impacts to biota (see above). However, the project design would consider the management of stormwater quality through water quality basins as discussed in Section 1.4 and through the environmental management measures discussed in Appendix O (Technical working paper: Surface water quality and hydrology). This would include designing the operational wastewater treatment plant at the Gore Hill Freeway so that the effluent would be of suitable quality for discharge to the ultimate receiving environment, Flat Rock Creek (see Appendix O (Technical working paper: Surface water quality and hydrology)).

Discharge volumes from the operational wastewater treatment plant at the Gore Hill Freeway would be ultimately received by Flat Rock Creek via the local stormwater system at a flow rate of about 16 litres per second. This rate is lower than the creek flow rate under a two-year ARI flood event (0.02 kilolitres per second). It is therefore considered that the Flat Rock Creek bed and banks would be resilient to the expected wastewater treatment plant flow rates without impacting the creek form and geomorphic processes (refer to Appendix O (Technical working paper: Surface water quality and hydrology)). The impact of the discharge flows to freshwater ecology aligns with that discussed in Section 4.2.2, noting that there would likely be positive long-term impacts in terms of greater creek connectivity in what are naturally ephemeral watercourses, greater mixing of the water column and removal of terrestrial mats of weeds currently covering many parts of the stream beds.

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 the potential for sediment transport and sedimentation to occur at downstream waters, particularly after storm events. Environmental management measures are proposed for minimising this potential risk during construction and while revegetated areas are re-establishing (see Section 5).

In the Wakehurst Parkway stormwater catchments, which include several unnamed and unmapped ephemeral freshwater streams that flow in either an east–west direction into Manly Reservoir or in a west–east direction into Bantry Bay, the proposed stormwater and drainage works would provide an overall beneficial water quality outcome (refer to Appendix O (Technical working paper: Surface water quality and hydrology)). In some catchments around the Wakehurst Parkway there would be a reduction in total suspended solid levels and equivalence or reductions in phosphorous levels. In catchments where the annual nitrogen and phosphorous loading would exhibit a minor increase, the impact to freshwater ecology is considered minor. This includes the population of climbing galaxias (*Galaxias brevipinnis)* in Manly Creek and Manly Dam given the elevated concentrations of nitrogen already recorded in both Manly Creek and Manly Dam (refer to Appendix O (Technical working paper: Surface water quality and hydrology)).

As described in Appendix N (Technical working paper: Groundwater), surface environmental water availability and flows have the potential to be reduced due to groundwater drawdown during operation of the project as detailed below:

- The maximum predicted drawdown at Willoughby Creek, Cammeray during the operational phase is predicted to be up to six metres. Despite this, baseflow reductions are likely to be negligible
- Maximum water table drawdown beneath Burnt Bridge Creek, North Balgowlah is predicted to be up to six metres. The predicted reduction in baseflow to Burnt Bridge Creek shows little changes, estimated at 16.7 kilolitres per day (a 79 per cent reduction) at the beginning of operation to 16.8 kilolitres per day (a 96 per cent reduction) after about 100 years of operation. Baseflow impacts at Burnt Bridge Creek during the operational phase have the potential to be considerable
- Treated wastewater from the Gore Hill Freeway operational wastewater treatment plant would be discharged into Flat Rock Creek via the local stormwater system at a rate of 16 litres per second
- The drawdown beneath Quarry Creek during the operational phase is predicted to be up to 18 metres and would occur in the upper reaches. The maximum predicted drawdown at Flat Rock Creek during the operational phase is predicted to be up to 29 metres. The conservative baseflow impacts at Flat Rock Creek and Quarry Creek during the operational phase have the potential to be significant (39 per cent and 69 per cent reduction respectively after 100 years of operation), noting operational wastewater treatment plant discharges to Flat Rock Creek may offset this impact
- An estimated drawdown of less than one metre is expected at Manly Dam resulting in a maximum baseflow reduction of two per cent
- Manly Creek and Trefoil Creek would be unaffected by changes to baseflow.

As a result of the above predictions, operational impacts of groundwater drawdown would be expected to have significant long-term effects to the baseflows of Burnt Bridge Creek and Quarry Creek. Given baseflow in these creeks would not be reduced completely it would not cause the complete loss of any aquatic habitat. Pools would be retained because the bases of the two creeks consist of scoured bedrock or thin layers of silt on bedrock (see Section 3.1) and there would still be high flows in the whole of the waterways immediately after rainfall events. Between rainfall events there would still be some (low) flow along the entirety of the waterways. Outside of the pool areas, substantially reduced flows between rainfall events would be expected to alter assemblages of freshwater biota in these creeks to generally include only those species that are most tolerant to low flows. For long-term impacts of groundwater drawdown to GDEs in Quarry Creek along the watercourses refer to the updated biodiversity assessment.

4.5 Key threatening processes

4.5.1 Degradation of native riparian vegetation along New South Wales water courses (FM Act)

The project would involve the removal of a small area of native riparian vegetation adjacent to Burnt Bridge Creek. An exclusion zone is proposed to be established around riparian vegetation adjoining Burnt Bridge Creek adjacent to the surface road works at Balgowlah where reasonable and feasible to minimise disturbance. Rehabilitation and revegetation of disturbed riparian vegetation would occur progressively during construction and the spread and introduction of exotic plant species would also be managed (refer to the updated biodiversity assessment). Hence, this KTP is unlikely to be triggered or exacerbated as riparian vegetation would not be permanently 'degraded' and rehabilitation of the impact area would likely improve current conditions.

4.5.2 Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants (EPBC Act)

This KTP relates to the risk of the spread or establishment of exotic species in native vegetation. This KTP is unlikely to be triggered/further exacerbated by the project as environmental management measures would be implemented to avoid and minimise any introduction or further spread of exotic vegetation during construction (see Section 5).

4.5.3 Human-caused climate change (FM Act) and Loss of climatic habitat caused by anthropogenic emissions of greenhouse gasses (EPBC Act

The project construction and operation has potential to increase greenhouse gas emissions associated with this KTP. However, greenhouse gases emitted during project construction would be negligible in comparison to that emitted in the wider Sydney region. Although the project may induce increases in vehicles on the road network and may therefore contribute to general increases in vehicles used in the Sydney region, the greenhouse gases potentially emitted during operation would be negligible in comparison to that emitted in the wider Sydney region. Identified threat abatement actions for this KTP include:

- Community and stakeholder liaison, awareness and education
- Research/monitoring
- Habitat rehabilitation for threatened species impacted by climate change.

The project is unlikely to interfere with any of these actions.

4.5.4 Installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams (FM Act)

The project would require the installation or modification to instream structures including the installation of culverts and other drainage infrastructure. The two waterways within the study area that would be directly impacted by this include an existing aboveground watercourse within Flat Rock Reserve and Burnt Bridge Creek. These structures and modifications also have potential to alter natural flow regimes of these waterways. However, the design of these structures and modifications would be in accordance with *Why do fish need to cross the road?: Fish passage requirements for waterway crossings* (Fairfull & Witheridge, 2003) and with consultation with Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) to ensure natural flow regimes and fish passage is maintained (Section 1.4). Instream flows would also be maintained during construction.

Increased flows into watercourses during construction and operation from wastewater treatment plants are discussed in sections 4.2.2 and 4.4. Appendix O (Technical working paper: Surface water quality and hydrology) indicates that anticipated flows in the waterways from the additional discharges are minor compared to a two-year ARI event. As such, the project is unlikely to trigger or exacerbate this KTP.

4.5.5 Removal of large woody debris from New South Wales rivers and streams (FM Act)

The project has potential to remove large woody debris during instream works (Section 4.1.2). However, if found within the area associated with instream works these habitat structures would be salvaged and relocated downstream of the area of impact thus, not lost from the waterway (Section 5). Hence, the project is unlikely to trigger or exacerbate this KTP.

4.5.6 Novel biota and their impact on biodiversity (EPBC Act)

Threat abatement guidelines for this KTP outlines objectives for community and stakeholder liaison and awareness, legislative development and implementation and research and monitoring. The project would not conflict these guidelines and is unlikely to introduce and spread novel biota throughout the study area. Environmental management measures would be implemented to prevent novel biota from spreading further than their current distribution or introduce new species as a result of the project (refer to Section 5). Hence, the project is unlikely to trigger or further exacerbate this KTP.

5 Environmental management measures

The project has been designed to avoid and minimise potential impacts to freshwater ecology (Section 1.4) under the hierarchy of 'avoid, minimise, mitigate and offset'. Under the *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011) the management of biodiversity should aim to mitigate impacts where avoidance is not possible.

The primary potential impacts to freshwater ecology identified are associated with alterations to water quality, geomorphology and flow. Recommended environmental management measures to address any residual impacts to freshwater ecology upon the application of project controls outlined in Section 1.4 are provided in Table 5-1.

Table 5-1 Environmental management measures to protect freshwater ecology and geomorphology

Identifier	Potential impact pathway	Environmental management measure	Timing	Responsibility
FE1	Permanent loss of freshwater habitat	▪ Aquatic habitats should be protected in accordance with *Guide 10: Aquatic habitats and riparian zones of the Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011) and the *Policy and guidelines for fish habitat conservation and management* (NSW DPI, 2013). This should include flow and sufficient fish passage to be maintained similar to current conditions during instream works where reasonable and feasible.	Design Pre-construction Construction	Transport for NSW Construction contractor
FE2	Increased erosion and sedimentation input into watercourses	▪ Development and implementation of an Erosion and Sediment Control Plan (ESCP) ▪ Minimise the extent of disturbed areas exposed at any one time, where practicable ▪ Implement erosion and sedimentation controls while revegetated areas are establishing ▪ Routine and event-based monitoring of sedimentation levels as per the (ESCP).	Construction Post-construction	Construction contractor
FE3	Alterations to geomorphology and natural flow regimes	▪ Flow and sufficient fish passage similar to natural conditions should be maintained during any instream works ▪ As far as practicable, native freshwater fauna should be captured and relocated to a similar habitat along the same waterway by a suitably qualified ecologist prior to the commencement of instream works (eg during dewatering) (also seethe updated biodiversity assessment) ▪ Construction drainage and discharge outlet infrastructure should direct flows downstream to minimise alterations and erosion of the bed and banks. Energy dissipation and erosion scour protection should be implemented only if unexpected scouring occurs.	Construction	Construction contractor
FE3	Discharge of contaminant-laden runoff	▪ Wastewater treatment plants should 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 ▪ Management of contaminated soils and ASS should be carried out in accordance with relevant management plans ▪ The project proposes to adopt the (ANZECC and ARMCANZ, 2000) default trigger values for	Construction	Construction contractor

Identifier	Potential impact pathway	Environmental management measure	Timing	Responsibility
		physical and chemical stressors for estuarine and lowland river ecosystems and the ANZG (2018) 90 (for construction phase) or 95 per cent (for operational phase) species protection levels for toxicants when designing wastewater treatment plants. For toxicants known to bioaccumulate, the ANZG (2018) 95 (for construction phase) or 99 (for operational phase) per cent species protection level would be adopted. The draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water) would also be adopted during construction (refer to Appendix O (Technical working paper: Surface water quality and hydrology)).		
FE4	Accidental spills of contaminants such as hydrocarbons	▪ Development and implementation of an emergency spill plan ▪ Washdowns and refuelling to occur in bunded areas ▪ Spill kits readily available and staff made aware of location.	Construction	Construction contractor
FE5	Spread of exotic species	▪ Weed management controls should be implemented in accordance with *Biodiversity Guidelines: Protecting and managing biodiversity on RTA projects* (RTA, 2011) ▪ Any exotic fauna encountered during instream works should be humanely euthanised and removed from the waterway ▪ Instream habitat landscaping should favour habitat requirements of native species.	Construction	Construction contractor
FE6	Loss of riparian vegetation	▪ In order to reduce impacts on native vegetation, an exclusion zone is proposed to be established around riparian vegetation adjoining Burnt Bridge Creek adjacent to the surface road works at Balgowlah where reasonable and feasible.	Construction	Construction contractor
FE7	Impact to aquatic fauna from dewatering	▪ Any dewatering activities should be carried out in accordance with the *Technical Guideline: Environmental Management of Construction Site Dewatering* (RTA 2011), in a manner that prevents pollution of waters ▪ Dewatering of the stormwater harvesting dam at Balgowlah Golf Course should be carried out with consideration of native aquatic fauna and appropriate measures should be implemented to relocate native aquatic fauna as required.	Construction	Construction contractor

5.1 Offsets

If freshwater habitat is to be removed or irreparably damaged, the Policy outlines steps in determining the area of aquatic habitat that would be lost, including its quality (ie through GIS mapping in conjunction with categorisation of KFH ‘Type’ according to the Policy (NSW DPI, 2013)). It is important to note the ‘Types’ of KFH that would be lost, so that their value can be adequately compensated either through creating like-for-like habitat or through enhancing or protecting more sensitive, or threatened, KFH. These are detailed in Section 3.3.3 of the Policy.

The Policy requires a minimum 2:1 offset for the total area of the three ‘Types’ of KFH lost (see NSW DPI, 2013 for definitions) to help redress direct and indirect impacts of development. The Policy uses a rate of $52 per square metre, or $104 per square metre to meet the 2:1 offsetting requirement. The rate above is from the 2013–14 financial year and is consistent with aquatic ecosystem services rates calculated by

Costanza et al. (1997). However, the offset rate is subject to annual inflation from 1 July each financial year. Department of Planning, Industry and Environment (Regions, Industry, Agriculture and Resources) officers can confirm the current rate but for the purposes of this assessment the current rate has been estimated for 2020-21 to be $115 per square metre (using annual inflation rates based on the Consumer Price Index). Based on current design, about a 15 metre length of Burnt Bridge Creek would be directly affected by the culvert extension works and/or scour protection. Assuming an average bed width of about four metres in the affected area, this equates to a net loss of about 60 square metres of Type 2 – moderately sensitive KFH. According to the Policy this would equate to an offset requirement of about $6900. Final offset calculations should be carried out following further design development.

6 References

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ATTACHMENT

A

WATER QUALITY DATA

Attachment A

Table A1 Water quality at the unnamed tributary of Flat Rock Creek and the Wakehurst Golf Course dam

Parameter	Unnamed tributary of Flat Rock Creek	Wakehurst Golf Course dam
Temperature (°C)	18.73	21.38
Conductivity (mS/cm)	149	0.162
Salinity (ppt)	0.7	0.08
pH	7.58	7.75
ORP	621.4	6.38.4
Turbidity (NTU)	4.8	0.6
Dissolved oxygen (% saturation)	47.9	53.5
Dissolved oxygen (mg/L)	4.47	4.71

Annexure E – EPBC Significant impact assessments

Syzygium paniculatum (Magenta Lilly Pilly)

Syzygium paniculatum is listed as Vulnerable under the EPBC Act. The species has a limited distribution, being distributed along a 400 kilometre stretch of coastal NSW between Upper Lansdowne in the north to Conjola National Park in the south (OEH, 2012). The species naturally occurs in littoral rainforest or subtropical rainforest.

Eleven individuals of *Syzygium paniculatum* recorded at the Burnt Bridge Creek Deviation were located within landscaped/planted areas with a mulched understorey. Some specimens had stakes attached to them and appeared to have been planted in linear rows. The species is commonly grown and cultivated in the horticultural industry. These planted individuals are not of conservation significance and are not assessed further.

One individual of *Syzygium paniculatum* was recorded next to Wakehurst Parkway in PCT 1250. The species is not known to be associated with this vegetation type and it is considered unlikely to occur naturally at this location; there is only one other record of the species within two kilometres of this specimen (DPIE (EES), 2020a). As stated in the Recovery Plan for the species (OEH, 2012), any record of an isolated individual of *Syzygium paniculatum* in the Sydney Metropolitan Area should be considered with caution, given the popularity of the species in ornamental plantings. However, there is no evidence that this specimen has been planted, and it may be of wild provenance; therefore it is assumed to be remnant at this location.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of the species

The project would result in removal of one isolated individual of *Syzygium paniculatum* from roadside habitat.

All confirmed naturally occurring populations of *Syzygium paniculatum* are considered to be important (OEH, 2012). Although the species is considered unlikely to naturally occur at the location recorded next to the Wakehurst Parkway, this cannot be confirmed.

Reduce the area of occupancy of an important population

About 0.1 hectares of occupied habitat, containing one individual of *Syzygium paniculatum,* would be removed for the project. This reduction in area of occupancy is considered negligible.

Fragment an existing important population into two or more populations

The individual of *Syzygium paniculatum* recorded next to the Wakehurst Parkway in the subject land is currently isolated and fragmented from other areas of habitat for the species. The project would not result in further fragmentation.

Adversely affect habitat critical to the survival of a species

All habitat in which naturally occurring populations of *Syzygium paniculatum* are found is considered to be critical to the survival of the species.

The small area of occupancy of the population that would be cleared (0.1 hectares) is not considered likely to be critical to the habitat of the species. Other areas of suitable potential habitat in the subject lands do not link this population to other populations of the species.

Disrupt the breeding cycle of an important population

Syzygium paniculatum is able to produce fertile seed both sexually and asexually; where it reproduces asexually, offspring are clones of the maternal plant (OEH, 2012). The species has a generalised pollination strategy, and pollination is likely to be aided by a range of nectar and pollen-feeding vertebrates and invertebrates, including flying-foxes, possums, honeyeaters, lorikeets, introduced and native bees, beetles, moths and butterflies. Dispersal of seeds is achieved via water in riparian habitats, by gravity, and by animals which feed on the fruit (OEH, 2012).

The removal of one individual of *Syzygium paniculatum* as well as a small area of occupied habitat is not considered likely to disrupt the breeding cycle of a population.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

Syzygium paniculatum is associated with 29 PCTs, including PCT 1841 which occurs in the subject land. The isolated individual of *Syzygium paniculatum* recorded next to Wakehurst Parkway in the subject land was recorded in PCT 1250. The action would require removal of around 1.89 hectares of PCT 1841 and 0.6 hectares of PCT 1250, summing to a total loss of 2.49 hectares of potential habitat for the species. The species has not been identified as naturally occurring in other areas of potential habitat within the subject land during targeted seasonal surveys. The area of occupied habitat is much smaller (0.1 hectares). The removal of 2.49 hectares of potential habitat for the species is considered unlikely to result in further decline of the species.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

OEH (2012) identifies *Lantana camara* and *Chrysanthemoides monilifera* subsp. *rotundata* (Bitou Bush) as species that pose a direct threat to *Syzygium paniculatum. Lantana camara* was recorded near the isolated individual of the species adjoining Wakehurst Parkway.

The upgrade of Wakehurst Parkway would be susceptible to weed establishment due to earthworks carried out in widening the road. Management measures would be implemented to minimise the risk of introduction and spread of weeds.

Introduce disease that may cause the species to decline.

As a member of the Myrtaceae family *Syzygium paniculatum* is vulnerable to Myrtle Rust. The rust is now considered to be widespread along the eastern seaboard, and *Syzygium paniculatum* has been identified as a known host in the field for the pathogen.

If sufficient precautionary measures are in place the action is unlikely to result in the introduction of Myrtle Rust or any other disease that may cause the species to decline.

Interfere substantially with the recovery of the species.

The recovery plan for *Syzygium paniculatum* identifies a range of actions for recovery of the species. The project would not interfere with any of these recovery actions.

Conclusion

Under the EPBC Act an action requires approval from the Australian Government Minister for the Environment (DAWE) if the action has, will have, or is likely to have, a significant impact on a matter of national environmental significance such as *Syzygium paniculatum.*

Based on the above assessment, it is concluded that the action would not have a significant impact on *Syzygium paniculatum.* The removal of one individual of the species from a 0.1 hectare of occupied habitat, as well as an additional 2.49 hectares of suitable potential habitat that has been subject to targeted seasonal surveys for the species, does not comprises a significant proportion of the local population of the species or of its habitat in the surrounding locality. The project is unlikely to introduce diseases or invasive species that would impact this species. As such the action does not require referral to DAWE.

Grey-headed Flying-fox (*Pteropus poliocephalus*)

The Grey-headed Flying-fox is listed as Vulnerable species under the EPBC Act. This species was recorded by WSP flying over a number of locations within the subject land, during surveys carried out in 2017.

In addition, a Grey-headed Flying-Fox camp (Balgowlah Camp) was identified at in the vegetated area between Balgowlah Road and the Burnt Bridge Creek Deviation, about 120 metres from the subject land. The camp occupies about 0.59 hectares comprised of occupied and partially occupied roosting habitat (Ecosure, 2016). This camp is not identified as a nationally important Grey-headed Flying-fox camp (Flying-fox Camp I.D. 529) by *National Flying-fox monitoring viewer* (DAWE, 2020c) and it has supported up to 10,000 Flying-foxes in recent years. Another camp (Flying-fox Camp I.D. 487) is located within Centennial Park, about eight kilometres south-east of the subject land and is a nationally important Grey-headed Flying-fox camp. It has supported up to 50,000 Flying-foxes in recent years.

The *Referral guideline for management actions in grey-headed and spectacled flying-fox camps* (DoE, 2015) does not apply developments that are in the vicinity of camps which may have indirect impacts and therefore has not been used in this Significant Impact Assessment as the proposal would not directly impact the Balgowlah Camp.

The Grey-headed Flying-fox is generally found within 200 kilometres of the eastern coast of Australia, from Rockhampton to Adelaide. The species may be found in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps, while additional foraging is provided by urban gardens and cultivated fruit crops. The Grey-headed Flying-fox is a highly mobile species with a nightly feeding range of 20 to 50 kilometres from a roosting camp. Diet typically comprises of a wide variety of flowering and fruiting plants (Tidemann, 1995; Churchill, 1998) with non-indigenous and exotic tree species introduced to the urban landscape providing additional foraging habitat for this species. Grey-headed Flying-foxes roost in large numbers, with up to tens of thousands of Flying-foxes using individual camps for mating, birth and rearing of young.

It is likely that the individuals recorded flying over the subject land were from these camps (although a number of other camps are located within the species' foraging range) and were observed flying overhead during their nightly foraging activities. The subject land provides foraging habitat for the Grey-headed Flying-fox, given the presence of preferred blossom and fruit tree species that occur within parks, road verges and private land (eg residential gardens). A number of PCTs within the subject land (refer to Section 3.6.2.4.6) support tree species that offer a foraging resource for the species, as listed by *Ranking the feeding habitats of Grey-headed Flying-foxes for conservation management* (Eby and Law, 2008). These tree species are listed in Table 1.

Table 1 Grey-headed Flying-fox feed trees recorded at sites within the subject land

Tree species recorded that are in the blossom diet of Grey-headed Flying-foxes	Tree species recorded that are in the fruit diet of Grey-headed Flying-foxes
Angophora costata *Corymbia gummifera* *Corymbia maculata* *Syncarpia glomulifera* *Eucalyptus saligna* *Eucalyptus resinifera* *Eucalyptus robusta* *Eucalyptus pilularis* *Syncarpia glomulifera* *Eucalyptus piperita* *Eucalyptus paniculata* *Eucalyptus punctata*	*Elaeocarpus reticularis* *Pittosporum undulatum*

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

Important populations are those that may be identified as such in recovery plans, and/or that are:

- Key source populations either for breeding or dispersal
- Populations that are necessary for maintaining genetic diversity
- Populations that are near the limit of the species range.

The Grey-headed Flying-fox has no separate or distinct populations (DAWE, 2020b). The species constantly exchanges genetic information between camps throughout its geographic range.

The Balgowlah camp may support a population that is a key source of breeding or dispersal or important for maintaining genetic diversity and is considered an 'important population' for the purposes of this assessment.

The Grey-headed Flying-Fox camp (Balgowlah camp), located about 120 metres from the subject land, would not be directly impacted by the project. No vegetation occurring within the camp would be removed. The camp would be subjected to indirect impacts during construction (specifically, construction noise impacts), as it is located near Kitchener Street construction support site (BL11) and upgrade and integration works at Balgowlah.

The assessment of airborne noise impacts at Balgowlah (refer to section 5.2.3) determined that typical noise levels of key noise-generating construction activities during the day would be similar to, or less than, noise levels generated by existing day time road traffic noise on the Burnt Bridge Creek Deviation. That is, typical noise levels of key noise-generating construction activities listed in Table 5-5 are less than, or similar to, the ambient day time noise levels of 54 dB(A) (on a representative weekday) and 52 dB(A) (on a representative weekend) that were recorded near the camp.

Grey-headed Flying-foxes occupying the Balgowlah camp appear to be accustomed to background traffic noise and have persisted at the camp despite regular maintenance of the local council's gross pollutant trap (GPT) directly near core roosting habitat (Ecosure, 2016). Accordingly, typical noise levels of key noise-generating construction activities during the day are not anticipated to adversely impact the Grey-headed Flying-fox camp.

Some noise-generating construction activities would result in worst case noise levels that would exceed existing day time road traffic noise levels on Burnt Bridge Creek Deviation, as identified in Table 5-5. These activities include demolition works within Burnt Bridge Creek Deviation surface works and construction support site activities.

However, reasonable and feasible noise mitigation measures would be implemented when construction activities are occurring near the Grey-headed Flying-fox camp. Given the mobile nature of this species, Grey-headed Flying-foxes could temporarily disperse to other camps in the surrounding locality if sufficiently disturbed by construction noise at Balgowlah, as the species is known to occupy a network of camps across eastern Australia. This highly mobile has complex and irregular migration patterns, which are primarily determined by eruptive pulses of nectar flow produced in a range of forest and woodland communities (Eby *et al*., 1999). Accordingly, the size of camp populations and their patterns of occupation vary considerably between seasons and between years (DAWE, 2020b). Another camp (Flying-fox Camp I.D. 487) is located within Centennial Park, about eight kilometres south-east of the subject land, and this camp has supported up to 50,000 Flying-foxes in recent years. There are also two camps located in Avalon, north of the subject land. If the species does disperse to alternative camps, Grey-headed Flying-foxes could re-occupy the Balgowlah camp during times of low construction noise, and/or upon the completion of construction the project.

In summary, given that the species is highly mobile, is known to travel up to 50 kilometres from a camp during nightly foraging activities (DAWE, 2020B), and is known to migrate throughout the surrounding region in response to the availability of foraging resources, construction noise is unlikely to lead to a long-term decrease in the size of an important population. The species could disperse to other camps in the surrounding locality if sufficiently disturbed by construction noise and could re-occupy the Balgowlah camp during times of low construction noise, and/or upon the completion of construction the project. Noise related to the operation of the project (ie background traffic noise) would be of a similar nature and level to existing background noise levels.

Indirect impacts of light spill, during night works, would likely be negligible as individual Grey-headed Flying-foxes leave the camp to forage throughout the surrounding locality. The use of directional lighting, to avoid light-spill on the camp, would further reduce this potential impact. Therefore the project would not lead to a long-term decrease in the size of an important population

Reduce the area of occupancy of an important population

The project would result in the removal of up to 13.98 hectares of PCTs and 6.54 hectares of other vegetation that contains varying abundance of preferred feed trees. The removal of 20.52 hectares of vegetation, that contains varying abundance of the blossom and fruit trees that form part of the Grey-headed Flying-fox (as listed in Table 1), does not comprise a significant proportion of foraging habitat available to the species in the surrounding locality. Preferred feed trees occur commonly in large tracts of native vegetation contained within Garigal National Park, Manly Warringah War Memorial State Park, Ku-ring-gai Chase National Park, Lane Cove National Park, smaller bushland reserves, golf courses, residential gardens and street trees.

The removal of this 20.52 hectares of potential foraging habitat would have a minimal impact on the area of occupancy of the species.

Fragment an existing important population into two or more populations

The removal of 20.52 hectares of potential foraging habitat from the subject land would not fragment the population of the Grey-headed Flying-fox into two or more populations.

Adversely affect habitat critical to the survival of a species

While the project would result in the removal of 20.52 hectares of potential foraging habitat, this habitat is not likely to be habitat critical to the survival of this species. Alternative foraging habitat is readily available in in large tracts of native vegetation contained within Garigal National Park, Manly Warringah War Memorial State Park, Ku-ring-gai Chase National Park, Lane Cove National Park, smaller bushland reserves, golf courses, residential gardens and street trees.

Disrupt the breeding cycle of an important population

Disruptions to the breeding cycle of Grey-headed Flying-foxes at the Balgowlah camp may occur when noise-generating construction activities occur in close proximity to the camp, during the following seasonal activities (Ecosure, 2016) (Table 2).

Table 2 Seasonal activities and relevance to project

Season	Grey-headed Flying-fox breeding-related activity
Summer	Juvenile Grey-headed Flying-foxes are becoming independent but are still prone to stress and falling to the ground which may result in death directly, or through starvation/predation
Autumn	Mating and conception
Winter	Stressed adult females could abort young
Spring	Birth and lactation. Stressed adult females could abort or abandon young. When not attached to mother, stressed young are at risk of falling to ground which may result in death October directly, or through starvation/predation

Stress mainly relates to heat-stress, and the project would not affect ambient temperatures. However, if Grey-headed Flying-foxes are already under stress from other factors (noise, low food resources, disease or a combination of these things), they may be more prone to heat stress events.

As described previously, the species could disperse to other camps in the surrounding locality if sufficiently disturbed by construction noise, although this would be unlikely, given that predicted construction noise impacts should be similar to existing noise levels, and measures are proposed to reduce worst case construction noises levels to noise levels that are close to existing ambient levels. The species could re-occupy the Balgowlah camp during times of low construction noise, and/or upon the completion of construction the project. Noise related to the operation of the project (ie background traffic noise) would be of a similar nature and level to existing background noise levels.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The removal of 20.52 hectares of vegetation, that contains varying abundance of the blossom and fruit trees that form part of the Grey-headed Flying-fox diet (as listed in Table 1), does not comprises a significant proportion of foraging habitat available to the species in the surrounding locality. The loss of 20.52 hectares of vegetation with varying abundance of foraging resources is not likely to be significant to the species such that it is likely to decline. Preferred feed trees occur commonly in large tracts of native vegetation contained within Garigal National Park, Manly Warringah War Memorial State Park, Ku-ring-gai Chase National Park, Lane Cove National Park, smaller bushland reserves, golf courses, residential gardens and street trees.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The action is unlikely to result in the establishment of an invasive species that is harmful to the Grey-headed Flying-fox. Known predators of the species include native reptiles and birds; no invasive exotic fauna species are known to predate upon Grey-headed Flying-foxes. The action is highly unlikely to result in the establishment of invasive flora species that are harmful to the Grey-headed Flying-fox.

Introduce disease that may cause the species to decline, or

The action is highly unlikely to introduce disease that may cause the Grey-headed Flying-fox to decline.

Interfere with the recovery of the species

There is currently no approved Recovery Plan in place for the Grey-headed Flying-fox. A Draft National Recovery Plan for the Grey-headed Flying-fox was prepared in July 2009 (DECCW, 2009). The Draft National Recovery Plan lists 13 specific objectives for the five-year timeframe of the Plan. Of these, two could be considered relevant to the project:

- Objective 1: To identify and protect foraging habitat critical to the survival of Grey-headed Flying-foxes throughout their range. While the project would result in the removal 20.52 hectares of vegetation, that contains varying abundance of the blossom and fruit trees that form part of the Grey-headed Flying-fox diet, this habitat is not likely to habitat critical to the survival of this species. Preferred feed trees occur commonly in large tracts of native vegetation contained within Garigal National Park, Manly Warringah War Memorial State Park, Ku-ring-gai Chase National Park, Lane Cove National Park, smaller bushland reserves, golf courses, residential gardens and street trees.
- Objective 2: Identify, protect and enhance roosting habitat of Grey-headed Flying-fox camps. The project would not directly impact the camp located at Burnt Bridge Creek in Balgowlah, and the species could disperse to other camps in the surrounding locality if sufficiently disturbed by construction noise. Grey-headed Flying-foxes could re-occupy the Balgowlah camp during times of low construction noise, and/or upon the completion of construction the project.

Conclusion

Under the EPBC Act an action requires approval from the Australian Government Minister for the Environment (DAWE) if the action has, will have, or is likely to have, a significant impact on a matter of national environmental significance such as the Grey-headed Flying-fox.

Based on the above assessment, it is concluded that the action would not have a significant impact on the Grey-headed Flying-fox. The removal of 20.52 hectares of vegetation, that contains varying abundance of the blossom and fruit trees that form part of the Grey-headed Flying-fox, does not comprises a significant proportion of foraging habitat available to the species in the surrounding locality. The project would not directly impact the camp located at Burnt Bridge Creek in Balgowlah, and the species could temporarily disperse to other camps in the surrounding locality if sufficiently disturbed by construction noise. Grey-headed Flying-foxes could re-occupy the Balgowlah camp during times of low construction noise, and/or upon the completion of construction the project. The project is unlikely to introduce diseases or invasive species that would impact this species. As such the action does not require referral to DAWE.

Large-eared Pied Bat (*Chalinolobus dwyeri*)

The Large-eared Pied-bat is listed as Vulnerable under the EPBC Act. They are found mainly in areas with extensive cliffs and caves, from Rockhampton in Queensland south to Bungonia in the NSW Southern Highlands. It is generally rare with a very patchy distribution in NSW. It roosts in caves (near their entrances), crevices in cliffs, old mine workings and in the disused, bottle-shaped mud nests of the Fairy Martin (*Petrochelidon ariel*), frequenting low to mid-elevation dry open forest and woodland close to these features (DPIE (EES), 2020d). Females have been recorded raising young in maternity roosts (c. 20-40 females) from November through to January in roof domes in sandstone caves and overhangs (DPIE (EES), 2020d), rock escarpments and collapsed cliff lines within small honeycombed holes in sandstone, the hollowed-out rooves of boulders and long slits in flaking sheets of sandstone (Lothian 2019). They show roost fidelity to the same cave over many years. They are found in well-timbered areas containing gullies (DPIE (EES), 2020d).

The Threatened Biodiversity Data Collection (DPIE (EES), 2020c) identified habitat for the species as all PCTs associated with Large-eared Pied Bat that are within two kilometres of rocky areas containing caves, overhangs, escarpments, outcrops, or crevices, or within two kilometres of old mines or tunnels. Rocky features are visible on aerial photography within two kilometres of the subject land at the Wakehurst Parkway and Burnt Bridge Creek Deviation. This amounted to rocky outcrops within seven PCTs listed in Table 7.3.

During desktop searches for potentially occurring threatened species for this project, the Large-eared Pied-bat was identified from the Threatened Biodiversity Data Collection and Species Profile and Threats Database (SPRAT) searches as a subject species. There are recent Bionet records of the species foraging in the Wakehurst Parkway east construction support site (BL13) and around 800 metres east of the Wakehurst Parkway in 2018 (DPIE (EES), 2020a).

Targeted surveys for breeding habitat and signs of breeding individuals were carried out in accordance with the '*Species credit' threatened bats and their habitats – NSW survey guide for the Biodiversity Assessment Method* (OEH, 2018a) as outlined in Section 2.6.2.2.

No Large-eared Pied-bat were caught during harp trapping surveys to confirm breeding, in fact no microbats were trapped (see Section 2.10 on limitations). However, the Large-eared Pied-bat was acoustically recorded 125 metres southeast of the Wakehurst Parkway east construction support site (BL13), outside the subject land. One call was positively identified during Anabat surveys on a single night (one pass definitively recorded and numerous passes were possible for this species over the three nights of recording). These calls were recorded at a dam with both grassland and woodland surrounding it and included feeding buzzes, so most likely reflected one or more individuals foraging.

It is likely that the species utilises the subject land for foraging, however unlikely that it is breeding or roosting in rocky habitat in proximity to the subject land, due to the absence of bats during roost inspections and of breeding individuals in the harp traps. Potential breeding habitat is likely to be present in proximity to the subject land as day roosts for the species have been documented to be located within 700 metres of foraging habitat (Williams and Thomson 2019). Based on the above information on this species within the subject land and surrounds, potential impacts to Large-eared Pied-bat from the project can be divided into direct and indirect categories. Direct impacts include:

- Clearing of foraging habitat
- Injury or mortality during clearing and operations.

Indirect impacts include:

- Noise and vibration
- Light
- Dust.

The following works would occur in proximity to potential foraging, roosting and breeding habitat for the species to trigger indirect impacts:

- Excavation of the tunnel construction access declines or shafts
- Construction of driven tunnels
- Construction of cut and cover and trough structures
- Civil finishing and fitout of the tunnel and pavement works on Wakehurst parkway to tie-in tunnel ramps
- Construction of operational facilities
- Testing and commissioning
- Establishment, operation and removal of the Wakehurst Parkway east (BL13) and Wakehurst Parkway south (BL12) construction support sites.

They are discussed in more detail while addressing each of the specific question relating to impact to this species.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Lead to a long-term decrease in the size of an important population of a species

Important populations are those that may be identified as such in recovery plans, and/or that are:

- Key source populations either for breeding or dispersal
- Populations that are necessary for maintaining genetic diversity and/or
- Populations that are near the limit of the species range.

The *National Recovery Plan for the Large-eared Pied Bat Chalinolobus dwyeri* (Department of Environment and Resource Management, 2011) identifies important populations as populations in areas dominated by sandstone escarpments, including those in the Sydney Basin. The subject land is within an area dominated by sandstone escarpments with a positive identification of the species within 125 metres of the subject land. Therefore, the population of Large-eared Pied-bat within the area constitutes an important population.

The subject land contains potential foraging habitat but does not contain breeding or roosting habitat. Potential breeding habitat was identified within 100 metres of the subject land at the Wakehurst Parkway (southern end) during targeted surveys. However, it is considered unlikely breeding and/or roosting is occurring within 100 metres, though highly likely within 700 metres of the subject land (see Section 5.3.2).

The project would remove around 13.51 hectares of potential foraging habitat for the species adjacent to the Wakehurst Parkway and Burnt Bridge Creek Deviation. This area is already partially edge-affected and is a relatively small part of the extensive bushland that is connected to Garigal National Park and Manly Warringah War Memorial State Park that lie either side of the Wakehurst Parkway. Indirect impacts, especially noise from blasting and rock hammering activities may have temporary impacts on habitat outside of the subject land, within 100 metres and beyond that are unlikely to cause a long term decrease in the size of an important population. Activity-specific controls to reduce impacts of noise on foraging or breeding Large-eared Pied-bat will be developed by a suitably qualified and experienced microbat specialist.

Reduce the area of occupancy of an important population

The project would remove around 13.51 hectares of potential foraging habitat for the species adjacent to the Wakehurst Parkway and Burnt Bridge Creek Deviation. This habitat contains limited preferred habitat (wetlands and ecotones between grasslands and woodland habitat) and is impacted by adjacent roads and, in the case of the Burnt Bridge Creek Deviation, residential development and the Balgowlah Golf Course. This habitat is unlikely to be preferential for the species, particularly in the Wakehurst Parkway where there are large tracts of intact vegetation in adjacent national parks and reserves, and mosaic and wetland habitat is surrounding areas, including the site where Large-eared Pied-bat was recorded as part of surveys for this project. The removal of this potential foraging habitat is therefore unlikely to reduce the area of occupancy of an important population. Potential indirect impacts to nearby potential foraging, breeding and roosting habitat from construction activities are short term and would impact nearby habitat occupancy temporarily.

Fragment an existing important population into two or more populations

The removal of potential foraging habitat along the edge of two roads and indirect construction noise and vibration in this area is unlikely to fragment the existing population of the Large-eared Pied Bat occurring adjacent to the subject land into two or more populations.

Adversely affect habitat critical to the survival of a species

Diurnal roosts for shelter and breeding habitat are identified in the National Recovery Plan as critical to the survival of the species (Department of Environment and Resource Management, 2011). Diurnal roosts include disused mine shafts, caves, overhangs and abandoned Fairy Martin nests. Rocky features of the subject land were inspected during field surveys (WSP, 2018) and no evidence of microbat use was found, nor were any deemed suitable for breeding and/or roosting. Suitable breeding habitat was identified within 100 metres of the subject land at Wakehurst Parkway (southern end) during targeted surveys (Figure 3-9). However, no microbats, or signs of their habitation, were observed during diurnal roost searches. Therefore this area is considered unlikely to contain breeding or roosting individuals, but given that the species has been recorded foraging with the vicinity of the subject land, breeding and roosting may occur in close proximity to the subject land and exposed to construction noise and vibration impacts, particularly from blasting and rock hammering in breeding and roosting habitat. Given noise and vibration intensive works would be short term and roosting and breeding is unlikely to occur within 100 metres of the subject land, impacts to shelter and breeding habitat are likely to be low.

Disrupt the breeding cycle of an important population

The subject land does not support breeding habitat. It is possible, though unlikely, breeding roosts are present within 100 metres of the subject land, and likely the species is breeding within 700 metres of the subject land. Noise and vibration intensive activities could impact breeding individuals however, impacts would be short term.

Modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline

The project would require the removal of 13.51 hectares of potential foraging habitat for the Large-eared Pied Bat. This habitat contains limited preferred resources (ie wetlands and ecotones) and is subject to significant disturbance from existing roads and, in the case of the Burnt Bridge Creek Deviation, residential development and the Balgowlah Golf Course. This habitat is unlikely to be preferred by the species, particularly in proximity to the Wakehurst Parkway where there are large tracts of intact vegetation in adjacent national parks and reserves. The loss of a small amount of potential foraging habitat is not likely to be significant to the species such that it is likely to lead to population decline.

Result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat

The action is unlikely to result in the establishment of an invasive species that is harmful to the Large-eared Pied Bat. Weeds and pest animal species already occur in this area, and the project will include weed and pest management measures to reduce the risk of further occurrence of such species.

Introduce disease that may cause the species to decline, or

The action is highly unlikely to introduce disease that may cause the Large-eared Pied Bat to decline.

Interfere with the recovery of the species

The National Recovery Plan for the Large-eared Pied Bat lists five specific objectives (Department of Environment and Resource Management, 2011). The project would not interfere with these recovery objectives.

Conclusion

Under the EPBC Act an action requires approval from the Australian Government Minister for the Environment if the action has, will have, or is likely to have, a significant impact on a matter of national environmental significance such as the Large-eared Pied Bat.

Based on the above assessment, it is concluded that the action is unlikely to have a significant impact on the Large-eared Pied Bat. The removal of 13.51 hectares of potential foraging habitat does not comprise a significant proportion of foraging habitat available to the species in the surrounding locality. Indirect impacts to adjacent breeding habitat would be temporary in nature and unlikely to lead to population decline. The project is unlikely to introduce diseases or invasive species that would impact this species. As such the action does not require referral to DAWE.

White-bellied Sea-Eagle (*Haliaeetus leucogaster*)

White-bellied Sea-Eagle is listed as a Migratory species under the EPBC Act.

This species was observed flying above Sydney Harbour from Balls Head Reserve. It has been previously recorded in the subject land, foraging the waters of Sydney Harbour near Balls Head (DPIE (EES), 2020a).

The White-bellied Sea-Eagle is a large eagle that is distributed along the east coast of NSW (around bays and inlets, beaches, reefs, lagoons, estuaries and mangroves), and along all major inland rivers, swamps, freshwater lakes and reservoirs. This species hunts above large areas of open water for fish, freshwater turtles, waterbirds, reptiles, mammals and carrion. White-bellied Sea-Eagles typically construct a large stick nest in a large emergent eucalypt, within mature tall open forest, open forest, tall woodland, and swamp sclerophyll forest close to foraging habitat. However, nests may be built in a variety of sites including bushes, mangroves, cliffs, rocky outcrops, caves, crevices, on the ground or on artificial structures (DAWE, 2020b). White-bellied Sea-Eagles may be solitary, or live in pairs or small family groups consisting of a pair of adults and dependent young. Resident pairs are territorial and occupy nesting territories of hundreds of hectares.

The subject land is not known to support a White-bellied Sea-Eagle nest. The closest known nesting site is located in Newington Nature Reserve, next to the Parramatta River and about 12 kilometres north-west of the subject land. A pair of White-bellied Sea-Eagles currently occupies this nest, and these birds are often observed feeding on a mullet or other fish from nearby wetlands (Birdlife, 2018).

The subject land offers foraging habitat to the species, due to the presence of preferred prey species that inhabit Sydney Harbour. The wider assessment area, outside of the subject land, offers potential perching habitat, due to the presence of trees that occurs along the harbour foreshore at Balls Head, Birchgrove and Waverton.

An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will:

Substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species.

An area of 'important habitat' for a migratory species is:

- habitat used by a migratory species occasionally or periodically within a region that supports an ecologically significant proportion of the population of the species, and/or
- habitat that is of critical importance to the species at particular life-cycle stages, and/or
- habitat used by a migratory species which is at the limit of the species range, and/or
- habitat within an area where the species is declining.

The small area of potential foraging habitat occurring within the subject land does not comprise important habitat for the White-bellied Sea-Eagle. The subject land does not support an ecologically significant proportion of the population of the species. The subject land does not support nesting habitat for the species (the nearest nest site is located at Newington Nature Reserve), and as such, foraging habitat within the subject land is not of critical importance to the species at particular life-cycle stages. The White-bellied Sea-Eagle is distributed along the coastline (including offshore islands) of mainland Australia and Tasmania. It also extends inland along some of the larger waterways, especially in eastern Australia; the subject land is not located at the limit of the species range. While there have been no published estimates of the area of occupancy, and no specific information is available on changes in the area of occupancy (DAWE, 2020b), the persistence of the species at the Newington Nature Reserve nest site, and successful fledging of White-bellied Sea-Eagle chicks from this same nest site in recent years, suggest that the species is not declining in the subject land, wider assessment area and Sydney Harbour.

Result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species.

The project is not expected to introduce, or facilitate the introduction, of an invasive species that is harmful to White-bellied Sea-Eagles.

Seriously disrupt the lifecycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species.

Works within Middle Harbour (ie installation of the cofferdams and dredging) would cause an increase in turbidity and sedimentation of marine waters, in turn causing localised degradation of potential foraging habitat for the White-bellied Sea-Eagle. An increase in suspended sediment near construction activities may adversely impact the occurrence and behaviour of fish and other prey species. However, the selected methodology for the project has considered dredging methods and controls to limit the potential for turbidity impacts and mobilisation of sediment, in order to minimise the impact on the surrounding marine environment. This includes, but is not limited to, the installation of floating silt curtains and other management measures. Accordingly, any potential increase in turbidity and sedimentation of marine waters near construction activities would be minimal, localised and temporary. While in operation, the cofferdams would temporarily remove a small proportion of potential foraging habitat for White-bellied Sea-Eagles, as the cofferdam structures would be dewatered following installation. However, these areas comprise a very small proportion of the foraging habitat available to the White-bellied Sea-Eagles in Middle Harbour. Following construction of the interface structures, the cofferdams would be removed and the marine environment would be rehabilitated. Accordingly, the loss of potential foraging habitat in marine waters at cofferdam locations would be minimal, localised and temporary.

Upon completion of construction and during operation, the project is not expected to adversely impact foraging habitat that occurs within the subject land. The project is not expected to seriously disrupt the lifecycle of the White-bellied Sea-Eagles that are known to range throughout Middle Harbour.

Coastal Upland Swamps in the Sydney Basin Bioregion

Coastal Upland Swamps in the Sydney Basin Region (hereafter referred to as Coastal Upland Swamps) is listed as Endangered under the EPBC Act. The community is located in the eastern part of the Sydney Basin Bioregion, primarily on the Woronora plateau in the south, and the Somersby-Hornsby plateaux in the north. It occurs primarily on poorly permeable sandstone plateaux in the low relief headwater valleys of streams and on sandstone benches with abundant seepage moisture, and is occasionally associated with weathered shale lenses and ironstone (DoE, 2014).

Coastal Upland Swamps includes a range of vegetation and fauna associated with periodically waterlogged soils on the Hawkesbury sandstone plateaux in the Sydney Basin. The swamps naturally occur in small patches, with nearly half of the mapped swamps that make up Coastal Upland Swamps less than one hectare in size (DoE, 2014).

Coastal Upland Swamps was not mapped or identified within the subject land. However, the TEC has been mapped near the subject land by OEH (2016), and review of aerial photography as well as ground truthing confirmed that the closest patch of Coastal Upland Swamps is in Garigal National Park about 95 metres west of the subject land. This area was ground-truthed in June 2021. Another small (0.07 hectare) area of Coastal Upland Swamp was identified north of Bantry Bay Oval, about 135 metres south-east of the subject land.

The project would not result in clearing of any areas of Coastal Upland Swamp, and most indirect impacts are also unlikely given that the mapped areas are not in proximity to any surface works. Coastal Upland Swamps may be sensitive to changes to groundwater flows, and two areas mapped as the community are located above areas of predicted water table drawdown.

An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will:

Reduce the extent of an ecological community

The project would not require clearing of any areas of Coastal Upland Swamps.

Fragment or increase fragmentation of an ecological community, for example by clearing vegetation for roads or transmission lines

The project would not require clearing or fragmentation of any areas of Coastal Upland Swamps.

Adversely affect habitat critical to the survival of an ecological community

Given the specific habitat requirements for Coastal Upland Swamps, the areas currently occupied and the associated sub-catchment are considered to be areas critical to the survival of the community (DoE, 2014).

The small (0.07 hectare) area of degraded Coastal Upland Swamp north of Bantry Bay Oval is not considered likely to be critical to the survival of the community, given the current level of modification to the landscape, hydrology, structure and floristics of this vegetation.

Modify or destroy abiotic (non-living) factors (such as water, nutrients, or soil) necessary for an ecological community's survival, including reduction of groundwater levels, or substantial alteration of surface water drainage patterns

Coastal Upland Swamp may be sensitive to changes to groundwater flows. Decreases to groundwater levels in swamp habitats are likely to reduce and/or change the location of baseflow discharges, affecting downstream ecosystems during periods of low rainfall (DoE, 2014).

Water table drawdown beneath two mapped patches of Coastal Upland Swamps 95 metres west of the Wakehurst Parkway in Garigal National Park is modelled to be between zero and one metre by 2028 and for the subsequent 100 modelled years. The groundwater dependence of this swamp is uncertain, as the water level is currently approximately 10 metres below ground level. The water table beneath this swamp may be affected by drawdown, but it is likely that the swamp receives water from surface runoff and subsurface drainage from upslope perched aquifers, and that the availability of this water to support the swamp would not be affected (see Attachment B of Annexure G of this report).

Water table drawdown beneath the small (0.07 hectare) area of Coastal Upland Swamp identified north of Bantry Bay Oval, about 135 metres south-east of the subject land, is modelled to be less than three metres. The regional water level is approximately 50 metres below ground level, so this swamp is likely to be connected to perched water tables, rather than the regional aquifer. Perched aquifers are predominantly fed by localised rainwater, or from downward drainage from upslope aquifers. It is therefore unlikely that this section of upland swamp would be affected by drawdown from the project (see Attachment B of Annexure G of this report).

The hydrology of this smaller patch has already been modified substantially, with a large dam constructed in the north of this area, a sports ground to the south which drains into the patch and surrounding disturbed bushland. Due to its small size, urbanised context and modified floristics, including numerous weedy exotic species, any potential impacts to this area of Coastal Upland Swamps are not considered likely to be significant.

Cause a substantial change in the species composition of an occurrence of an ecological community, including causing a decline or loss of functionally important species, for example through regular burning or flora or fauna harvesting

The project is not located in proximity to any areas of Coastal Upland Swamp, and these types of indirect impacts are not likely to occur as a result of the project.

Cause a substantial reduction in the quality or integrity of an occurrence of an ecological community, including, but not limited to:

- **assisting invasive species, that are harmful to the listed ecological community, to become established, or**
- **causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants into the ecological community which kill or inhibit the growth of species in the ecological community**

The project is not located in proximity to any areas of Coastal Upland Swamp, and these types of indirect impacts are not likely to occur as a result of the project.

Interfere with the recovery of an ecological community

There is currently no approved Recovery Plan in place for Coastal Upland Swamps. The Conservation Advice for Coastal Upland Swamps in the Sydney Basin Bioregion (DoE, 2014) lists a range of [priority recovery and threat abatement actions to stop the decline of, and support the recovery of, the community. The potential impacts from predicted water table drawdown resulting from the project are inconsistent with one of these actions:

- *Avoid disturbances to hydrology that may result in changes to the natural hydrological regime of the community.*

Conclusion

Under the EPBC Act an action requires approval from the Australian Government Minister for the Environment (DAWE) if the action has, will have, or is likely to have, a significant impact on a matter of national environmental significance such as Coastal Upland Swamps in the Sydney Basin Bioregion.

Based on the above assessment, it is concluded that the action would not have a significant impact on Coastal Upland Swamps in the Sydney Basin Bioregion. The project would not result in clearing of any areas of Coastal Upland Swamp, and most indirect impacts are also unlikely given that the mapped areas are not in proximity to any surface works. Two areas mapped as the community are located above areas of predicted water table drawdown and may be subject to adverse impacts from the lowering of the groundwater table beneath them. As discussed in Attachment B of Annexure G of this report, these areas of swamp are likely to be connected to perched water tables, rather than the regional aquifer, and it is therefore unlikely that Coastal Upland Swamp would be affected by water table drawdown as a result of the project. As such, the action does not require referral to DAWE.

Annexure F – Biodiversity credit reports

BAM Credit Summary Report

Proposal Details

Assessment Id	Proposal Name	BAM data last updated *
00022275/BAAS17030/20/00022276	Beaches Link and Gore Hill Freeway Connection - Direct Impacts	10/06/2021
Assessor Name	Report Created	BAM Data version *
Jane Rodd	15/11/2021	45
Assessor Number	BAM Case Status	Date Finalised
BAAS17030	Finalised	22/10/2021
Assessment Revision	Assessment Type	
1	Major Projects	

* Disclaimer: BAM data last updated may indicate either complete or partial update of the BAM calculator database. BAM calculator database may not be completely aligned with Bionet.

Ecosystem credits for plant communities types (PCT), ecological communities & threatened species habitat

Zone	Vegetation zone name	TEC name	Current Vegetation integrity score	Change in Vegetation integrity (loss / gain)	Area (ha)	BC Act Listing status	EPBC Act listing status	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Potential SAII	Ecosystem credits
Coastal enriched sandstone moist forest											
7	1841_Mod_Good	Not a TEC	65.3	65.3	1.4			High Sensitivity to Potential Gain	1.75		39
9	1841_Reveg	Not a TEC	37.7	37.7	1.3			High Sensitivity to Potential Gain	1.75		21

									Subtotal	**60**
Coastal sandstone gully forest										
1	1250_Mod_ Good	Not a TEC	82.5	82.5	0.2			High Sensitivity to Potential Gain	1.50		6
2	1250_Mod	Not a TEC	54	54.0	0.4			High Sensitivity to Potential Gain	1.50		8
									Subtotal	**14**
Coastal sandstone Heath-Mallee										
6	1824_Mod_ Good	Not a TEC	66.4	66.4	6.2			High Sensitivity to Potential Gain	1.50		154
									Subtotal	**154**
Coastal shale-sandstone forest										
8	1845_Mod_ Good	Not a TEC	78.1	78.1	0.39			High Sensitivity to Potential Gain	2.50		19
									Subtotal	**19**
Sydney ironstone Bloodwood-Silvertop Ash forest										
4	1786_Mod_ Good	Duffys Forest Ecological Community in the Sydney Basin Bioregion	69.1	69.1	0.84	Endangered Ecological Community	Not Listed	High Sensitivity to Potential Gain	2.00	TRUE	29
5	1786_Mod	Duffys Forest Ecological Community in the Sydney Basin Bioregion	40.5	40.5	0.37	Endangered Ecological Community	Not Listed	High Sensitivity to Potential Gain	2.00	TRUE	7
									Subtotal	**36**

Sydney North exposed sandstone woodland											
3	1783_Mod_Good	Not a TEC	62.9	62.9	4.2			High Sensitivity to Potential Gain	1.50		100
										Subtotal	**100**
										Total	**383**

Species credits for threatened species

Vegetation zone name	Habitat condition (Vegetation Integrity)	Change in habitat condition	Area (ha)/Count (no. individuals)	BC Act Listing status	EPBC Act listing status	Biodiversity risk weighting	Potential SAII	Species credits
Cercartetus nanus / Eastern Pygmy-possum (Fauna)								
1250_Mod_Good	82.5	82.5	0.2	Vulnerable	Not Listed	2	False	8
1783_Mod_Good	62.9	62.9	4.2	Vulnerable	Not Listed	2	False	133
1786_Mod_Good	69.1	69.1	0.84	Vulnerable	Not Listed	2	False	29
1786_Mod	40.5	40.5	0.37	Vulnerable	Not Listed	2	False	7
1824_Mod_Good	66.4	66.4	6.2	Vulnerable	Not Listed	2	False	205
1845_Mod_Good	78.1	78.1	0.39	Vulnerable	Not Listed	2	False	15
							Subtotal	**397**
Chalinolobus dwyeri / Large-eared Pied Bat (Fauna)								
1250_Mod_Good	82.5	82.5	0.2	Vulnerable	Vulnerable	3	True	12
1783_Mod_Good	62.9	62.9	4.2	Vulnerable	Vulnerable	3	True	200
1786_Mod_Good	69.1	69.1	0.84	Vulnerable	Vulnerable	3	True	44
1786_Mod	40.5	40.5	0.37	Vulnerable	Vulnerable	3	True	11
1824_Mod_Good	66.4	66.4	6.2	Vulnerable	Vulnerable	3	True	308
1841_Mod_Good	65.3	65.3	0.9	Vulnerable	Vulnerable	3	True	44

1845_Mod_Good	78.1	78.1	0.39	Vulnerable	Vulnerable	3	True	23
1250_Mod	54.0	54.0	0.4	Vulnerable	Vulnerable	3	True	16
							Subtotal	**658**
Pseudophryne australis / Red-crowned Toadlet (Fauna)								
1250_Mod_Good	82.5	82.5	0.2	Vulnerable	Not Listed	1.5	False	6
1783_Mod_Good	62.9	62.9	0.66	Vulnerable	Not Listed	1.5	False	16
1786_Mod	40.5	40.5	0.07	Vulnerable	Not Listed	1.5	False	1
1824_Mod_Good	66.4	66.4	0.05	Vulnerable	Not Listed	1.5	False	1
							Subtotal	**24**
Syzygium paniculatum / Magenta Lilly Pilly (Flora)								
1250_Mod_Good	N/A	N/A	1	Endangered	Vulnerable	2	False	2
							Subtotal	**2**

BAM Credit Summary Report

Proposal Details

Assessment Id	Proposal Name	BAM data last updated *
00022275/BAAS17030/20/00022282	Beaches Link and Gore Hill Freeway Connection - Indirect Impacts	10/06/2021
Assessor Name	**Report Created**	**BAM Data version ***
Jane Rodd	15/11/2021	45
Assessor Number	**BAM Case Status**	**Date Finalised**
BAAS17030	Finalised	22/10/2021
Assessment Revision	**Assessment Type**	
1	Major Projects	

* Disclaimer: BAM data last updated may indicate either complete or partial update of the BAM calculator database. BAM calculator database may not be completely aligned with Bionet.

Ecosystem credits for plant communities types (PCT), ecological communities & threatened species habitat

Zone	Vegetation zone name	TEC name	Current Vegetation integrity score	Change in Vegetation integrity (loss / gain)	Area (ha)	BC Act Listing status	EPBC Act listing status	Species sensitivity to gain class (for BRW)	Biodiversity risk weighting	Potential SAII	Ecosystem credits
Coastal sandstone gully forest											
3	1250_MG_ NewEdge	Not a TEC	82.5	16.5	0.22			High Sensitivity to Potential Gain	1.50		1
										Subtotal	**1**

Coastal sandstone Heath-Mallee											
2	1824_MG_IsolatedPatch	Not a TEC	66.4	66.4	0.01			High Sensitivity to Potential Gain	1.50		1
6	1824_MG_NewEdge	Not a TEC	66.4	13.3	4.2			High Sensitivity to Potential Gain	1.50		21
										Subtotal	**22**
Sydney ironstone Bloodwood-Silvertop Ash forest											
5	1786_MG_NewEdge	Duffys Forest Ecological Community in the Sydney Basin Bioregion	69.1	13.8	1.3	Endangered Ecological Community	Not Listed	High Sensitivity to Potential Gain	2.00	TRUE	9
										Subtotal	**9**
Sydney North exposed sandstone woodland											
1	1783_MG_IsolatedPatch	Not a TEC	62.9	62.9	0.05			High Sensitivity to Potential Gain	1.50		1
4	1783_MG_NewEdge	Not a TEC	62.9	12.6	2.6			High Sensitivity to Potential Gain	1.50		12
										Subtotal	**13**
										Total	**45**

Species credits for threatened species

Vegetation zone name	Habitat condition (Vegetation Integrity)	Change in habitat condition	Area (ha)/Count (no. individuals)	BC Act Listing status	EPBC Act listing status	Biodiversity risk weighting	Potential SAII	Species credits

Annexure G – Further information on predicted groundwater baseflow reductions and related environmental impact assessment

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

Further information on predicted groundwater drawdown, baseflow reductions and related environmental impact assessment

October 2021

Prepared for

Transport for NSW

Prepared by

Jacobs Group (Australia) Pty Ltd.

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Attachments

A: Assessment of baseflow changes in freshwater creeks (Cardno, 2021)

B: Groundwater dependent ecosystems assessment (Eco Logical Australia, 2021)

1 Introduction

1.1 Background

An environmental impact statement for the Beaches Link and Gore Hill Freeway Connection project ('the project') was placed on public exhibition on 9 December 2020, with an exhibition closing date of 1 March 2021.

Public exhibition provided the community, interested parties and key stakeholders (including Government agencies and Councils) with an understanding of the project and the opportunity to make a submission on the environmental impact statement. A description of the project can be found in Section A1.2 of the submissions report. One of the key issues raised in submissions by agencies and the community was in relation to the predicted groundwater drawdown, baseflow reductions and the related environmental impacts. In particular, concerns were raised with regards to potential long-term impacts on Flat Rock Creek, Quarry Creek and Burnt Bridge Creek.

The following components of the environmental impact statement provide important context for the revised assessment presented in this report:

- Groundwater was assessed in Chapter 16 (Geology, soils and groundwater) of the environmental impact statement and Appendix N (Technical working paper: Groundwater), including Annexure F (Groundwater modelling report)
- Surface water quality was assessed in Chapter 17 (Hydrodynamics and water quality) of the environmental impact statement and Appendix O (Technical working paper: Surface water quality and hydrology)
- Groundwater dependent ecosystems were assessed in Chapter 19 (Biodiversity) of the environmental impact statement and Appendix S (Technical working paper: Biodiversity development assessment report) including Annexure D (Freshwater ecology impact assessment)
- Social values were assessed in Chapter 21 (Socio-economic) of the environmental impact statement and Appendix U (Technical working paper: Socio-economic assessment).

1.2 Summary of key feedback

A range of issues were raised during the submissions process, as outlined in Section A3 of the submissions report. Many issues have interrelated components across a number of environmental aspects.

A number of stakeholders, including the Department of Planning, Industry and Environment (Water), Department of Planning, Industry and Environment (Environment, Energy and Science Group), Northern Beaches Council, and Willoughby City Council, as well as community members raised concerns regarding the predicted long-term groundwater baseflow reductions at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, and associated environmental issues.

Key concerns include:

- The environmental impacts of the predicted long-term reduction in baseflow are understated
- The level of uncertainty of the groundwater model predictions and methodology due to the manner in which the model was developed historically

- The consequent level of uncertainty related to impacts on freshwater ecology and groundwater dependent ecosystems as a result of the predicted groundwater drawdown and groundwater baseflow reductions to streams
- The lack of detail regarding the surface water quality impacts that would potentially result from the predicted groundwater drawdown and baseflow reductions
- Concern that there is insufficient consideration of the social impacts of the groundwater baseflow reductions in Flat Rock Creek, Quarry Creek and Burnt Bridge Creek.

Individual summaries and detailed responses to issues raised can be found in Part B (response to key stakeholder submissions) and Part C (response to community submissions) of the submissions report.

To address the concerns raised by stakeholders and community members in relation to the groundwater modelling and associated potential environmental impacts, it was determined that additional work would be carried out to be able to provide more detail in the responses, to provide context for the information presented in the environmental impact statement and to update the groundwater model predictions based on more recent investigations.

More detail on the uncertainty associated with the groundwater modelling has been provided in Appendix D of the submissions report.

1.3 Purpose

This report has been prepared to respond to submissions raised by Government agencies and the community and to update the findings of the environmental impact statement including:

- Revised groundwater drawdown predictions and baseflow reductions based on additional field investigations
- Expressing the revised baseflow reductions in terms of a reduction in streamflow
- Additional assessment of environmental issues, based on the revised baseflow reductions
- Any new or revised environmental management measures, if required.

The environmental impact statement did not include a definition of groundwater baseflow to explain that groundwater baseflow is only one component of streamflow. This report provides further detail of the relationship between streamflow and groundwater baseflow and expresses the revised baseflow reductions as an indicative reduction in streamflow to provide stakeholders with a broader appreciation of the potential impact of the project on Flat Rock Creek, Quarry Creek and Burnt Bridge Creek. A clarification is also provided in Section A5.1.15 of the submissions report on this definition.

1.4 Outline of revised assessments

As a result of the submissions received, and through discussions with the Department of Planning, Industry and Environment, some of the assessments in the environmental impact statement have been updated since public exhibition to inform the submissions report. These have focussed on the hydrological systems at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek as these are the creeks that have the potential to be most impacted by the project. The potential impacts of the project on groundwater baseflows and streamflow in Flat Rock Creek and Burnt Bridge Creek have also been reassessed.

The following assessments have been carried out:

- Additional field survey of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to assess the nature of each creek's streambed and the potential for interaction between surface water and groundwater
- Revised groundwater modelling for the Flat Rock Creek, Quarry Creek and Burnt Bridge Creek systems based on the results of the additional field survey
- Expressing the revised baseflow reductions as an indicative reduction in streamflow based on historical streamflow measurements to provide stakeholders with a broader appreciation of the potential impact of the project on Flat Rock Creek, Quarry Creek and Burnt Bridge Creek
- Targeted field survey of freshwater ecology at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to inform a revised assessment of potential impacts on freshwater ecology
- Targeted field survey and assessment of groundwater dependent ecosystems at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to inform a revised assessment of potential impacts on groundwater dependent ecosystems
- Additional analysis of findings relating to surface water quality at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, and a revised assessment of potential surface water quality impacts as result of the expected baseflow changes
- Additional analysis of community values in relation to Flat Rock Creek, Quarry Creek and Burnt Bridge Creek and revised assessment of potential social impacts as a result of the expected changes to waterways at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek.

2 Assessment approach

2.1 Key considerations

2.1.1 Definition of streamflow and groundwater baseflow

The water flowing in creeks and watercourses is known as streamflow. Streamflow is the combination of water from several sources including rainfall run-off, direct rainfall into the stream, discharge from stormwater pipes and groundwater contributions. The proportion of streamflow that comes from groundwater is referred to as groundwater baseflow. While the boundary of each of these sources of water is difficult to distinguish in reality, a schematic showing the basic elements of streamflow is provided in Figure 2-1.

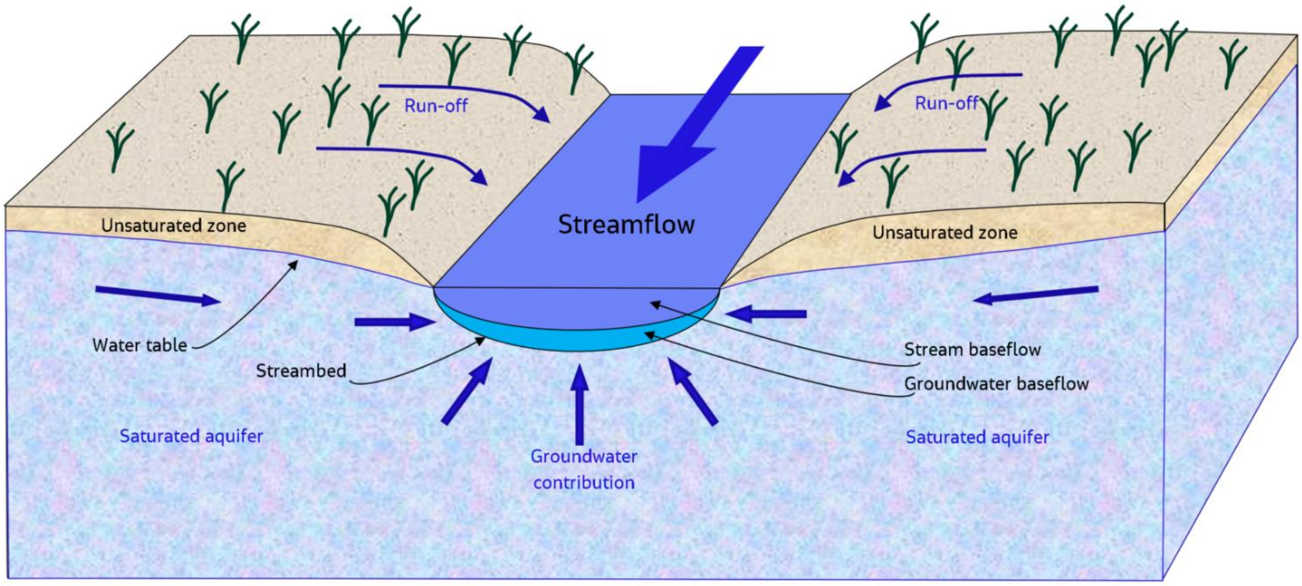


Figure 2-1 Basic elements of streamflow (modified from United States Geological Survey (USGS) (2001))

As groundwater baseflow is just one component of streamflow, it follows that the impact of a reduction in groundwater baseflow would be proportionate to its contribution to streamflow.

2.1.2 Interaction between groundwater and surface water

Streams are surface features that can be a point of interaction between groundwater and surface water. Streams can gain or lose water from the surrounding groundwater system as shown in Figure 2-2a and Figure 2-2b respectively. Losing streams can be connected to the groundwater system by a continuous saturated zone as shown in Figure 2-2b or disconnected from the groundwater system by an unsaturated zone as shown in Figure 2-2c (USGS, 2001). These conditions are identified by groundwater levels in contrast to the stream water level. Where the surrounding groundwater level is higher than the stream water level, the stream is considered a gaining stream. Where the surrounding groundwater level is lower than the stream water level, the stream is considered a losing stream.

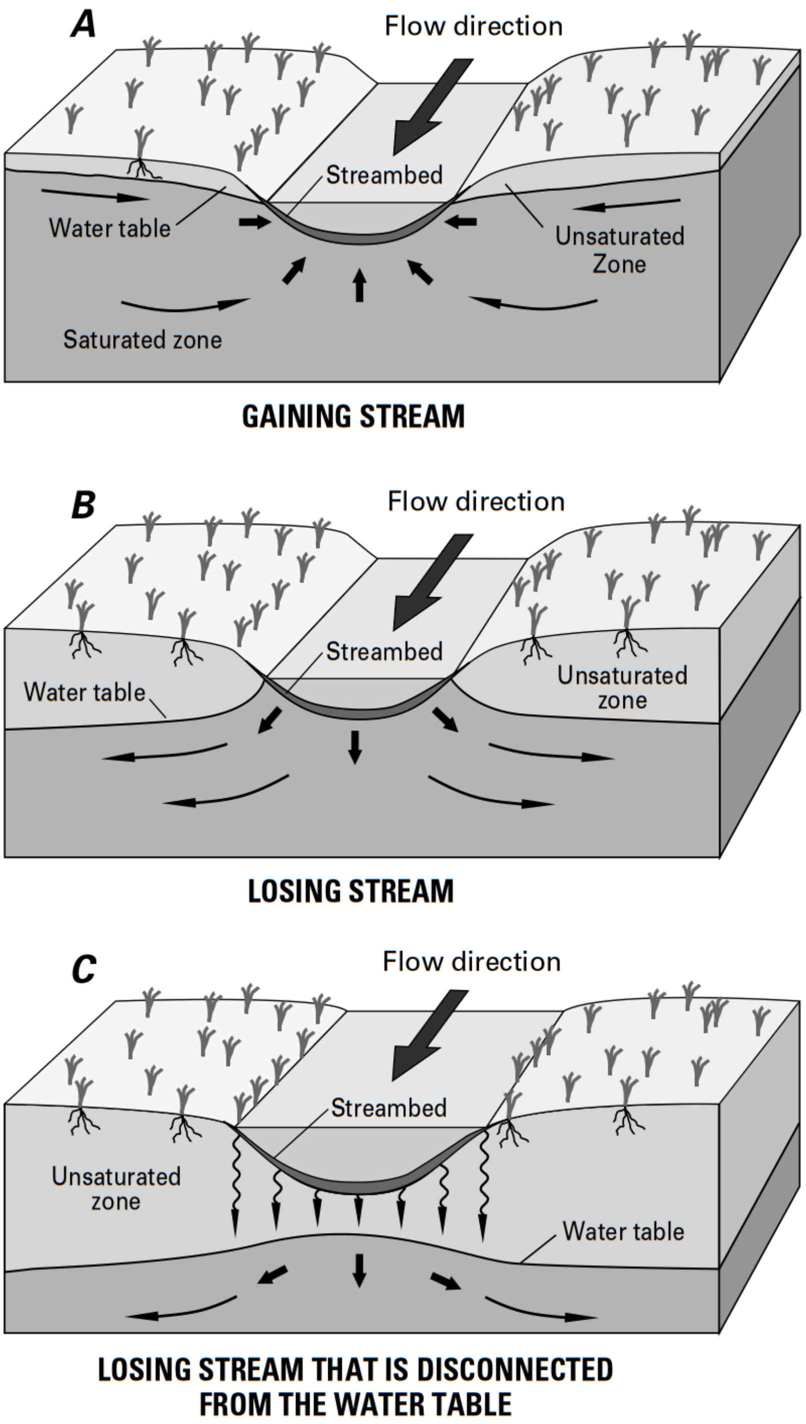


Figure 2-2 Interactions of a stream and a groundwater system (modified from USGS, 2001)

In some cases, stream beds consist of low hydraulic conductivity materials that can be natural or of human origin. A low hydraulic conductivity streambed can reduce the interaction between surface water and groundwater in both losing and gaining streams. Natural low conductivity material can include compacted fine sediments such as clay and silt and/or layered organic material. Many streams in urban areas have been lined with concrete or channelled into pipes to reduce flooding. These types of streambed materials can also alter the interaction between surface water and groundwater.

Near to the proposed alignment of the Beaches Link tunnels, the groundwater levels are assumed to generally be higher than the stream levels and so groundwater contributes a proportion of streamflow. The contribution of groundwater to streamflow is dependent on the hydraulic conductivity of the aquifer that is exposed in the stream bed and the condition and permeability of any potential lining in the stream bed. Localised groundwater seepage points were identified in watercourses during the additional field survey of the streambeds of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek mentioned in Section 1.4 above. However, the conductivity of the outcropping sandstone is considered to be relatively low, so the contribution of groundwater to streamflow is considered relatively low. Also, some of the streams in the project area are lined with concrete, culverted and filled over or channelled into underground pipes, which further limits the contribution of groundwater to surface water as noted above. Assumptions made about the permeability of creek beds and the level of connectivity between surface water, groundwater and the tunnel affects predictions of inflows to the tunnel and the magnitude of groundwater drawdown. Further information on these assumptions is provided in sections 2.1.3 and 2.2.1 below.

2.1.3 Inherent groundwater model conservatism

The potential groundwater impacts of the project were assessed in Appendix N (Technical working paper: Groundwater). The assessment used groundwater modelling to estimate potential changes in groundwater levels and groundwater baseflow due to the project. Details of the groundwater model are contained in a groundwater modelling report in Annexure F of Appendix N (Technical working paper: Groundwater).

The groundwater modelling was designed to meet Class 2 requirements of the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012) and conservative assumptions were made during its development taking into account experience from other recent major tunnel infrastructure projects in Sydney. The assessment of groundwater impacts in the environmental impact statement was inherently conservative, and is likely to have overestimated actual impacts for the following reasons:

- There was limited, site-specific geotechnical information available on which to base assumptions concerning the permeability of geological strata between the watercourses and the tunnels. It was therefore necessary to assume that there was a single connected groundwater system (aquifer) between the watercourses and the underlying tunnels. The groundwater model assumes continuous saturation (and hydraulic connectivity) between the tunnel and the shallow water table beneath the creeks. Under this assumption, all drawdown at tunnel depth would be realised at the surface, which could result in baseflow reductions in watercourses. In reality, the geology would be stratified, possibly with disconnected sections of the aquifer ie limited potential for vertical movement of groundwater. This means that the subsurface drawdown at tunnel depth might not result in the same (or any) drawdown in the shallow water table and might reduce actual drawdown substantially compared to the predictions so the predicted groundwater drawdown are unlikely to be fully realised in all locations
- To reduce the likelihood of underestimating potential tunnel groundwater inflows, there was a requirement for the model to simulate tunnels in a fully drained state ie with no controls in place to limit groundwater inflows to the tunnel. Put another way, the groundwater inflows to the tunnels were controlled by the permeability of the surrounding geological formation. As indicated in Table 7-1 and Table 7-2 of Annexure F of Appendix N (Technical working paper: Groundwater), this results in some situations where groundwater inflows to the tunnels exceed a design criterion limiting tunnel inflows in any one kilometre section of tunnel to a maximum of one litre per second per kilometre. In reality, measures will be implemented during construction to ensure that groundwater inflows into each tunnel during the operation phase do not exceed one litre per second per kilometre across any given kilometre, as required by revised environmental management measure SG16 (refer to Table D2-1 of the submissions report). As the tunnels would be designed and constructed to ensure this

design criteria is met, the predicted levels of groundwater drawdown in surrounding areas would be less than modelled.

When the environmental impact statement was being prepared there was limited information available on the state of the streambeds and specifically, whether they were conducive to water movement between the stream and the underlying aquifer. Due to this limited information, conservative assumptions were made in the groundwater modelling reported in the environmental impact statement. Transport for NSW has now carried out field surveys to inspect the condition of streambeds and gathered information that was not available when the environmental impact statement was prepared, as discussed in Section 2.2 below.

Consistent with the environmental impact statement, the revised groundwater modelling assumed that no tunnel lining would be provided to reduce groundwater inflow to the tunnels with the exception of a 125 metre section on either side of Middle Harbour and that groundwater inflows to the tunnels would be constrained by the permeability of the geological formation.

2.2 Revised groundwater modelling

Transport for NSW has carried out additional field investigations at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek since the environmental impact statement was finalised to gather further information regarding these creeks. Additional information was sought on these three creeks because they are the watercourses that were predicted in the environmental impact statement to experience a greater reduction in groundwater baseflow in 2128 after 100 years of operation than other watercourses near to the project area, as discussed in Section 17.4.5 of the environmental impact statement and Section 6.1.3.5 of Appendix N (Technical working paper: Groundwater). The groundwater modelling carried out for the environmental impact statement was based on the creek bottom surfaces shown in Figure A1-14 and A1-15 of Attachment 1 of Annexure F of Appendix N (Technical working paper; Groundwater) and described in Table 9-2 of Annexure F of Appendix N (Technical working paper; Groundwater).

The additional information collected in field investigations has enabled Transport for NSW to carry out additional environmental impact assessment to address concerns regarding the groundwater modelling results relating to surface water-groundwater interactions presented in the environmental impact statement.

Transport for NSW has carried out the following:

- Additional field survey of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to assess the nature of the creek streambed and the potential for interaction between creek surface waters and groundwater
- Revising the groundwater modelling carried out for the environmental impact statement, including updating the numerical groundwater model and revised predictions of groundwater level drawdown at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek.

As part of the above, the predicted baseflow reductions along individual, discrete sections of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek were recalculated to facilitate a more detailed analysis of potential impacts. These more detailed predictions of baseflow reductions were used to reassess the potential impacts to freshwater ecology, groundwater dependent ecosystems, surface water quality and social amenity.

To provide appropriate context for the predicted groundwater baseflow reductions and to make them readily understandable and tangible to the community, the revised predictions of groundwater baseflow reduction have also been expressed as a percentage reduction in streamflow using streamflow data collected in May 2018 during the 2017 to 2019 drought period (Bureau of Meteorology, 2021).

Presenting the potential impact in terms of a reduction in streamflow is expected to make it easier for stakeholders including the community to understand the magnitude of any potential impact.

While the revised groundwater modelling and groundwater baseflow reduction predictions are based on the additional information on streambed lining obtained during the May 2021 field survey and therefore there is less uncertainty about the predictions, the conservative assumptions applied to the groundwater modelling and groundwater baseflow reduction predictions in the environmental impact statement that were discussed in Section 2.1 above continue to apply.

2.2.1 Field survey

A field survey of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek was carried out during the week of 10 May 2021. The full length of each creek was surveyed by a principal hydrogeologist. Survey observations included the nature of the creek bed and banks and identification of groundwater seepage. Streamflows were also observed but not measured.

Based on the field observations, unique sections of each creek were classified in line with the descriptions provided in Table 2-1. Examples of each creek section classification are provided in Figure 2-3 to Figure 2-10.

Table 2-1 Classification of creek sections

Classification	Description	Example figures
Unlined	Locations where a creek flows over natural media and there is potentially free interaction between surface water and groundwater.	Figure 2-3
Unlined underground	Locations where a creek flows over natural media and there is potentially free interaction between surface water and groundwater, but the creek has been channelled into an underground culvert with no floor.	Figure 2-4
Unlined bedrock with springs	Locations where a creek is flowing over exposed bedrock, with localised groundwater seepage points.	Figure 2-5
Unlined bedrock, banks with baseflow	Locations where a creek is flowing over exposed country rock/basement rock with the creek banks contributing seepage to groundwater.	Figure 2-6
Constructed surface creek	Locations where a creek has been modified by human actions.	Figure 2-7
Constructed surface creek, banks with baseflow	Locations where a creek has been modified by human actions, with the creek banks contributing seepage to groundwater and to baseflow.	Figure 2-8
Lined underground	Locations where a creeks flows through a concrete pipe or culvert and the interaction between surface water and groundwater is likely to be minimal.	Figure 2-9
Lined contributing baseflow	Locations where a creek flows through a concrete pipe or culvert, and there are cracks, weep holes or other features that allow seepage and interaction between surface water and groundwater.	Figure 2-10

Figure 2-3 Example of a section of Burnt Bridge Creek classified as unlined or natural near Baringa Avenue at Seaforth (BBC005)

Figure 2-4 Example of a section of Flat Rock Creek classified as unlined underground under Willoughby Road bridge at Naremburn (FRC016)

Figure 2-5 Example of a section of Burnt Bridge Creek classified as unlined bedrock with springs near Baringa Avenue at Seaforth (BBC007)

Figure 2-6 Example of a section of Flat Rock Creek classified as unlined bedrock, banks with baseflow, about 100 metres east of Flat Rock Drive at Willoughby (FRC027)

Figure 2-7 Example of a section of Burnt Bridge Creek classified as a constructed surface creek at the end of Quirk Road at Balgowlah (BBC027)

Figure 2-8 Example of a section of Flat Rock Creek classified as constructed surface creek, banks with baseflow, in Flat Rock Reserve at Northbridge (FRC023)

Figure 2-9 Example of a section of Burnt Bridge Creek classified as lined underground at Kitchener Street bridge at Balgowlah (BBC017)

Figure 2-10 Example of a section of Flat Rock Creek classified as lined contributing baseflow near Glenview Road at Naremburn (FRC015)

The observation points along each creek and the resulting classification of each creek section are shown in Figure 2-11 to Figure 2-14.

The key differences between the creeks modelled in the environmental impact statement and the results from the field survey are:

- Additional sections in the upper reaches of Flat Rock Creek were identified and added to the groundwater model
- The upper reach of Flat Rock Creek is not lined where it is within a box culvert and instead, is in direct connection with the underlying sandstone bedrock, whereas modelling carried out for the environmental impact statement assumed there was no groundwater contribution from this section of the creek
- The underground box culvert within the upper reaches of Flat Rock Creek to the east of the Gore Hill Freeway was observed to potentially have groundwater contributing to it, whereas modelling carried out for the environmental impact statement assumed there was no groundwater contribution to this section of the creek
- Sections of Burnt Bridge Creek immediately west of the Burnt Bridge Creek Deviation and between the Burnt Bridge Creek Deviation and Manly West Park were previously assumed to be lined and therefore have no groundwater contribution. However, during the field survey theses sections of the creek were observed to have possible groundwater contribution.

Figure 2-11 Classification of sections of Flat Rock Creek between Artarmon and Bicentennial Park

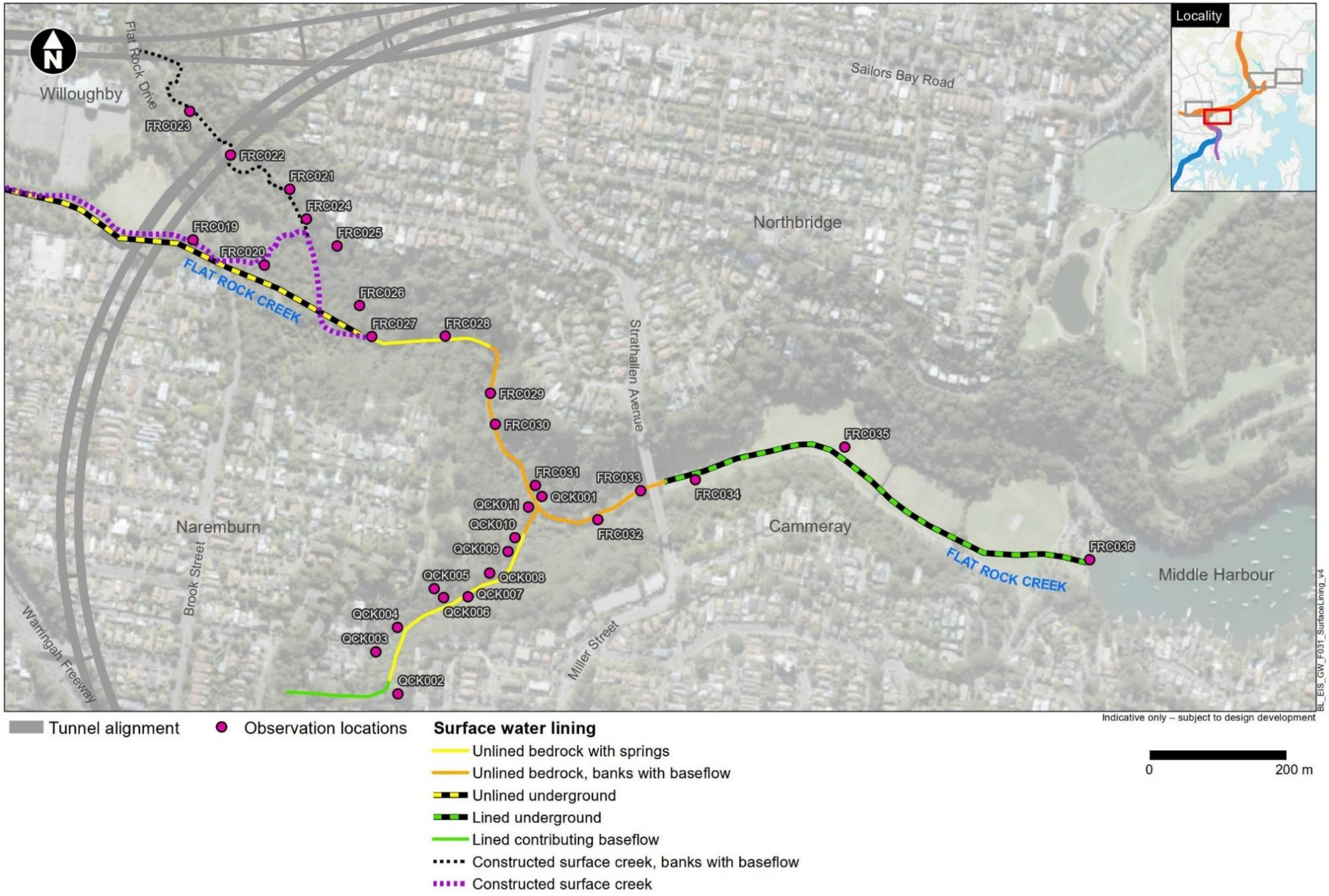


Figure 2-12 Classification of sections of Flat Rock Creek and Quarry Creek between Bicentennial Park and Middle Harbour

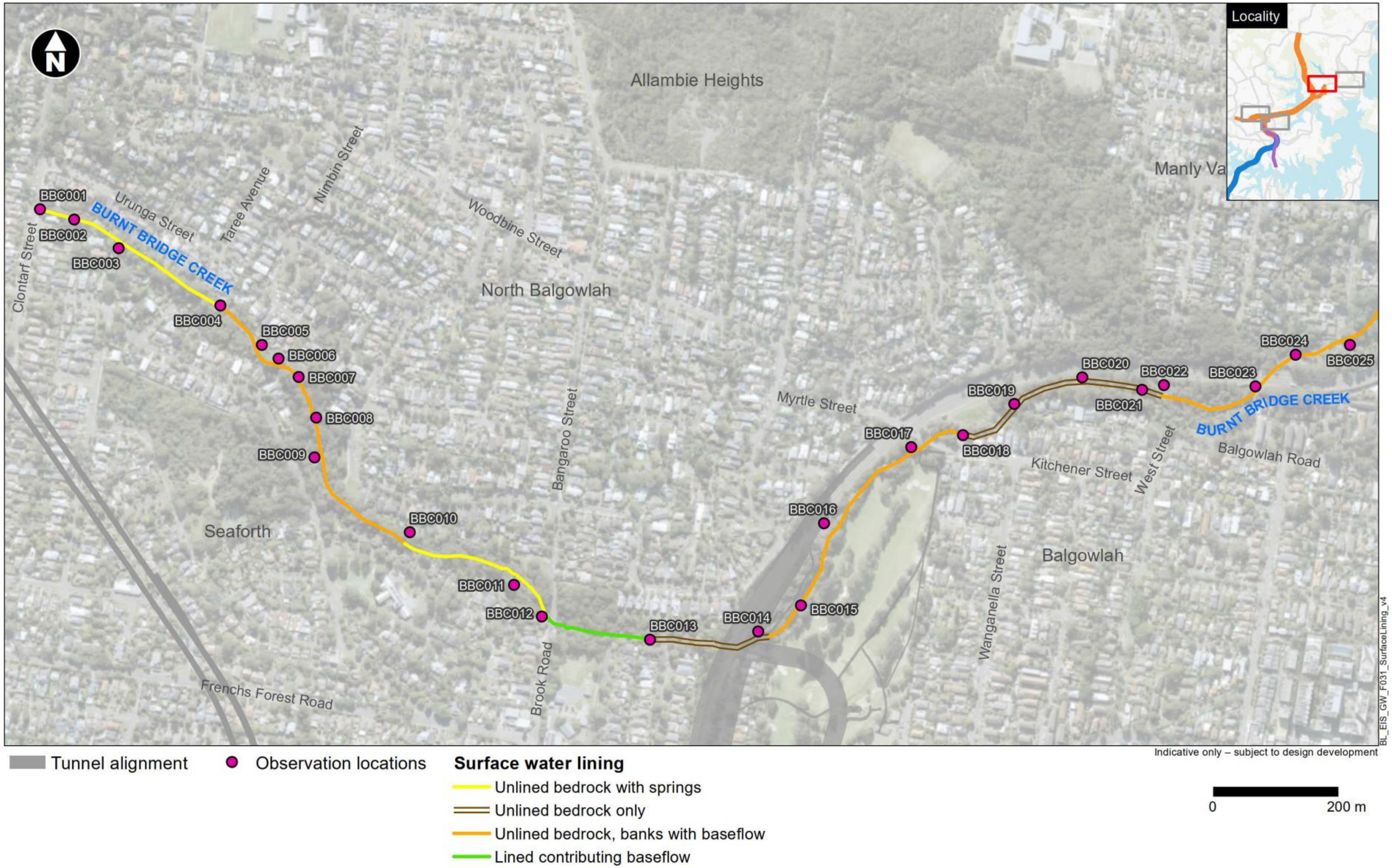


Figure 2-13 Classification of sections of Burnt Bridge Creek between North Balgowlah and Balgowlah

Figure 2-14 Classification of sections of Burnt Bridge Creek between Balgowlah and Fairlight

2.2.2 Groundwater modelling

Transport for NSW has revised the groundwater predictions for the project based on the results of the field survey described above. The revised groundwater modelling was carried out using the MODFLOW-USG (Unstructured Grid) model that is described in Section 4.4 of Appendix N (Technical working paper: Groundwater).

The revised groundwater modelling carried out involved:

- Assigning revised riverbed conductance term values to represent the groundwater-surface water interaction at unlined sections of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek based on a literature review of conductance for similar conditions. Riverbed conductance term values are discussed in Section 2.2.3
- Updating the no project and project numerical groundwater models to reflect the uniquely characterised sections of each creek based to enable baseflow to be separately analysed for each discrete section of the creeks
- Predicting groundwater level drawdown and baseflow changes at each uniquely characterised creek section. Given stakeholders' concerns about long-term impacts to baseflow, the revised modelling focused on these impacts after 100 years of operation of the project ie in the year 2128
- Expressing the revised baseflow reductions as an indicative reduction in streamflow based on historical streamflow measurements to provide a better appreciation of the potential impact of the project on each creek (refer to Section 2.2.4 below).

The revised groundwater modelling was carried out for the 'cumulative scenario', which considers the cumulative impact on groundwater of the project together with the Western Harbour Tunnel and Warringah Freeway Upgrade project and the Sydney Metro City & Southwest project as discussed in Section 16.4.5 of the environmental impact statement.

As previously indicated, to aid comprehension of the predicted changes to groundwater baseflow, the predictions are also presented in relation to relative changes to streamflow. Refer to Section 2.1for a discussion on streamflow components and their interrelationship.

2.2.3 Riverbed conductance

Riverbed conductance is a parameter used in MODFLOW to measure the flow of water between a riverbed/creek and the underlying aquifer, as discussed in Section 3.9.3 of Annexure F of Appendix N (Technical working paper: Groundwater). Riverbed conductance is defined in MODFLOW as the hydraulic conductivity (K) of the riverbed materials divided by the vertical thickness (T) of the riverbed materials, multiplied by the cross sectional area of the river ie width (W) of the river multiplied by the length (L) of the river being analysed, as shown in the equation below:

Riverbed conductance = (K/T)*W*L

The higher a riverbed conductance value, the greater the assumed flow of water between the river and the aquifer.

The vertical thickness (T) of the bed sediments of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek was assumed to be one metre, as discussed in Section 3.9.3 of Annexure F of Appendix N (Technical working paper: Groundwater).

The hydraulic conductivity (K) was conservatively based on the horizontal hydraulic conductivity of the cell containing the creek model boundary.

A conductance value of 0.001 m^2/day was used for channels in the F6 Extension Stage 1 Groundwater Modelling Report (RPS Australia West, 2018) prepared for the F6 Extension Stage 1 environmental impact statement (now known as the M6 Stage 1 project). The same conductance value has been adopted in the revised groundwater modelling for the project for consistency and given the regional proximity to the M6 Stage 1 project. This conductance value was used to represent sections of creek where the creek bed is not in full hydraulic connection with the underlying ground, but where groundwater baseflow (seepage) to the creek was observed. A conductance value of 100 m^2/day represents sections of creek where the creek bed is in full hydraulic connection with the underlying ground, and the flow between the creek and the underlying ground is controlled by the formation permeability. A conductance value of zero means there is no connection between groundwater and surface water.

2.2.4 Streamflow measurements

Estimated flow measurements were carried out at Flat Rock Creek, Quarry Creek (a tributary to Flat Rock Creek) and Burnt Bridge Creek in May 2018, as noted in Section 2.3 of Annexure F of Appendix N (Technical working paper: Groundwater). Streamflow was measured using a portable flow meter where applicable or was otherwise indirectly measured using either a velocity-cross sectional area relationship or measuring the time to fill a discrete volume. The locations where streamflow was estimated in May 2018 are shown in Figure 2-15.

The streamflow measurements in May 2018 were taken after two weeks of no rain. Estimated flow rates are listed in Table 2-2. The table also nominates a ‘confidence’ rating for these estimates, with greater accuracy assigned where a flow meter was used and the streambed geometry was well defined and lesser accuracy assigned where flow velocity was used and the streambed geometry was not well defined. Measurements considered to have relatively greater accuracy have higher confidence.

Table 2-2 Estimated creek streamflows – May 2018

Location	Estimated streamflow (kilolitres per day)	Confidence
Flat Rock Creek downstream	1908	High
Flat Rock Creek weir	2337	Low
Quarry Creek upstream	178	High
Burnt Bridge Creek midsection	130	Moderate
Burnt Bridge Creek downstream	1242	Low

These streamflow measurements provide a basis for calculating indicative impacts to streamflow from the revised predicted reductions in baseflow (refer to Section 3.3 below).

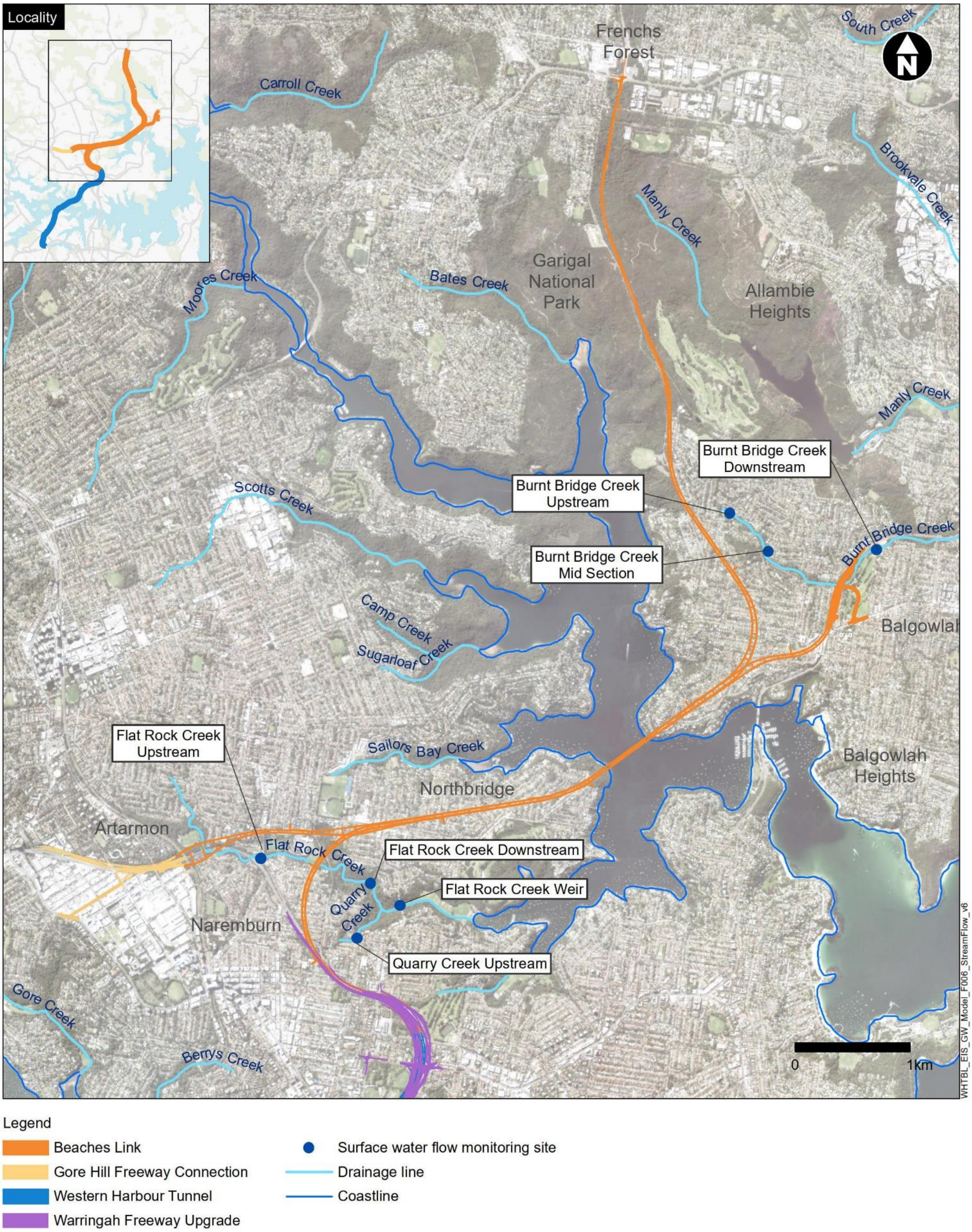


Figure 2-15 Streamflow measurement locations – May 2018

2.3 Related environmental impacts

The revised groundwater modelling predictions were used to revise the assessments of the impacts of the predicted groundwater drawdown at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek on freshwater ecology, groundwater dependent ecosystems, surface water quality and social and community values. The methodologies for revising these assessments are summarised below.

2.3.1 Freshwater ecology

The entire reaches of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek between the headwaters and the downstream estuaries were inspected between 26 - 28 May 2021 to identify habitat sensitivity, riparian condition and the proportion of shallow pools, deep pools or riffles/cascades.

Data was collected on the following:

- Instream features – within sections of each creek, visual estimates were made of the proportion of creek length that contained shallow pools (less than two metres depth), deep pools (more than two metres depth) or riffles/cascades. The type of substratum in pools (bare rock, earth, silt, sand, gravel or detritus) was also noted
- Quality of fish habitat - assessed with reference to the criteria in *Policy and guidelines for fish habitat conservation and management* (Department of Primary Industries, 2013)
- Riparian condition – assessed using a modified version of the Riparian, Channel, and Environmental (RCE) inventory method (Peterson, 1992, Chessman et al. 1997). This assessment involved evaluation and scoring of the characteristics of the various components of the riparian corridor, including adjacent land, condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. The maximum score indicates a stream with little or no obvious physical disruption and the lowest score indicates a heavily channelled stream without any riparian vegetation that is considered to be in poor condition. RCE scores were assigned to sections of the creeks, with boundaries occurring where there was a visible change in the riparian condition (eg a change in riparian native vs exotic trees/shrubs, channel form or riffle/pool sequence).
- Fish sampling – catch and release of fish using collapsible bait traps in line with Cardno's scientific collection permit F86/670(A)-8.2
- Macroinvertebrates – semi-quantitative Australian River Assessment System (AUSRIVAS) rapid assessment sampling method in pools with suitable representative edge habitat
- Water quality – measured in situ in line with Australian Guidelines: Australia, New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000.

This data, and the revised groundwater modelling predictions, were analysed and used to revise the assessment of the potential impacts of the project on freshwater ecology at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek.

Further details of the methodology used for the freshwater ecology survey are provided in Section 2 of Attachment A.

2.3.2 Groundwater dependent ecosystems

The assessment of the potential impacts of the project on groundwater dependent ecosystems was revised in line with the *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (Department of Primary Industries, 2012) and *Information Guidelines Explanatory Note: Assessing groundwater-dependent ecosystems* (Doody et al., 2019).

Ecologists conducted a rapid assessment survey of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek in June 2021 to confirm the vegetation, structure and landscape features and classify the plant community types and presence of groundwater dependent ecosystems.

The assessment of the potential impacts of the project on groundwater dependent ecosystems was revised by:

- Identifying and classifying the potentially impacted groundwater dependent ecosystems
- Assessing the level of dependence of these ecosystems on groundwater
- Identifying high value ecological components of the groundwater dependent ecosystems and their overall ecological value
- Reviewing the potential impact of the project on the aquifer based on the revised groundwater drawdown predictions from the groundwater model
- Assessing the risk magnitude to the groundwater dependent ecosystems as a result of the revised groundwater drawdown predictions
- Applying the groundwater dependent ecosystem risk matrix, derived from Serov et al. (2012) to identify both the level of management action required and the timeframe in which this action needs to be implemented, based on the identified ecological values.

Further detail of the risk assessment process adopted for the groundwater dependent ecosystems assessment is provided in Section 2 of Attachment B.

2.3.3 Surface water quality

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

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

The Australian and New Zealand Guidelines (ANZG) (2018) and ANZECC & ARMCANZ (2000) water quality guidelines and objectives applied in the assessment of surface water quality are identified in Table 2.1 of Appendix O (Technical working paper: Surface water quality). These guidelines and objectives are dependent on nominated environmental values. The nominated environmental values for Flat Rock Creek, Quarry Creek and Burnt Bridge Creek are the protection of freshwater ecosystems, visual amenity and secondary contact recreation.

A qualitative approach was used to revise the assessment of the potential impacts of the project on surface water quality at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, which included:

- Reviewing water quality data used in the environmental impact statement and from additional water quality monitoring carried out in January and February 2021 at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek
- Reviewing the revised groundwater modelling predictions and the revised freshwater ecology assessment
- Qualitatively assessing whether the revised groundwater modelling predictions would result in any potential impacts to the identified water quality objectives.

2.3.4 Social and community values

The following tasks were carried out to revise the assessment of the potential impacts of the project on social amenity:

- Identify and confirm community values relevant to Flat Rock Creek, Quarry Creek and Burnt Bridge Creek based on consultation completed for the environmental impact statement
- Review of community feedback received through the submission process relevant to social values and potential impacts on Flat Rock Creek, Quarry Creek and Burnt Bridge Creek
- Review the specialist findings of the revised groundwater drawdown impacts on Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to identify any changes in potential impacts on identified community values
- Consider if any changes to the identified environmental management measures would be required.

3 Revised groundwater modelling predictions

The groundwater model for the project was revised based on the streambed lining observations made during the May 2021 field surveys of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek (refer to Section 2.2.1).

The revised groundwater modelling predictions are discussed and presented in the following sections.

3.1 Maximum groundwater drawdown

The groundwater model was used to predict the maximum groundwater drawdown based on unconstrained inflows into the tunnel. This is a conservative assumption as explained above in Section 2.1.

The predicted maximum groundwater drawdown at Flat Rock Creek, Quarry Creek, Burnt Bridge Creek and the groundwater dependent ecosystems at Flat Rock Creek and Quarry Creek in 2128 after 100 years of operation of the project is provided in Table 3-1. This table also includes the groundwater drawdown predictions for these creeks that were outlined in Table 6-9 and Table 6-10 of Appendix N (Technical working paper: Groundwater).

Table 3-1 Predicted maximum groundwater drawdown in 2128

Feature	Predicted maximum groundwater drawdown in 2128 (metres)	
	Reported in the environmental impact statement	Revised groundwater modelling
Creeks		
Flat Rock Creek	Up to 29 metres	Up to 28 metres
Quarry Creek	Up to 18 metres	Up to 19 metres
Burnt Bridge Creek	Up to 6 metres	Up to 3 metres
Groundwater dependent ecosystems		
Vegetation at Flat Rock Creek and Quarry Creek	Up to 12 metres	Up to 12 metres

Contour maps showing the predicted groundwater drawdown in 2128 following 100 years of operation of the project based on the revised groundwater modelling for the sections of the project south and north of Middle Harbour are provided in Figure 3-1 and Figure 3-3 respectively. Similar contour maps based on the groundwater modelling carried out for the environmental impact statement are also reproduced below in Figure 3-2 and Figure 3-4.

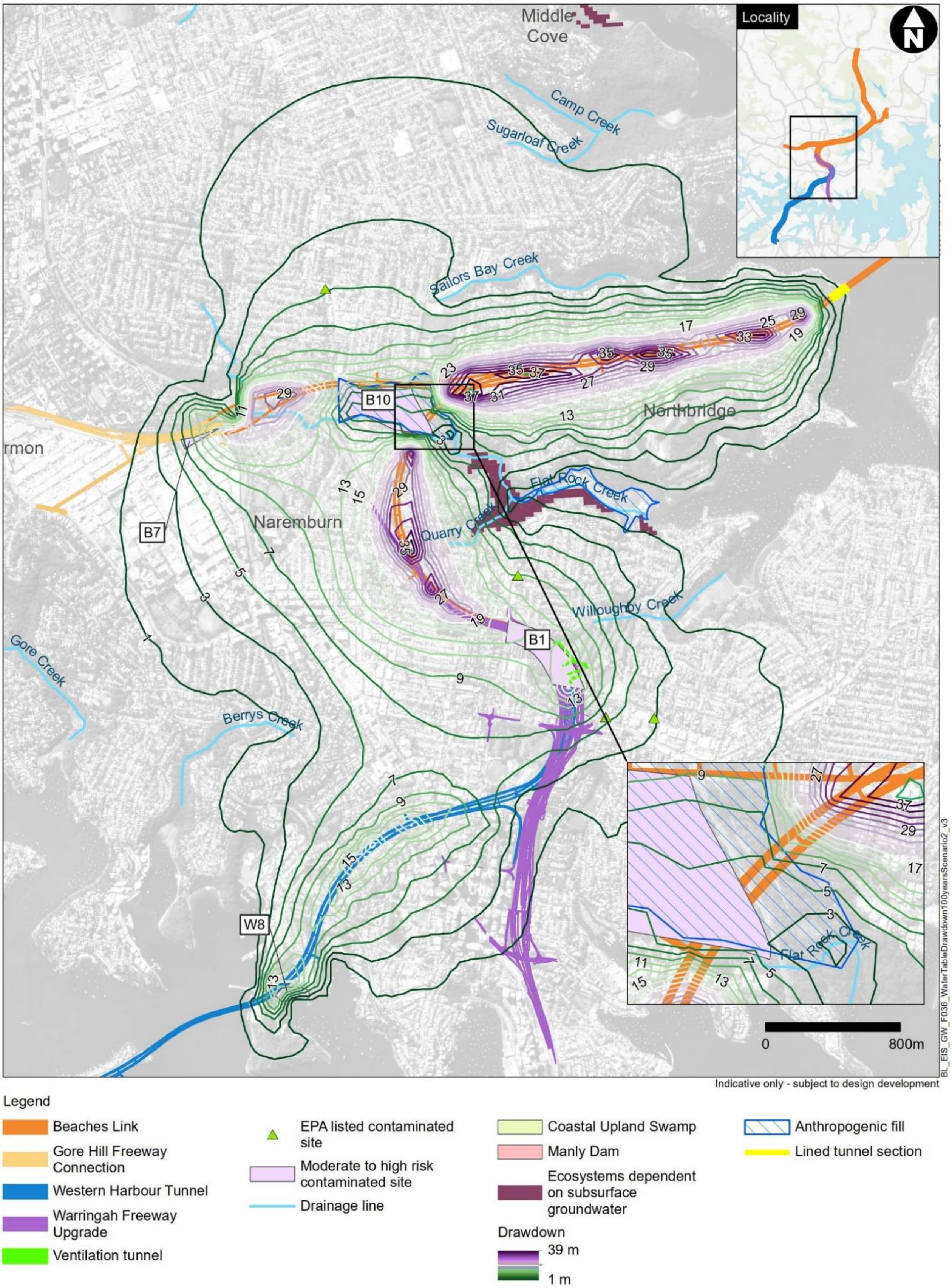


Figure 3-1 Predicted maximum groundwater drawdown south of Middle Harbour based on the revised groundwater modelling

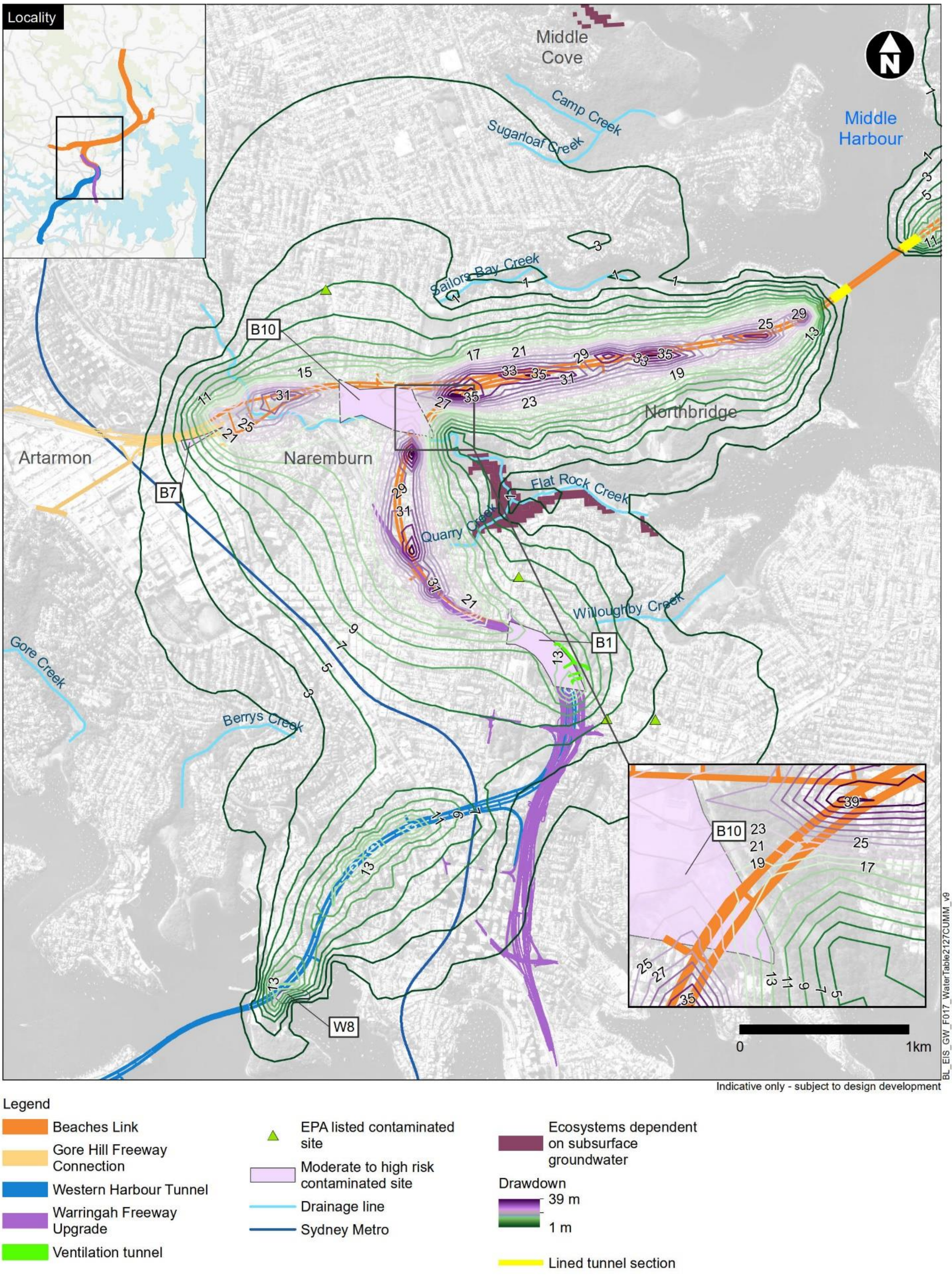


Figure 3-2 Predicted maximum groundwater drawdown south of Middle Harbour as shown in Figure 6-7 of Appendix N (Technical working paper: Groundwater)

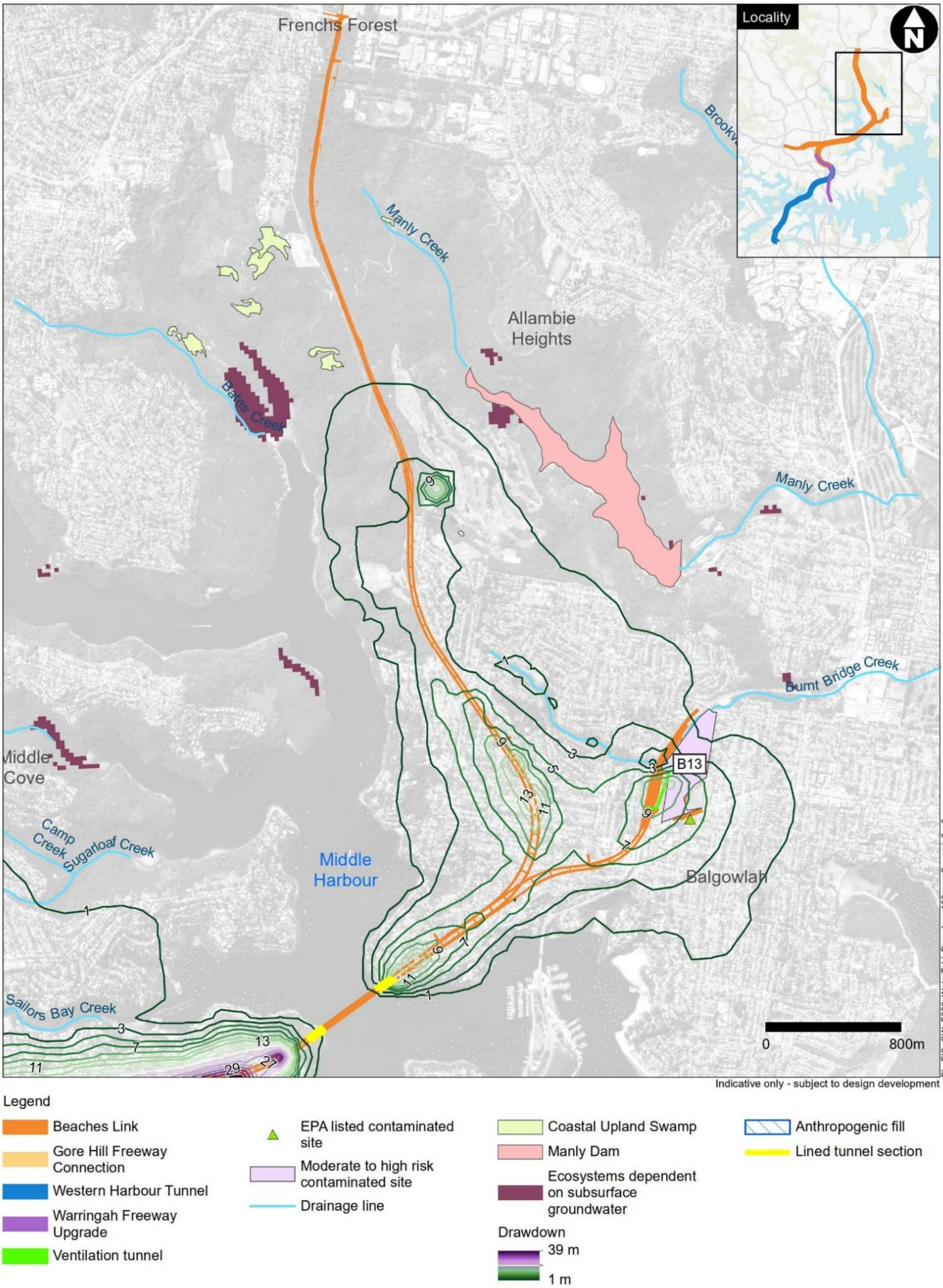


Figure 3-3 Predicted maximum groundwater drawdown north of Middle Harbour based on the revised groundwater modelling

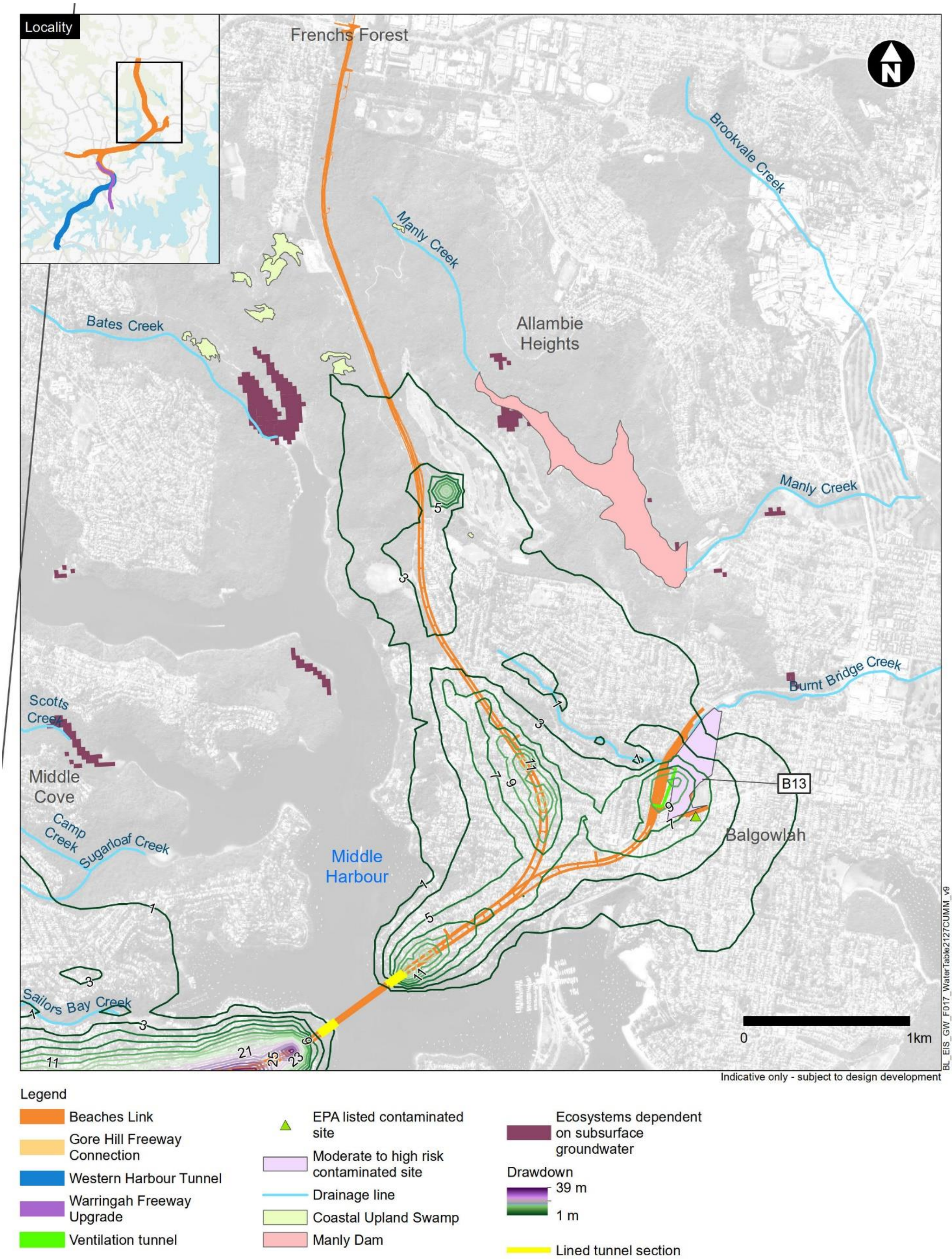


Figure 3-4 Predicted maximum groundwater drawdown north of Middle Harbour as shown in Figure 6-8 of Appendix N (Technical working paper: Groundwater)

The revised groundwater drawdown predictions at Flat Rock Creek, Quarry Creek, Burnt Bridge Creek and the groundwater dependent ecosystem at Flat Rock Creek and Quarry Creek are very similar to those presented in the environmental impact statement as demonstrated in Figure 3-1 to Figure 3-4.

The maximum drawdown predicted at any point along Flat Rock Creek, Quarry Creek, Burnt Bridge Creek and at the groundwater dependent ecosystem at Flat Rock Creek and Quarry Creek based on the revised groundwater modelling is also similar to the predictions contained in the environmental statement as indicated in Table 3-1. This indicates that the additional creek sections added to the model and the changes to creek linings observed during the recent field survey, have had only a minor effect on the groundwater drawdown predictions.

3.2 Changes to groundwater baseflow

Groundwater baseflow was analysed in the environmental impact statement for the entire lengths of creeks by averaging the groundwater baseflow predicted in the groundwater modelling, as discussed in Section 6.2.3.5 of Appendix N (Technical working paper: Groundwater). A similar approach was applied to the revised groundwater modelling completed.

Groundwater baseflows in Flat Rock Creek, Quarry Creek and Burnt Bridge Creek in 2128 with and without the project have been predicted based on the revised groundwater modelling and are presented in Table 3-2. The table also includes the predicted groundwater baseflows in 2128 with and without the project from the modelling carried out for the environmental impact statement to enable easy comparison between the two sets of predictions.

Table 3-2 Predicted groundwater baseflow in 2128 with and without the project

Creek	Predicted groundwater baseflow to creeks in 2128 (kilolitres per day)			
	Reported in the environmental impact statement		Revised groundwater modelling	
	Without the project	With the project	Without the project	With the project
Flat Rock Creek	215	131	1748	1222
Quarry Creek	17	5	17	6
Burnt Bridge Creek	18	1	34	14

The project is predicted to result in a reduction in groundwater baseflow in Flat Rock Creek, Quarry Creek and Burnt Bridge Creek in 2128 as indicated by the ‘without the project’ predictions in Table 3-2 being higher than ‘with the project’ predictions for both the revised groundwater modelling and the groundwater modelling carried out for the environmental impact statement. The difference between the predictions reported in the environmental impact statement and the revised groundwater modelling is due to the additional reaches of Flat Rock Creek identified in the May 2021 field survey that were not previously included in the modelling, as well as changes to the streambed classifications of some sections of both Flat Rock Creek and Burnt Bridge Creek and consequently, the contribution of groundwater baseflow to these creek sections.

Table 3-3 Predicted reduction in groundwater baseflow in 2128 with the project

Creek	Predicted reduction in groundwater baseflow to creeks in 2128			
	Reported in the environmental impact statement		Revised groundwater modelling	
	kilolitres per day	%	kilolitres per day	%
Flat Rock Creek	85	39%	526	30%
Quarry Creek	11	69%	11	63%
Burnt Bridge Creek	17	96%	20	60%

The predicted baseflow reductions for Flat Rock Creek and Quarry Creek based on the revised groundwater modelling are similar to the predicted baseflow reductions for these creeks contained in the environmental impact statement. For Burnt Bridge Creek, less baseflow reduction is predicted with the revised groundwater modelling, which reflects the presence of creek linings observed during the field survey.

The groundwater baseflow reduction predictions in Table 3-3 are calculated by summing the predictions for discrete sections of each creek. The discrete creek sections used in the revised groundwater modelling are based on the classifications of creek sections shown in Figure 2-11 to Figure 2-14. The cumulative baseflow reductions for the discrete creek sections are provided in Figure 3-5 for Flat Rock Creek and Quarry Creek and Figure 3-6 for Burnt Bridge Creek.

Figure 3-5 Predicted cumulative reduction in groundwater baseflow along sections of Flat Rock Creek and Quarry Creek

Figure 3-6 Predicted cumulative reduction in groundwater baseflow along sections of Burnt Bridge Creek

3.3 Changes to streamflow

As indicated in Section 2.1.1, groundwater baseflow is difficult to distinguish from other sources of water and makes up only a portion of streamflow that is observed in creeks. Therefore, the predicted groundwater baseflow reductions have also been presented in the context of overall streamflow using measurements made in May 2018 at Flat Rock Creek weir and Burnt Bridge Creek downstream to better illustrate the tangible effects of the project on these creeks.

The contribution of baseflow to streamflow is predicted to vary considerably along the length of the creeks, for example it is predicted to comprise about one per cent of streamflow at Flat Rock Creek upstream, about 79 per cent of streamflow at Flat Rock Creek downstream and 67 per cent of streamflow at Flat Rock Creek Weir, while baseflow is predicted to comprise about six per cent of streamflow at Burnt Bridge Creek midsection and two per cent of streamflow at Burnt Bridge Creek downstream,

Flat Rock Creek weir is the most downstream location at which streamflow was measured in May 2018. The predicted groundwater baseflow contribution to streamflow at Flat Rock Creek weir in 2128 without the project is about 1562 kilolitres per day, which is about 67 per cent of the streamflow measured at the weir in May 2018. Groundwater baseflow is predicted to reduce to 1041 kilolitres per day at Flat Rock Creek weir in 2128 with the project, which is about 45 per cent of the streamflow measured at the weir in May 2018. The predicted reduction in streamflow at Flat Rock Creek weir in 2128 as a result of groundwater baseflow reductions caused by the project is therefore 521 kilolitres per day or about 22 per cent as shown in Table 3-4 and illustrated in Figure 3-7. Flat Rock Creek weir is located downstream of the confluence of Quarry Creek and Flat Rock Creek, so it includes streamflow contribution from both creeks.

A similar analysis of the potential impact of the project on streamflow in Burnt Bridge Creek has been carried out and is presented in Table 3-4 and illustrated in Figure 3-7. It is predicted that in 2128 after 100 years of operation, the project would result in a one per cent reduction (20 kilolitres per day) in streamflow at Burnt Bridge Creek due to the predicted groundwater baseflow reduction at this location.

Table 3-4 Reduction in streamflow due to the predicted reduction in groundwater baseflow in 2128 based on the revised groundwater modelling

May 2018 streamflow measurement		Predicted groundwater baseflow				Predicted reduction in streamflow	
Location	Streamflow (kilolitres per day)	Without the project		With the project		With the project	
		(kilolitres per day)	% of streamflow	(kilolitres per day)	% of streamflow	(kilolitres per day)	%
Flat Rock Creek weir[1]	2337	1562	67%	1041	45%	-521	-22%
Burnt Bridge Creek downstream	1242	29	2%	9	1%	-20	-1%

Notes

1 Flat Rock Creek weir is located downstream of the confluence of Quarry Creek and Flat Rock Creek, therefore it includes streamflow from both creeks.

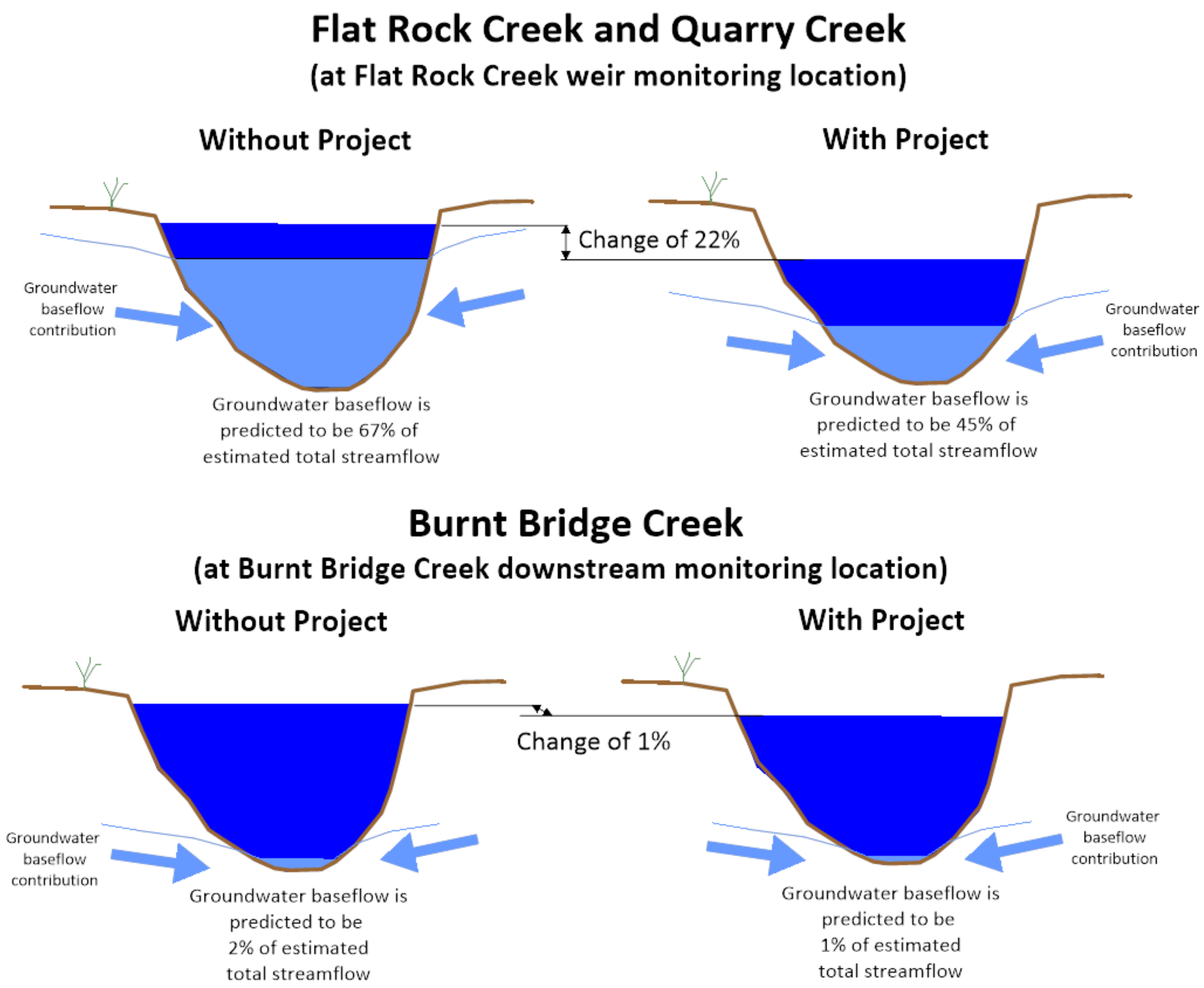


Figure 3-7 Illustration of the effect of the predicted reduction in groundwater baseflow on streamflow in 2128 (based on May 2018 streamflow measurements)

3.4 Environmental management measures

Transport for NSW has developed a suite of environmental management measures to mitigate the potential impacts of the construction and operation of the project and these are detailed in Table D2-1 of the submissions report. Environmental management measures that will be implemented to mitigate the potential impacts to groundwater include:

- As more information becomes available on groundwater levels and contamination through ongoing groundwater monitoring, groundwater modelling will be updated to refine the predictions. Inflow predictions will be updated prior to finalising detailed design and will include designed tunnel linings, and the detailed design will be updated based on the updated operational inflow and impact predictions.

  If refined predictions of groundwater levels and drawdown indicate that impacts would be greater than the impacts presented in the environmental impact statement, feasible and reasonable mitigation measures will be incorporated into the detailed design and implemented.

Groundwater modelling will be conducted considering *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012), including sensitivity analysis and consideration of future climate change, as required (refer to revised environmental management measure SG2)

- Following completion of environmental management measure SG2, a focussed study will be carried out in consultation with Department of Planning, Industry and Environment (Environment, Energy and Science Group) to confirm potential groundwater drawdown and associated baseflow reductions at Burnt Bridge Creek, Flat Rock Creek and Quarry Creek due to tunnelling, and confirm potential impacts on freshwater ecology in the affected watercourses and nearby groundwater dependent ecosystems. The study will consider how existing site features affect the interaction between surface water and groundwater along the affected reaches of these watercourses, and the hydraulic connectivity in the underlying geology. Where ecological impacts are predicted to be worse than that presented as part of the environmental impact statement/submissions report, feasible and reasonable mitigation measures to address the impacts will be identified in consultation with a suitably qualified and experienced specialist, incorporated into the detailed design, and implemented during construction. The mitigation measures considered will include tunnel linings (refer to revised environmental management measure SG6)
- Measures will be implemented during tunnel construction to ensure that groundwater inflows into each tunnel during the operation phase do not exceed 1L/s/km across any given kilometre (refer to revised environmental management measure SG16).

No changes to the environmental management measures listed in Table D2-1 of the submissions report are considered necessary based on the results of the revised groundwater modelling.

In addition to the above environmental management measures, during operation of the project, the proposed Gore Hill Freeway wastewater treatment plant would discharge into Flat Rock Creek via the local stormwater system at a rate of up to about 1425 kilolitres per day as outlined in Table 6-1 of Appendix O (Technical working paper: Surface water quality and hydrology). The proposed operational wastewater treatment plant discharge to Flat Rock Creek may offset the impact of the predicted reduction in baseflow to this creek given that the expected daily discharge volume to Flat Rock Creek from the wastewater treatment plant exceeds the revised predicted reduction in baseflow (526 kilolitres per day, refer to Table 3-3 above).

4 Revised environmental impact predictions

4.1 Freshwater ecology

A report to revise the findings in the environmental impact statement regarding the predicted reduction in groundwater baseflows to the freshwater ecology of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek has been prepared by Cardno and is provided in Attachment A. A summary of the findings is presented below.

4.1.1 Existing environment

Flat Rock Creek

Flat Rock Creek is a first order waterway upstream of the Quarry Creek confluence and a second order waterway downstream. It drains the Flat Rock Creek catchment into Middle Harbour and flows in a generally easterly direction from Marlow Road at Artarmon into Middle Harbour at Tunks Park at Cammeray. It is considered to be freshwater upstream of its confluence with Quarry Creek and estuarine downstream. At the time of inspection, moderate flow was observed downstream of Flat Rock Drive. Low flow was observed at its source but the creek was dry in some of its upper parts. There are many stormwater outlets along the length of Flat Rock Creek and at the time of inspection, these had low or non-existent flow. Flat Rock Creek is generally unlined and this includes the dry areas of the upper parts of the creek. Much of the middle section of the creek is lined with concrete as is the far downstream area flowing to an underground weir at Tunks Park.

Flat Rock Creek includes a mixture of shallow and deep pools and riffle/cascade zones in its upper and middle reaches before reaching the estuarine section.

The Riparian, Channel, and Environmental (RCE) scores for all of Flat Rock Creek were generally high. Where it is not underground or concrete lined, much of Flat Rock Creek has evidence of active bush regeneration and is dominated by native trees and shrubs. The riparian condition of much of the creek is either quasi-natural or only partly modified.

Quarry Creek

Quarry Creek is a second order waterway. It drains into the Flat Rock Creek catchment and subsequently into Middle Harbour. It generally flows in a north-easterly direction from Bridgeview Avenue, Cammeray into Tunks Park, Cammeray. It appears to be estuarine downstream of its confluence with Flat Rock Creek. Quarry Creek is shorter than Flat Rock Creek, has no stormwater outlets along its length and apart from the upper section, generally flows down a steep gradient. At the time of inspection, moderate flow was observed. Quarry Creek is generally unlined apart from the far upper part of the creek. Quarry Creek generally consists of riffle/cascade zones with few shallow or deep pools.

Most of Quarry Creek is among natural bushland and the RCE scores for all of Quarry Creek were generally good. The riparian condition of much of the creek is either quasi-natural or only partly modified.

Burnt Bridge Creek

Burnt Bridge Creek is a first order waterway in the Burnt Bridge Creek catchment which flows in a generally easterly direction from Clontarf Street, Seaforth to Kenneth Road, Manly where it enters Manly Lagoon. At the time of inspection, low flow was observed at its source. There are numerous stormwater outlets along the length of Burnt Bridge Creek and at the time of inspection, these had low or non-existent flow.

Burnt Bridge Creek is generally unlined apart from a small section upstream of the Burnt Bridge Creek Deviation and within the Balgowlah industrial area. It includes a mixture of shallow and deep pools and riffle/cascade zones in its upper and middle reaches before flowing into a concrete-lined culvert when it reaches the Balgowlah industrial area.

The RCE scores for Burnt Bridge Creek ranged from 17 (in the lower reaches within the Balgowlah industrial area) to 41 (in the upper reaches). Upstream of the Burnt Bridge Creek Deviation, the riparian corridor is considered quasi-natural. This area has evidence of active bush regeneration and is dominated by native trees and shrubs with frequent long deep pools, riffles and cascades. The riparian condition of the middle and downstream areas of the creek is either partially or highly modified. None of the riparian zones of Burnt Bridge Creek are dependent, either entirely or in part, on the presence of groundwater for their health and/or survival (refer to Appendix S (Technical working paper: Biodiversity development assessment report)).

Fish

No native fish species were caught or observed. Schools of the pest species Mosquito Fish (*Gambusia holbrooki*) were caught in the two collapsible bait traps deployed at site BB03 in Burnt Bridge Creek (ie the long, deep pool upstream of the weir, immediately downstream of the Burnt Bridge Creek Deviation).

Macroinvertebrates

The number of macroinvertebrate taxa collected in the Australian River Assessment System (AUSRIVAS sampling sites ranged between 10 and 36. Both the Observed to Expected ratio (OE50 - provides a measure of biological impairment at the site) and Stream Invertebrate Grade Number (SIGNAL2 – a scoring system for macroinvertebrates which gives an indication of water quality) scores indicated assemblages at all creeks were either severely or extremely impaired and suffered from severe pollution.

Water quality

Some sections of the creeks have undergone significant modifications to the original bedrock channel or alterations from natural channels to artificial, hard (concrete-lined) channels to accommodate higher volumes and flow velocities after rain, from an increase in urban, impervious surfaces. This hydrological alteration from natural conditions would be expected to promote the transport of sediments and contaminants to downstream receiving environments (eg Middle Harbour and Manly Lagoon).

Detailed analysis of water quality for Flat Rock Creek, Quarry Creek and Burnt Bridge Creek carried out for the environmental impact statement is provided in Appendix O (Technical working paper: Surface water quality and hydrology). The water quality of these three creeks was considered likely to be substantially influenced by the surrounding urban development. Sources of contaminants, such as suspended sediments, heavy metals and persistent organic pollutants include stormwater, wastewater overflows and leachate from contaminated lands.

Recent investigations of the water quality of Flat Rock Creek and Burnt Bridge Creek were carried out in March 2021 by ERM during a period of rainfall. These investigations confirmed the presence of some heavy metals and that nutrients (total nitrogen, reactive nitrogen and total phosphorous) were in excess of the ANZECC & ARMCANZ 2000 default guideline values for slightly to moderately disturbed ecosystems, defined as ecosystems in which “aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity” (Chapter 3 of ANZECC & ARMCANZ (2000)).

Further discussion on surface water quality is provided in Section 4.3.

Summary

The freshwater sections of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek all have depauperate (ie lacking in numbers of variety of species) assemblages of macroinvertebrates, non-existent assemblages of native fish and generally very few, if any, native macrophytes. The AUSRIVAS results suggest the freshwater ecology of the creeks is generally partially or severely impaired and affected by severe pollution. Sensitive macroinvertebrate groups such as *Ephemeroptera, Trichoptera* and *Plecoptera* were absent from all creeks. This is despite the riparian habitat of many parts of all of the creeks being in reasonable to good condition. Hence, although much of the freshwater reaches of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek appear to look healthy, the effect is aesthetic only and the freshwater ecology is considered to be generally poor.

The reasons for freshwater ecology being in such poor condition are likely to be a consequence of the following:

- Generally high levels of some nutrients and dissolved metals in the creeks (refer to Section 5 of Appendix N (Technical working paper: Groundwater))
- Regular scouring after heavy rain from torrents of stormwater (ie bare substratum in most shallow pools and a lack of aquatic habitat for macroinvertebrates in most pools generally, such as fine sand, gravel and detritus)

The presence of weirs in Flat Rock Creek and Burnt Bridge Creek, and steep cascades in all creeks, would prevent some species from colonising middle to upper reaches of creeks from downstream areas.

4.1.2 Impact assessment

Impact of groundwater drawdown to freshwater ecology

The revised groundwater modelling has allowed estimates of the project's predicted effects to the baseflow of the creeks to be refined. The refined estimates indicate baseflow would still be expected to be reduced by as much as 30 per cent to 63 per cent after 100 years, depending on the creek. Notwithstanding this, additional information about the relative contribution of baseflow to total streamflow suggests that for the most part, baseflow only represents a small proportion of total streamflow and reductions in streamflow would be less. The exception would be for some parts of Flat Rock Creek, but given there are significant stormwater inflows and an operational discharge into the creek of up to about 1425 kilolitres per day of good quality water from the project wastewater treatment plant during operation, there would be a net increase in flow in this creek.

Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report) considered that there would still be some (low) flow along the entirety of the creeks between rainfall events and additional studies have confirmed this would be the case after the effects of the project on baseflow are considered. The additional survey completed in May 2021 indicates the presence of pool habitats in most reaches of the creeks and that even in periods of low flow in dry periods in summer, it would be expected that many of these pools would be deep enough to retain water and therefore freshwater habitat. Notwithstanding the finding that assemblages of aquatic macroinvertebrates and fish are generally depauperate in the creeks, even in extremely dry times, some pools would be deep enough to provide refuge for aquatic macroinvertebrates, albeit only those species that are most tolerant to low flows.

Based on the evidence that changes to baseflow caused by groundwater drawdown would not substantially alter the flow regime after 100 years of operation in any of the creeks to the extent that it would alter instream habitat to already depauperate assemblages of aquatic macroinvertebrates, fish and macrophytes, it was concluded that the project would not significantly impact the freshwater ecology of Flat Rock Creek, Quarry Creek or Burnt Bridge Creek.

Impact of groundwater drawdown on riparian habitat

Where the creeks are not diverted underground, the general findings of the study indicate the riparian corridors of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek appear to be in good condition, with native vegetation dominating apart from the middle and downstream areas of Burnt Bridge Creek. Ongoing efforts of bush regeneration in the upper parts of Flat Rock Creek and Burnt Bridge Creek appear to have removed much of the weeds that had previously been noted in these areas during investigations for the environmental impact statement. Much of the riparian vegetation of Quarry Creek and in downstream areas of Flat Rock Creek depend on groundwater. It is expected that the additional creek flows from treated water from the operational wastewater treatment plant could partially feed the surrounding groundwater system. None of the riparian zones of Burnt Bridge Creek, including the project exclusion zone in its middle section, are dependent, either entirely or in part, on the presence of groundwater for their health and/or survival (refer to Appendix S (Technical working paper: Biodiversity development assessment report)).

4.1.3 Environmental management measures

As no impacts are expected on the freshwater ecology of Flat Rock Creek, Quarry Creek or Burnt Bridge Creek as a result of the revised predictions of groundwater baseflow reductions, no additional environmental management measures beyond those identified in Table D2-1 of the submissions report are required to manage these impacts.

4.2 Groundwater dependent ecosystems

A report to revise the finding in the environmental impact statement regarding the predicted reduction in groundwater baseflows to groundwater dependent ecosystems near the project has been prepared by Eco Logical Australia (refer to Attachment B). A summary of the findings is presented below.

4.2.1 Existing environment

A detailed account of the geology and hydrogeology of the project area is provided in Section 5.3 and Section 5.5 respectively of Appendix N (Technical working paper: Groundwater). Groundwater dependent ecosystems are discussed in Appendix S (Technical working paper: Biodiversity development assessment report).

The following groundwater dependent ecosystems are the focus of this revised assessment:

- Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, and Coastal Sand Forest in the mid reaches of Flat Rock Creek, about 280 metres south-east of the tunnel alignment and the Flat Rock Drive construction support site (BL2). These have been mapped as having a moderate to high potential for groundwater dependence (Bureau of Meteorology, 2018)
- A small patch of Coastal Upland Swamp in the Sydney Basin Bioregion, which is an endangered ecological community under the *Biodiversity Conservation Act 2016* and the *Environment Protection and Biodiversity Conservation Act 1999*. This is not mapped in the Groundwater Dependent Ecosystems Atlas (Bureau of Meteorology, 2018), but is potentially sensitive to changes in groundwater flow (Arcadis, 2020). Three patches occur in the project area: two about

95 metres west of the Wakehurst Parkway in Garigal National Park, and one north of Bantry Bay Oval, about 135 metres south-east of the construction footprint.

Most of the project area is underlain by the Hawkesbury Sandstone, with a small amount of localised fill or Quaternary sediment near Flat Rock Creek.

The Hawkesbury Sandstone is an unconfined aquifer at the surface, but becomes increasingly confined with depth because of the highly stratified nature of the sandstone and interbedded shales. Groundwater flow occurs mostly via secondary permeability and bedding.

The regional water table generally mimics the surface topography, with groundwater moving from high areas to low areas where they discharge to surface drainage lines. The water table varies from close to ground surface to 100 metres below ground level.

The Hawkesbury Sandstone was deposited in a fluvial paleo-environment, likely by a large braided river and as such is highly stratified. Localised perched water tables occur as a result of the stratified nature of the sandstone, which can be interspersed with lenses of low permeability that restrict the downward draining of water. This can mean that at some locations throughout the project area there are shallow perched water tables overlying a deeper water table.

Fractures in the sandstone create preferential flow paths for groundwater. Shallow or perched groundwater systems may discharge to surface water via shallow fracture networks, or may emerge from the sides of bare sandstone as springs.

Baseline ecological value and ecological condition

The value of a groundwater dependent ecosystem is determined by the biota it supports, as well as the processes performed by the ecosystem (Serov et al., 2012). Biota includes the flora, fauna and microbiota, while the processes performed include nutrient processing, hydrological filtration, and other biological, hydrological, physical, and chemical processes.

The ecological conditions of groundwater dependent ecosystems in the project area have been determined from information contained in Appendix S (Technical working paper: Biodiversity development assessment report) and subsequent field survey by the project terrestrial ecologists in June 2021.

Flat Rock Creek, Quarry Creek and Burnt Bridge Creek are all considered to be in a poor ecological condition, as they have a depauperate macroinvertebrate fauna, no native fish community, and very few if any native macrophytes (Cardno, 2021).

Flat Rock Creek

In the upstream reaches, Flat Rock Creek is modified and alternates between above and below-ground sections and has reaches where it is lined with either concrete or bedrock. In addition, this area is dominated by stormwater flows which have shaped the creek form. This part of the creek is not considered key fish habitat (Cardno, 2020; Cardno 2021). The channel is natural as it flows through Flat Rock Reserve, with the bed made of sandstone in the upstream section of reserve, and alluvium downstream. There are occasional ripples and pools, and the banks are steep in places, and range from three to 10 metres above the creek bed. The invertebrate fauna of Flat Rock Creek consists of 16-36 taxa which indicates that the creek is either severely or extremely impaired, and therefore is in poor ecological condition (Cardno, 2021).

Riparian vegetation is densely vegetated with generally native overstorey and an understorey of native and exotic species. Vegetation consists of PCT 1841 Smooth-barked Apple-Turpentine-Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region, with infestations of weeds and exotics in disturbed areas. The vegetation is likely to only provide marginal quality habitat for disturbance-tolerant species of amphibians, reptiles, mammals, invertebrates and birds (Cardno, 2020). There are numerous impediments to fish passage including underground sections bedrock bars and narrow pipe culverts, and there is little fauna habitat present in the form of logs, leaf litter or rocks. In the lower reaches of the creek immediately upstream of the Quarry Creek confluence, there is a small amount of instream timber that may provide fish habitat. Flat Rock Creek is considered to be in poor ecological condition (Cardno, 2021); therefore it is a low ecological value groundwater dependent ecosystem.

Downstream of the Quarry Creek confluence, Flat Rock Creek becomes estuarine and continues to receive stormwater discharge (like the mid to upper reaches). The bed consists of unconsolidated sediments and there is some channel and bank erosion. It remains aboveground.

Quarry Creek

Quarry Creek is a short (500 metre) waterway that joins Flat Rock Creek at Flat Rock Reserve. Quarry Creek begins at an altitude of 50 metres Australian Height Datum (AHD) and descends over a distance of 300 metres to an altitude of 10 metres AHD. The creek crosses the modelled groundwater contour (Jacobs, 2020) at an altitude of 30 metres, indicating that the final 300 metres of the creek is fed to varying degrees by groundwater.

Upstream of the confluence, Quarry Creek is a first order stream that flows through an underground culvert reach into a natural bedrock channel as part of Flat Rock Reserve. Vegetation along Quarry Creek is similar to that along Flat Rock Creek. Quarry Creek has a depauperate community of aquatic macroinvertebrates (10-25), with those taxa present indicating extreme or severe levels of impact on the ecology (Cardno, 2021). The creek is considered a low ecological value groundwater dependent ecosystem.

Burnt Bridge Creek

Burnt Bridge Creek is a first order waterway that is intermittent and receives stormwater input from multiple locations. It was not identified as being groundwater dependent in the *Groundwater Dependent Ecosystems Atlas* (Bureau of Meteorology, 2018), but receives some of its contribution from groundwater (Jacobs, 2020). The creek has low dissolved oxygen concentration and elevated heavy metal and nutrient concentrations (Cardno, 2020). The channel consists of bedrock with sand and silt patches and rocky outcrops. Pools are partially connected and contain exotic in-stream vegetation and moderate riparian shading. Burnt Bridge Creek is likely to provide only marginal quality habitat suitable for disturbance tolerant species. There is minimal structural habitat (rocks, logs, leaf litter) and water quality is poor (Cardno, 2020). The freshwater ecology of Burnt Bridge Creek is severely or extremely impaired, with 14-24 taxa (Cardno, 2021). Therefore it is considered a low ecological value groundwater dependent ecosystem.

Riparian vegetation ranges in width from 0 to 30 metres and consists of Water Gum-Coachwood riparian scrub that has a mix of native and exotic species. The area has been significantly disturbed and contains weeds and large areas of exposed ground.

Groundwater dependent vegetation communities of Flat Rock Reserve

A patch of Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest extends for about one kilometre in the middle reaches of Flat Rock Creek. The vegetation is in moderate to good condition and contains mostly native species (*Eucalyptus spp., Angophora costata, Allocasuarine littoralis*) on the upper or mid-slopes, but is dominated by exotic species in the flatter areas beside the creek. Vegetation in the gully closer to the creek is sheltered and appears to be in good condition with no signs of stress. Palms and ferns occur on the lower flat beside the creek. This groundwater dependent ecosystems is considered a moderate ecological value groundwater dependent ecosystem.

Coastal Upland Swamps

Coastal Upland Swamps in the Sydney Basin Bioregion are listed as an endangered ecological community under the *Biodiversity Conservation Act 2016* and the *Environment Protection and Biodiversity Conservation Act 1999*. This makes them a high ecological value groundwater dependent ecosystem. This vegetation community occurs on poorly permeable sandstone plateaux in low relief headwater valleys of streams and on sandstone benches with abundant seepage moisture (Department of the Environment, 2014). Coastal Upland Swamps generally occur in small patches of less than a hectare (Department of the Environment, 2014). There is small patch of swamp west of the Wakehurst Parkway in Garigal National Park, and another small patch north of Bantry Bay Oval. During a site visit to this swamp in 2021, ecologists found it difficult to delineate the swamp from the surrounding heathland.

4.2.2 Impact assessment

Terrestrial vegetation communities of Flat Rock Creek and Quarry Creek

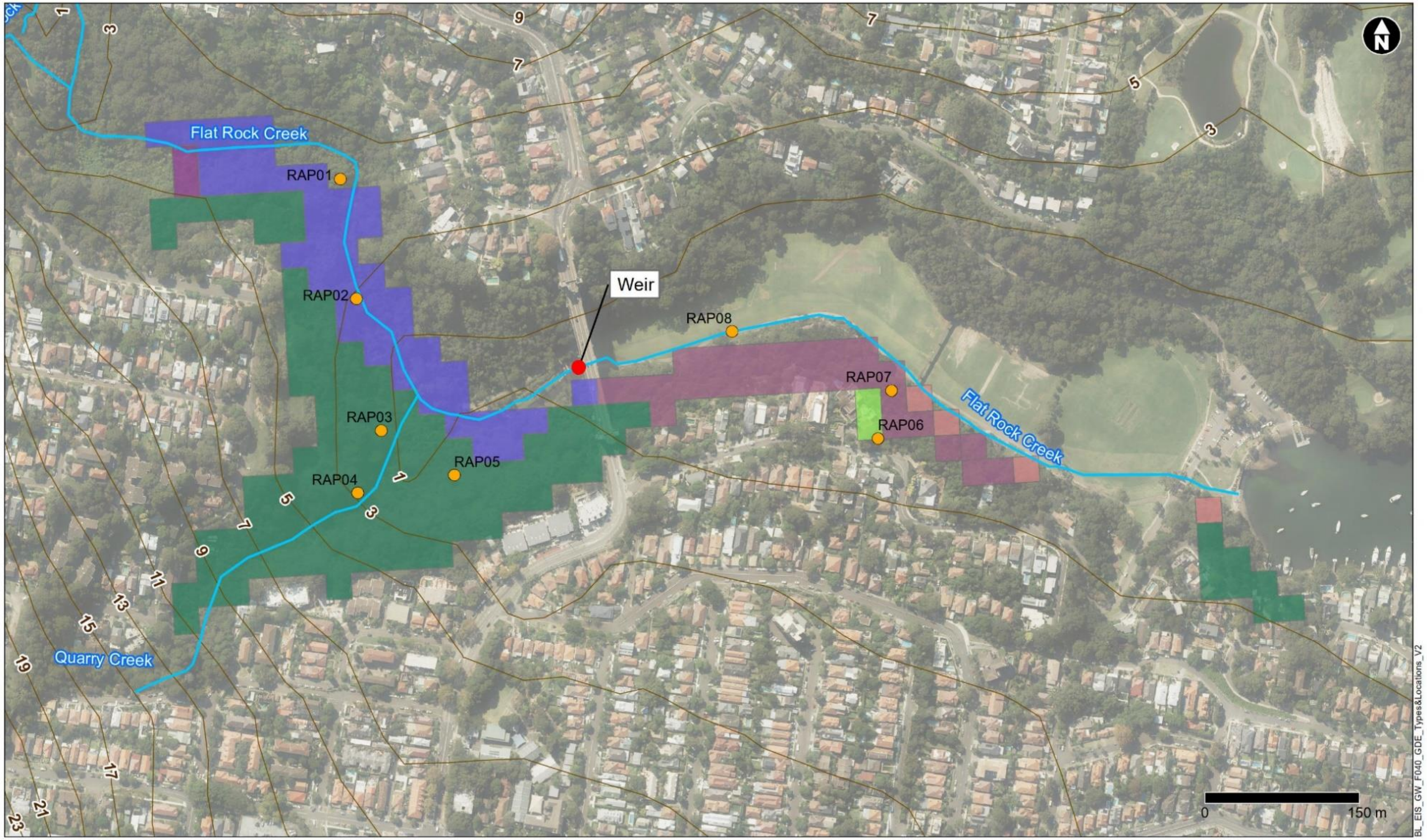
About 10.5 hectares of Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest is within the area subject to groundwater drawdown around Flat Rock Creek as shown in Figure 4-1. Drawdown beneath this vegetation is predicted to be less than five metres at the upstream end of Flat Rock Creek, about 11 metres at the upstream end of Quarry Creek, and less than one metre at the confluence of Flat Rock Creek and Quarry Creek. Vegetation growing on the upper slopes of the sandstone ridges is likely to be supported by perched aquifers that are isolated from the regional water table. Drawdown in the regional aquifer is therefore likely to have minor spatial impacts on vegetation health, so the magnitude of risk would be small given that the vegetation community is not solely dependent on regional groundwater.

The small alluvial aquifer of Flat Rock Creek at the Quarry Creek confluence would be recharged by the releases of up to about 1425 kilolitres per day of treated water from the project operational wastewater treatment plant discharge into Flat Rock Creek at Artarmon. This may replace any baseflow losses and sustain vegetation communities dependent on groundwater in the shallow alluvium.

Coastal Upland Swamp

Groundwater drawdown beneath the section of coastal upland swamp beside Wakehurst Golf Club is modelled to be less than three metres. Regional water level is about 50 metres below ground level, so this swamp is likely to be connected to perched water tables rather than the regional aquifer. Perched aquifers are predominantly fed by localised rainwater, or from downward drainage from upslope aquifers. It is unlikely that this section of upland swamp would be affected by drawdown from the project.

Drawdown beneath the swamp west of the Wakehurst Parkway is modelled to be between zero and one metre by 2128. The groundwater dependence of this swamp is uncertain, as the water level is about 10 metres below ground level. The water table beneath this swamp may be affected by drawdown, but it is likely that the swamp also receives water from surface runoff and subsurface drainage from upslope perched aquifers, and that the availability of this water to support the swamp would not be affected.



Legend

Groundwater Dependent Ecosystems (Bureau of Meteorology, 2018)

- Coastal Sand Forest
- Coastal Sandstone Gully Forest
- Coastal Sandstone Plateau Heath
- Estuarine Fringe Forest
- Illawarra Gully Wet Forest
- Sandstone Riparian Scrub
- Rapid Assessment Point
- Drawdown contours
- Creek

Figure 4-1 Groundwater dependent ecosystems at Flat Rock Creek and predicted groundwater drawdown after 100 years of operation

4.2.3 Environmental management measures

The risk assessment considered recommended management actions for the identified groundwater dependent ecosystems, taking into consideration the existing ecological conditions. The assessment found that:

- As the ecological condition of the creeks is already poor, the ongoing ecological monitoring of these waterways is unlikely to indicate whether baseflow loss would have an impact
- The release of treated water into Flat Rock Creek from the operational wastewater treatment plant at Artarmon would compensate for the water lost through groundwater drawdown and ensure that pool and riffle habitats in middle reaches of Flat Rock Creek, which are classified as Type 1 key fish habitat, are able to persist and maintain their ecological functions
- There is a very low risk that the Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, and Coastal Sand Forest ecosystems around Flat Rock Creek would be impacted by groundwater drawdown, particularly the vegetation growing close to the creek where flow would be supplemented from the operational wastewater treatment plant
- Vegetation communities on the sandstone slopes of Flat Rock Creek Gully are likely to be buffered against the impacts of groundwater drawdown by shallow perched aquifers. These aquifers are recharged by rainfall and surface runoff, and in the upper slopes of the gully, may be disconnected from the deeper regional aquifer
- Given the uncertainty of whether the two patches of Coastal Upland Swamp around Wakehurst Parkway are groundwater dependent, and the low likelihood that they will be impacted by the project, no specific monitoring of these ecosystems is recommended.

Further investigation and monitoring of the potential water table drawdown impacts on groundwater baseflow and groundwater dependent ecosystems will be carried out during further design development in line with revised environmental management measure SG6:

> *Following completion of environmental management measure SG2, a focussed study will be carried out in consultation with Department of Planning, Industry and Environment (Environment, Energy and Science Group) to confirm potential groundwater drawdown and associated baseflow reductions at Burnt Bridge Creek, Flat Rock Creek and Quarry Creek due to tunnelling, and confirm potential impacts on freshwater ecology in the affected watercourses and nearby groundwater dependent ecosystems. The study will consider how existing site features affect the interaction between surface water and groundwater along the affected reaches of these watercourses, and the hydraulic connectivity in the underlying geology. Where ecological impacts are predicted to be worse than that presented as part of the environmental impact statement/submissions report, feasible and reasonable mitigation measures to address the impacts will be identified in consultation with a suitably qualified and experienced specialist, incorporated into the detailed design, and implemented during construction. The mitigation measures considered will include tunnel linings.*

4.3 Surface water quality

4.3.1 Existing environment

An assessment of existing surface water quality and potential impacts from the construction and operation of the project was provided in Appendix O (Technical working paper: Surface water quality). The findings from the revised groundwater modelling predictions have been used to inform the revised assessment presented below.

Flat Rock Creek

Background water quality data collected during preparation of the environmental impact statement indicated that Flat Rock Creek experiences elevated nutrients (Oxidised Nitrogen (NO_x)), Total Nitrogen (TN), Total Phosphorus (TP) and metals (Copper and Zinc) at the upstream reach. Also, pH levels also frequently fell outside the ANZG (2018) guidelines limits of 6.5-8 due to elevated pH (>8.5). Downstream, pH levels were generally lower and compliant. However, nutrients and metals were still elevated, and generally higher downstream. Recent sampling carried out in January and February 2021 shows that pH is still elevated and exceeds upper limit for protection of freshwater ecosystems. Turbidity and total suspended solids concentrations were generally low which was complemented by clear, highly transparent water. Nutrients, whilst still exceeding the guidelines, were recorded in much lower concentrations than during previous investigations carried out for the environmental impact statement. Copper and zinc concentrations in January and February 2021 also exceeded the guidelines however were recorded in higher concentrations compared to previous monitoring. Zinc was generally double the median concentration previously recorded with the exception of the downstream site in February 2021 where concentrations in Flat Rock Creek were 100 times the guideline limit and 18 times greater than median concentrations previously recorded at this site during the environmental impact statement investigations.

Quarry Creek

Quarry Creek is a tributary of Flat Rock Creek which flows into Long Bay in Middle Harbour. Background water quality data collected during the environmental impact statement phase showed that similarly to Flat Rock Creek, Quarry Creek has elevated nutrient and metal concentrations with NO_x, TN, TP, copper and zinc all exceeding the recommended guideline limits (ANZG, 2018) for protection of estuarine aquatic ecosystems. Dissolved oxygen and iron were also recorded outside guideline limits on occasion. More recent monitoring has not been carried out at Quarry Creek.

Burnt Bridge Creek

Data collected during preparation of the environmental impact statement indicated that Burnt Bridge Creek exhibits poor water quality that does not meet the required limits for protection of freshwater ecosystems due to low dissolved oxygen concentrations, and elevated copper, zinc, TN and NO_x, with concentrations generally higher upstream. Additionally, lead, iron and TP also frequently exceeded the recommended limits at the upstream site in Burnt Bridge Creek.

Recent sampling carried out in January and February 2021 shows that dissolved oxygen levels are higher and pH is generally compliant with the recommended guideline limits (ANZG, 2018), with the exception of pH in February 2021 at the downstream site which exceeded the upper limit. Nutrient concentrations in Burnt Bridge Creek have decreased significantly, particularly at the downstream site since monitoring carried out during preparation of the environmental impact statement, although still exceeded the recommended guidelines for NOx and TN in February 2021, and TP in January and February 2021. Metal concentrations in Burnt Bridge Creek are generally compliant with the recommended guideline limits (ANZG, 2018) with the exception of copper and zinc which continue to exceed the recommended limits of protection of freshwater ecosystems. Copper concentrations were generally lower than median concentrations recorded in the investigations carried out during the preparation of the environmental impact statement.

4.3.2 Impact assessment

Impact of groundwater drawdown on surface water quality

The water quality of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek is generally poor due to elevated nutrients and metals as discussed in Section 4.3.1. As outlined in Section 3.2and

Section 3.3, baseflow in Quarry Creek and Burnt Bridge Creek and the upstream section of Flat Rock Creek is a very small proportion of surface flow. As such, the predicted drawdown estimated is unlikely to influence surface water quality at these sites.

Streamflow in Flat Rock Creek at the weir and downstream is made up of a greater proportion of groundwater baseflow which may influence the current water quality condition in the creek which is generally poorer downstream. Groundwater quality as reported in Appendix O (Technical working paper: Surface water quality and hydrology) documented that groundwater bores in the area exhibit elevated concentrations of metals and nutrients, which together with runoff, are the likely cause of the poor water quality observed. The predicted reduction in groundwater baseflow in this section of Flat Rock Creek may also result in a reduction of poor quality groundwater entering surface water which over time may result in a reduction of metal and nutrient concentrations in Flat Rock Creek. Additionally, Flat Rock Creek is to receive treated wastewater during the operation of the project that would be of a better quality than is currently observed. As a result, it would be expected that this could lead to improved water quality during the operational phase of the project.

Impact of groundwater drawdown on achieving the NSW Water Quality Objectives

During the operation of the project, there would be minimal change in baseflow reduction in Quarry Creek and Burnt Bridge Creek and upstream Flat Rock Creek. Therefore, the estimated drawdown in groundwater would not affect achieving the nominated water quality objectives of freshwater ecosystems, visual amenity and secondary contact recreation.

The predicted reduction in groundwater baseflow could result in a reduction of nutrient and metal concentrations in Flat Rock Creek. This reduction, combined with discharge of treated wastewater to a level that is consistent with the guidelines specified in revised environmental management measure WQ17 (refer to Table D2-1 of the submissions report), could slightly improve water quality and contribute to achieving the nominated water quality objectives of protection of aquatic ecosystems, visual amenity and secondary contact recreation.

4.3.3 Environmental management measures

No additional environmental management measures beyond those identified in Table D2-1 of the submissions report are considered necessary to manage the expected surface water quality impacts resulting from the project.

4.4 Social and community values

4.4.1 Existing environment

An assessment of existing social and community values and potential impacts from the construction and operation of the project was provided in Appendix U (Technical working paper: Socio-economic assessment).

The socio-economic assessment recognises the importance of Flat Rock Reserve to local communities and community concerns about potential impacts on water quality in Flat Rock Creek. The importance of this area for its local amenity and the physical and mental health and wellbeing of local and regional communities were reiterated in submissions made by community members on the environmental impact statement. Submissions on the EIS identified the importance of Flat Rock Reserve to local communities due to its active and passive recreation opportunities; the landscape, scenic and amenity values offered by the bushland, green space and waterways; and the habitat it provides for flora and fauna

Burnt Bridge Creek Bushland Reserve is a riparian corridor that runs along Burnt Bridge Creek between Seaforth and North Balgowlah. The reserve is important to local and regional communities for its natural, visual and recreational values (Manly Council, undated). This was confirmed in submissions on the environmental impact statement, which identified Burnt Bridge Creek as a place that is valued by the community for its natural environment and bushland, wildlife, contribution to local amenity, and recreational uses.

4.4.2 Impact assessment

Submissions on the environmental impact statement about Flat Rock Creek and Quarry Creek mainly related to concerns about potential impacts on aquatic habitats and groundwater dependent ecosystems. As confirmed in Section 4.1 and Section 4.2 above, the revised assessment has confirmed that the project would not result in negative impacts to the flora and fauna.

Submissions on the environmental impact assessment raised several issues relating to potential impacts on community values associated with changes in groundwater flow in Flat Rock Creek and Burnt Bridge Creek.

Socio-economic issues raised in submissions about potential impacts of the project on Flat Rock Creek included concerns about:

- Negative impact of construction activities on Flat Rock Creek water quality and the potential reduction in recreation opportunities
- Loss of greenspace and the recreational values of the natural environment at Flat Rock Reserve.

Socio-economic issues raised in submissions relating to Burnt Bridge Creek included concerns about:

- The loss of community values due to reduced flows in Burnt Bridge Creek
- Potential for water loss to impact local amenity, and the recreational values of the creek environment for dog walkers, commuters, and bike riders
- Impacts on the environment of Burnt Bridge Creek negatively affecting the well-being of local residents and resulting in the loss of lifestyle
- Cost associated with the removal of dead trees that result from water loss within the creek.

As discussed in Section 3, the revised groundwater modelling carried out for the project has found that changes to groundwater baseflow caused by groundwater drawdown would not substantially alter the flow regime within Flat Rock Creek, Quarry Creek and Burnt Bridge Creek and that adverse impacts on freshwater ecology, groundwater dependent ecosystems and surface water quality are not expected. As noted in Section 4.2.2, the small alluvial aquifer of Flat Rock Creek at the Quarry Creek confluence would be recharged by the releases of up to about 1425 kilolitres per day of treated water from the project operational wastewater treatment plant discharge into Flat Rock Creek at Artarmon. This may replace any baseflow losses and sustain vegetation communities dependent on groundwater in the shallow alluvium.

Consequently, impacts of the project associated with changes to groundwater baseflow on the natural environment and community values are not expected. Flat Rock Creek, Quarry Creek and Burnt Bridge Creek of Flat Rock Reserve would continue to provide local amenity and recreational uses and contribute to the physical and mental health and wellbeing of local and regional communities.

The socio-economic assessment in Section 21.4.5 of the environmental impact statement identified that there would be adverse changes in visual amenity, local character and health and wellbeing in some locations due to the presence of construction works and vegetation clearing within the construction footprint. As required by environmental management measure V11, all areas disturbed by construction and not required for operation of the project will be restored as soon as practicable to their existing condition or in accordance with the urban design and landscape plan where applicable (environmental management measure V1).

4.4.3 Environmental management measures

No additional environmental management measures beyond those identified in Table D2-1 of the submissions report are considered necessary to manage the potential socio-economic impacts resulting from the project.

5 Conclusion

5.1 Summary of findings

The revised groundwater modelling predicts groundwater drawdown levels and groundwater baseflow reductions at Flat Rock Creek and Quarry Creek that are similar to those presented in the environmental impact statement. The revised predicted groundwater drawdown level and groundwater baseflow reduction at Burnt Bridge Creek is less than that predicted in the environmental impact statement.

The revised assessments of impacts to freshwater ecology, groundwater dependent ecosystems, surface water quality and social and community values at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek are also similar to the findings in the environmental impact statement.

5.1.1 Revised groundwater modelling results

The revised groundwater modelling predicts groundwater baseflow reductions in 2128 with the project of 30 per cent, 63 per cent and 60 percent for Flat Rock Creek, Quarry Creek and Burnt Bridge Creek respectively. The revised predictions for Flat Rock Creek and Quarry Creek are similar to those contained in the environmental impact statement of 39 per cent and 69 percent respectively. The revised prediction for Burnt Bridge Creek is less than the 96 per cent groundwater baseflow reduction predicted for this creek in the environmental impact statement.

Considering the available streamflow data collected in May 2018 during a drought period, the predicted reduction in groundwater baseflow to Burnt Bridge Creek in 2128 would only result in about a one per cent reduction in streamflow, which is a negligible impact. Applying the same approach to the downstream reaches of Flat Rock Creek, the project would result in about a 22 per cent reduction in streamflow in 2128. In periods that had more rainfall leading up to and during May 2018, there would be more surface water runoff into the creeks and the predicted reduction in groundwater baseflow would result in a smaller reduction in streamflow than predicted.

While the revised groundwater modelling and groundwater baseflow reduction predictions are based on the additional information on streambed lining obtained during the May 2021 field survey, they remain conservative due to:

- Predicted inflows to the tunnels being controlled by the permeability of the surrounding geological formation
- Full hydraulic connectivity being assumed between the creek and the surrounding groundwater system at the tunnel depth.

The groundwater environmental management measures in Table D2-1 of the submissions report will address the potential impacts discussed in this assessment including:

- Following completion of environmental management measure SG2, a focussed study will be carried out in consultation with Department of Planning, Industry and Environment (Environment, Energy and Science Group) to confirm potential groundwater drawdown and associated baseflow reductions at Burnt Bridge Creek, Flat Rock Creek and Quarry Creek due to tunnelling, and confirm potential impacts on freshwater ecology in the affected watercourses and nearby groundwater dependent ecosystems. The study will consider how existing site features affect the interaction between surface water and groundwater along the affected reaches of these watercourses, and the hydraulic connectivity in the underlying geology. Where ecological impacts are predicted to be worse than that presented as part of the environmental impact statement/submissions report, feasible and reasonable mitigation measures to address the impacts will be identified in consultation with a suitably qualified and experienced specialist, incorporated into the detailed design, and implemented during construction. The mitigation measures considered will include tunnel linings. (refer to revised environmental management measure SG6)

- Measures will be implemented during tunnel construction to ensure that groundwater inflows into each tunnel during the operation phase do not exceed one litre per second per kilometre across any given kilometre (refer to revised environmental management measure SG16).

The small alluvial aquifer of Flat Rock Creek and at the Quarry Creek confluence would be recharged by the releases from the project operational wastewater treatment plant discharge into Flat Rock Creek at Artarmon. This would sustain vegetation communities dependent on groundwater in the shallow alluvium.

5.1.2 Freshwater ecology

The freshwater sections of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek all have depauperate (ie lacking in numbers of variety of species) assemblages of macroinvertebrates, non-existent assemblages of native fish and generally very few, if any, native macrophytes. The AUSRIVAS results suggest the freshwater ecology of the creeks was generally partially or severely impaired and affected by severe pollution. Sensitive macroinvertebrate groups such as *Ephemeroptera, Trichoptera* and *Plecoptera* were absent from all creeks.

The riparian habitat of many parts of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek is generally in reasonable, if not good condition. However, although much of the freshwater reaches of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek appear to look healthy, the effect is aesthetic only and the freshwater ecology is considered to be generally poor.

The revised groundwater modelling predictions have confirmed that changes to baseflow caused by groundwater drawdown would not substantially alter the flow regime in any of the creeks. Instream habitat is already in poor condition and is not expected to be altered by the predicted groundwater drawdown. Consequently, the project would not significantly impact the freshwater ecology of Flat Rock Creek, Quarry Creek or Burnt Bridge Creek.

5.1.3 Groundwater dependent ecosystems

As a consequence of the poor ecological condition of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, all three creeks have been assessed as being low ecological value groundwater dependent ecosystems. The groundwater dependent vegetation communities of Flat Rock Reserve are considered to be a moderate ecological value groundwater dependent ecosystem.

There are small patches of Coastal Upland Swamps west of the Wakehurst Parkway in Garigal National Park, and another small patch north of Bantry Bay Oval, which are considered to be high ecological value groundwater dependent ecosystem.

Drawdown in the regional aquifer is likely to have minor impacts on vegetation health, so the magnitude of risk to vegetation communities of Flat Rock Creek would be small given that the vegetation community is not solely dependent on groundwater.

The small alluvial aquifer of Flat Rock Creek at the Quarry Creek confluence would be recharged by the releases from the project operational wastewater treatment plant discharge into Flat Rock Creek at Artarmon. This would sustain vegetation communities dependent on groundwater in the shallow alluvium.

Due to the separation between regional water levels and the section of Coastal Upland Swamp beside Wakehurst Golf Club, it is unlikely that this section of upland swamp would be affected by drawdown from the project.

The groundwater dependence of the swamp west of the Wakehurst Parkway is uncertain, as the water level is about 10 metres below ground level. The water table beneath this swamp may be affected by drawdown, but it is likely that the swamp also receives water from surface runoff and subsurface drainage from upslope perched aquifers, and that the availability of this water to support the swamp would not be affected.

5.1.4 Surface water quality

The water quality of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek is generally poor due to elevated nutrients and metals. Baseflow in Quarry Creek and Burnt Bridge Creek and the upstream section of Flat Rock Creek is a very small proportion of surface flow and therefore is unlikely to influence surface water quality. As such, the minimal drawdown estimated is unlikely to influence surface water quality at these sites, and would not impact on achieving the nominated water quality objectives of freshwater ecosystems, visual amenity and secondary contact recreation.

The predicted reduction in baseflow in Flat Rock Creek at the weir and downstream may result in a reduction of poor quality groundwater entering surface water which over time may result in a reduction of metal and nutrient concentrations in Flat Rock Creek. Additionally, Flat Rock Creek is to receive treated wastewater during the operation of the project that would be of a better quality than is currently observed. Overall, it is expected that this could slightly improve water quality over time, which could contribute to achieving the nominated water quality objectives.

5.1.5 Social and community values

The revised groundwater modelling has found that changes to baseflow caused by groundwater drawdown would not substantially alter the flow regime within Flat Rock Creek, Quarry Creek and Burnt Bridge Creek and that adverse impacts on freshwater ecology, groundwater dependent ecosystems and surface water quality are not expected. Consequently, any changes in water flows are not expected to impact on the natural environment, residential amenity and recreational uses associated with these creeks.

5.2 Recommended environmental management measures

The revised groundwater modelling and associated revised environmental impact assessments have confirmed that the environmental management measures presented in Table D2-1 of the submissions report are sufficient to manage the potential impacts of the project. Therefore no additional environmental management measures are required.

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Attachment A. Assessment of baseflow changes in freshwater creeks (Cardno, 2021)

Executive Summary

Cardno (NSW/ACT) Pty Ltd, was commissioned by Transport for NSW to prepare a more detailed ecological assessment of the potential effects on aquatic ecosystems due to changes to baseflows at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek predicted to occur as a result of groundwater drawdown 100 years following the opening of the Beaches Link and Gore Hill Freeway Connection project (the project). This was in response to a number of agency and community submissions on the project's environmental impact statement which had queried the predicted groundwater impacts to these creeks.

The scope of work involved field investigations at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to:

> Assess the quantity, type and condition of aquatic habitat (eg pools and riffles) and riparian vegetation

> Assess the type and condition of assemblages of macrophytes, fish and macroinvertebrates.

This data from the field investigation was then interpreted in combination with existing water quality, surface flow, wastewater discharge volumes from operational waste water treatment plants and ecological information that had already been collected for the environmental impact statement, as reported in Appendix N (Technical working paper: Groundwater), Appendix O (Technical working paper: Surface water quality and hydrology), Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report), recent investigations of surface water quality for Burnt Bridge Creek and Flat Rock Creek by ERM (2021) and further inputs from the project groundwater specialist.

Burnt Bridge Creek is generally unlined apart from a small section upstream of the Burnt Bridge Creek Deviation and within the Balgowlah industrial area. It includes a mixture of shallow and deep pools and cascade/riffle zones in its upper and middle reaches before becoming essentially a concrete-lined culvert that runs through the Balgowlah industrial area to Manly Lagoon. Upstream of the Burnt Bridge Creek Deviation the riparian corridor could be considered 'quasi natural, with frequent long deep pools, riffles and cascades. Ongoing efforts of bush regeneration appear to have removed much of the weeds that had previously been noted in this part of Burnt Bridge Creek during investigations for the environmental impact statement. The riparian condition of the middle and downstream areas of the creek is either partially or highly modified. Flat Rock Creek and Quarry Creek also include a mixture of shallow and deep pools and cascade/riffle zones in their upper and middle reaches before reaching the estuarine section. The riparian corridors of these two creeks are also generally good and the results of active bush regeneration in Flat Rock Creek were also notable.

Stormwater flows have a considerably large influence on all three creeks, generally scouring the bedrock base and removing coarse and fine sediments. Very few instream macrophytes were recorded in the creeks and there were no native fish observed or caught. AUSRIVAS analyses indicated macroinvertebrate assemblages at all creeks were either severely or extremely impaired and suffered from severe pollution.

Indicative dry period flow measurements taken in 2017 indicate that baseflow is generally small (<30 kilolitres per day) for many areas of the creeks. Baseflow only makes up less than one per cent of total stream flow in upstream areas of Flat Rock Creek and generally less than six per cent at Quarry Creek and Burnt Bridge Creek. In these areas, most of the total stream flow would be expected to be coming from stormwater input from various points. In dry periods, even though groundwater drawdown from the project is predicted to reduce baseflow by between 25 per cent and 67 per cent, this would generally equate to less than three per cent reduction to total stream flow for the upstream part of Quarry Creek and both the mid-stream and downstream parts of Burnt Bridge Creek. After rainfall, given baseflow is likely to be an insignificant proportion of the total stream flow, due to an increased contribution from stormwater, any changes from the project to baseflow in the upstream parts of Flat Rock Creek and Quarry Creek and for most parts of Burnt Bridge Creek would be negligible.

Along the downstream sections of Flat Rock Creek, baseflows are estimated to comprise larger proportions of total stream flow, at 67 per cent to 79 per cent respectively, meaning that any reductions to baseflow resulting from groundwater drawdown in these areas has potential to be a larger proportion of total stream flow than for upper Flat Rock Creek or for the other two creeks. During dry periods, at the downstream area of Flat Rock Creek and at the weir, groundwater drawdown in dry periods would be expected to reduce total stream flow by 27 per cent and 22 per cent respectively. Notwithstanding this, others factors would potentially mitigate or offset these effects. The high dry period stream flows in these areas mean that reasonable flows would be maintained despite the effects of groundwater drawdown, and, at the weir, where there is an estuarine influence, any changes to stream flow would be inconsequential relative to tidal influence.

Further, Flat Rock Creek would also receive a maximum of 1425 kilolitres per day of treated wastewater from the operational wastewater treatment plant. Although a portion of this discharge will potentially be directed to Council assets for external use, the remainder would be expected to result in a net increase in total stream

flow generally from the project. The discharged wastewater will be treated to meet ANZG (2018) 95 per cent species protection levels for estuarine and lowland river ecosystems for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels, and the draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water).

The freshwater sections of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek all had depauperate assemblages of macroinvertebrates, non-existent assemblages of native fish and generally very few, if any, native macrophytes. This is despite the riparian habitat of many parts of all of the creeks being in reasonable, if not good condition, and containing mostly native vegetation, again as a consequence of the effects of recent bush regeneration and weed management. Hence, although much of the freshwater reaches of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek appear to look good to the 'naked eye' due to reasonable or good quality riparian corridors, the effect is 'aesthetic only' and the aquatic ecology can be considered to be generally poor.

The reasons for aquatic ecology being in such poor condition are not clear but are likely to be a consequence of the following factors:

> Generally high levels of some nutrients and dissolved metals in the creeks (see Appendix N (Technical working paper: Groundwater) and recent investigations by ERM (2021))

> Regular scouring after heavy rain from torrents of storm water (ie bare substratum in most shallow pools and a paucity of aquatic habitat for macroinvertebrates in most pools generally, such as fine sand, gravel and detritus)

> The presence of weirs in Flat Rock Creek and Burnt Bridge Creek, and steep cascades in all creeks, that would prevent some species from colonising middle to upper reaches of creeks from downstream areas.

Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report) considered that there would still be some (low) flow along the entirety of the creeks between rainfall events and additional studies have confirmed this would be the case after the effects of the project on baseflow are considered. Further, detailed field investigations indicate the presence of pool habitats in most reaches of the creeks and that even in periods of low flow in dry periods in summer it would be expected that many of these pools would be deep enough to retain water and hence aquatic habitat. Notwithstanding the finding that assemblages of aquatic macroinvertebrates and fish are generally depauperate in the creeks, even in extremely dry times some pools would be deep enough to provide refuge for aquatic macroinvertebrates, albeit only those species that are most tolerant to low flows.

It is noted that none of the riparian zones of Burnt Bridge Creek, including the exclusion zone in its middle section are dependent, either entirely or in part, on the presence of groundwater for their health and/or survival. Much of the riparian vegetation of Quarry Creek and in downstream areas of Flat Rock Creek depend on groundwater and a revised assessment of impacts to GDEs is provided in Attachment B of Annexure G of this updated biodiversity assessment.

Given the above, it is considered that changes to baseflow caused by groundwater drawdown would not substantially alter the flow regime after 100 years in any of the creeks to the extent that it would alter instream habitat to already depauperate assemblages of aquatic macroinvertebrates, fish and macrophytes. Based on this evidence, it can be concluded that the findings are generally consistent with the environmental impact statement and that the project would not significantly impact the aquatic ecology of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek.

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1 Introduction

1.1 Background and previous investigations

As part of the environmental impact statement, predicted changes to the baseflows of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, as a result of groundwater drawdown during construction and operation of Beaches Link and Gore Hill Freeway Connection project (the project) were presented in Appendix N (Technical working paper: Groundwater). Cardno considered these changes in combination with investigations of the existing environment to make predictions of potential ecological impacts in the creeks (Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report)). These studies were carried out to comply with the project Secretary's environmental assessment requirements dated 22 April 2020 which identified the following key issue and desired performance outcome in relation to aquatic biodiversity as:

"6. Biodiversity

The project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity."

Requirement 6(8) of the Secretary's environmental assessment requirements states:

"Impacts on biodiversity values that cannot be assessed using the Biodiversity Assessment Method (BAM) must also be otherwise assessed".

As described in Appendix N (Technical working paper: Groundwater), surface environmental water availability and flows have the potential to be reduced at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek as a result of worst case groundwater drawdown for the project by a maximum of:

> 20 per cent reduction in baseflow at Flat Rock Creek at the end of construction and 96 per cent reduction after about 100 years of operation

> 23 per cent reduction in baseflow at Quarry Creek at the end of construction and 69 per cent reduction after about 100 years of operation

> 79 per cent reduction in baseflow at Burnt Bridge Creek at the end of construction and 96 per cent reduction after about 100 years of operation.

As groundwater inflows to tunnels during project construction and operation would be collected, treated and discharged to Flat Rock Creek, and during construction to Burnt Bridge Creek, this was expected to largely offset baseflow reduction to these watercourses at those times (see Appendix N (Technical working paper: Groundwater)). The environmental impact statement considered that given baseflows in Flat Rock Creek, Quarry Creek and Burnt Bridge Creek would not be reduced completely, it would not cause the complete loss of any aquatic habitat. The conclusion was based on the assumption that pool habitats within the creeks would be largely unaffected given there would still be some (low) flow along the entirety of the waterways between rainfall events. Outside of the pool areas, substantially reduced flows between rainfall events would be expected to alter assemblages of freshwater biota in Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to generally include only those species that are most tolerant to low flows.

Notwithstanding this, a number of agency and community submissions on the environmental impact statement queried the predicted project groundwater impacts to the ecology of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek. As such, Transport for NSW requested that Cardno prepare a more detailed assessment of the effects on the aquatic ecology of these creeks, following updated predictions of groundwater drawdown (as presented in Annexure G of this updated biodiversity assessment).

1.2 Scope of works

The aim of this study has been to provide further support for the findings in the environmental impact statement regarding the effect of altered baseflows to freshwater ecology of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, principally from groundwater drawdown as a consequence of construction and operation of the project.

The scope of work included field investigations of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek:

> Assess the quantity, type and condition of aquatic habitat (eg pools and riffles) and riparian vegetation

> Assess the type and condition of assemblages of macrophytes, fish and macroinvertebrates.

This data from the field investigation was then interpreted in combination with existing water quality, surface flow, wastewater discharges volumes from operational waste water treatment plants and ecological information that had already been collected for the environmental impact statement (as reported in Appendix N (Technical working paper: Groundwater), Appendix O (Technical working paper: Surface water quality and hydrology) and Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report)) , recent investigations of surface water quality for Flat Rock Creek and Burnt Bridge Creek by ERM (2021) and further inputs from the project groundwater specialist. Further groundwater inputs, as documented in Appendix E of this submissions report, include:

> Confirmation of creek form
> Reassessment of conductance values
> Remodelling to refine localised changes in baseflow and assessment against total streamflow.

2 Methodology

2.1 Study area

The study area for this report included the following creeks within the Willoughby, North Sydney and Northern Beaches local government areas:

> Flat Rock Creek

> Quarry Creek

> Burnt Bridge Creek (see **Figure 2-1**).

2.2 Aquatic habitat and riparian condition

Field investigations of the entire reaches of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek (between the headwaters and the downstream estuaries) were inspected between 26 - 28 May 2021 to determine habitat sensitivity, riparian condition and the proportion of shallow or deep pools or riffles/cascades.

2.2.1 Instream features

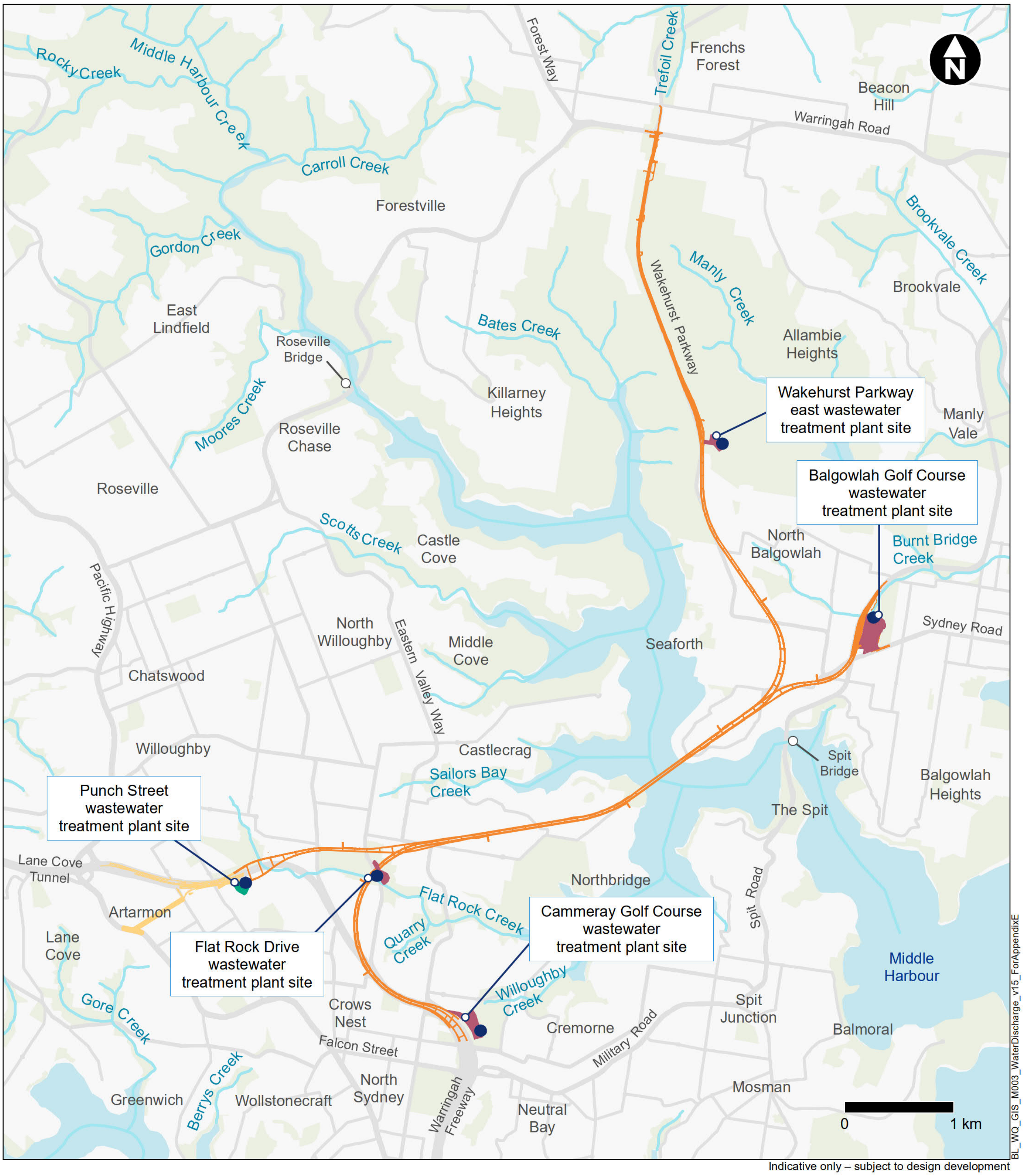
Within sections of each creek, visual estimates were made of the proportion of creek length that contained shallow pools (<2 metres depth), deep pools (>2 metres depth) or riffles/cascades**.** The type of substratum in pools (bare rock, earth, silt, sand, gravel or detritus) was also noted.

The quality of fish habitat in the watercourses was determined with reference to the criteria in **Table 2-1** and **Table 2-2** in accordance with the *Policy and Guidelines for Fish Conservation and Management* (NSW DPI, 2013).

2.2.2 Riparian condition

The condition of riparian habitat in creeks was assessed using a modified version of the riparian, channel and environmental (RCE) inventory method (Peterson, 1992; Chessman, *et al*. 1997). This methodology was developed by Peterson (1992) but modified for Australian conditions by Chessman *et al*. (1997) by combining some of the descriptors, modifying some of the associated categories and simplifying the classifications from 1 to 4 (**Table 2-3**).

This assessment involved evaluation and scoring of the characteristics of the various components of the riparian corridor, including adjacent land, condition of riverbanks, channel and bed of the watercourse, and degree of disturbance evident at each site. The maximum score (52) indicates a stream with little or no obvious physical disruption and the lowest score (13) indicates a heavily channelled stream without any riparian vegetation that can be considered to be in poor condition. RCE scores were assigned to sections of the creeks, with boundaries occurring where there was a visible change in the riparian condition (eg a change in riparian native vs exotic trees/shrubs, channel form or riffle/pool sequence)**.**



Legend

- Beaches Link
- Gore Hill Freeway Connection
- Waterways
- Treated wastewater discharge location
- Construction wastewater treatment plant site
- Construction/operational wastewater treatment plant

Figure 2-1 Construction footprint, relevant temporary construction support sites, wastewater treatment plant discharge locations and associated waterways

Table 2-1 Classification of waterways for fish passage (NSW DPI, 2013)

Classification	Habitat type
Class 1 – Major key fish habitat	Major permanently or intermittently flowing waterway (eg river or major creek), habitat of a threatened fish species.
Class 2 – Moderate key fish habitat	Named permanent or intermittent stream, creek or waterway with clearly defined bed and banks with semi - permanent to permanent waters in pools or in connected wetland areas. Marine or freshwater aquatic vegetation is present. Known fish habitat and/or fish observed inhabiting the area.
Class 3 – Minimal key fish habitat	Named or unnamed waterway with intermittent flow and potential refuge, breeding or feeding areas for some aquatic fauna (eg fish, yabbies). Semi - permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or recognised aquatic habitats.
Class 4 Unlikely key fish habitat	Named or unnamed waterway with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free standing water or pools after rain events (eg dry gullies or shallow floodplain depressions with no permanent aquatic flora present).

Table 2-2 Key fish habitat and associated sensitivity classification scheme (NSW DPI, 2013)

Classification	Habitat type
Type 1 – Highly sensitive key fish habitat	– Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, or native aquatic plants – Any known or expected protected or threatened species habitat or area of declared ‘critical habitat’ under the NSW *Fisheries Management Act 1994* – Mound springs.
Type 2 – Moderately sensitive key fish habitat	– Freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in Type 1 – Weir pools and dams up to full supply level where the weir or dam is across a natural waterway.
Type 3 – Minimally sensitive key fish habitat	– Freshwater habitats not included in Types 1 or 2 – Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation.
Not considered key fish habitat	– First and second order streams on gaining streams (based on the Strahler method of stream ordering) – Farm dams on first and second order streams or unmapped gullies – Agricultural and urban drains – Urban or other artificial ponds (eg evaporation basins, aquaculture ponds) – Sections of stream that have been concrete-lined or piped (not including a waterway crossing) – Canal estates.

Table 2-3 RCE ratings (Peterson, 1992; Chessman, *et al*. 1997)

Degree of modification	Score / rating	Description	Colour coding
Quasi natural	41-52 / 4	Creek is not modified and resembles natural state. Vegetation is mainly native with minimal weeds. Can include active vegetation rehabilitation. Features include: – Adjacent to undisturbed native vegetation – Width of riparian strip more than 30 m – Native trees/shrubs present – Banks fully stabilised by trees/roots, no undercutting – Channel form deep (width/depth ratio less than 7:1) – Frequent alternation of riffles and pools – Many large boulders and/or debris – Little or no accumulation of loose sediments, stream bottom mainly clean stones – Detritus mainly unsilted wood, bark and leaves Eg Natural creek	
Partly modified	27-40 / 3	Creek may be modified and some non-native and/or weeds present. Features include: – Adjacent mixed native vegetation and pastures/exotics – Width of riparian strip between 5-30 m – Banks firm, undercutting present on curves/constrictions – Channel form medium (width/depth ratio 8:1 to 15:1); – Long pools with infrequent short riffles – Rocks/logs present, limited damming effect – Some gravel bars, stream bottom mainly stones – Much fine detritus. Eg Partly natural with sections of modifications.	
Highly modified	14-26 / 2	Creek is modified and vegetation is a mix of native and non-native plants and/or weeds. Features include: – Adjacent pasture, crops or plantation land use – Width of riparian strip less than 5 m – Banks loose, frequent undercutting – Channel form shallow (width/depth ratio greater than 15:1) – Natural channel form without riffle/pool sequence – Rocks/logs present, but unstable – Bars of sand and silt common, heavily silted bottom – Mainly fine detritus. Eg lined beds/banks.	
Completely modified or underground	1-13 / 1	Creek is highly and/or totally modified and vegetation is mostly non-native and/or weeds. Features include: – Adjacent urban land use – No woody vegetation – Exotic grasses/weeds only – Banks unstable, with bank collapse common – Artificial channel form with no riffle/pool sequence – Stream with few retention devices. Eg cuverts (open/underground), stormwater.	

2.3 Fish

Fish were sampled using two collapsible bait traps (40 centimetres x 20 centimetres x 20 centimetres with 2-3 millimetre mesh, tapering to a 3 centimetres entrance) in accordance with Cardno's scientific collection permit F86/670(A)-8.2. Bait traps were deployed at two sites in each of Flat Rock Creek and Quarry Creek and three sites in Burnt Bridge Creek and for up to 30 minutes and all caught fish identified. If native species were caught, they were released unharmed, while non-native species were euthanised humanely.

2.4 Macroinvertebrates

2.4.1 Sample collection

Semi-quantitative AUSRIVAS sampling was carried out in pools with suitable representative edge habitat (eg detritus, overhanging vegetation, macrophytes and substrate present). Sampling was carried out at the end of the AUSRIVAS sampling season (autumn).

Aquatic macroinvertebrates were collected using the AUSRIVAS rapid assessment methodology (RAM) (Turak *et al*. 2004) at two sites in each of Flat Rock Creek and Quarry Creek and three sites in Burnt Bridge Creek (**Figure 2-2**). Samples were collected in pool edge habitat with dip nets (250 micrometres mesh) over a period of 3-5 minutes from a 10 metres length of habitat within a 100 metres reach of the creek at each site. The dip net was used to agitate and scoop up material from vegetated river edge habitats. Where the habitat was discontinuous, patches of habitats with a total length of 10 metres were sampled over the 100 metres reach.

Each RAM sample was rinsed from the net onto a white sorting tray from which animals were 'picked' live using forceps and pipettes. Each tray was picked for a minimum period of forty minutes, after which they were picked at ten-minute intervals either until no new specimens had been found or total of 60 minutes (eg the initial 40 minutes plus up to another 20 minutes). Care was taken to collect cryptic and fast moving animals in addition to those that were conspicuous and/or slow. The animals collected at each site were placed into a labelled jar containing 70 per cent alcohol/water for subsequent taxonomic identification in Cardno's laboratory.

Environmental variables, including alkalinity, modal river width and depth, percentage boulder or cobble cover, latitude and longitude were recorded in the field. Distance from source, altitude, and land-slope were determined from appropriate topographic maps. Mean annual rainfall was determined in the laboratory from the regional precipitation maps presented in the AUSRIVAS sampling and processing manual (Turak *et al*., 2004). All of these variables are required for running the autumn AUSRIVAS predictive model for (pool) edge habitat to give an estimate of the 'health' of the creek with the derived output as OE50 and SIGNAL2 scores. OE50 provides a measure of biological impairment, while SIGNAL2 is a simple biotic index for macroinvertebrates that uses the pollution tolerance levels of different macroinvertebrate types.

Figure 2-2 AUSRIVAS sampling sites. FRC01 (top, left), FRC02 (top, right), QC01 (second row, left) and QC02 (second row, right), BBC01 (third row, left), BBC02 (third row, right), BBC03 (bottom row left), see Figure 3-9 and Figure 3-20 in Section 3 for locations of sampling sites (Photos collected: 26/5/2021 - 28/05/2021)

2.5 Water quality

Water quality was measured *in situ* with a YSI 6920 water quality probe that was calibrated prior to sampling. Water quality was measured before aquatic fauna were sampled to avoid disturbance to the waterway. The following variables were recorded:

> Temperature (°C)
> Electrical conductivity (EC) (μs/cm)
> pH
> Dissolved oxygen (DO) (mg/L and percentage saturation)
> Oxidation reduction potential (ORP) (millivolts [mV])
> Turbidity (NTU).

Two replicate readings of each variable were taken in accordance with Australian Guidelines: Australia, New Zealand Environment Conservation Council 2000 (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand 2000 (ARMCANZ).

Mean water quality measurements were compared with the ANZECC/ARMCANZ 2000 default guideline values for protection of aquatic ecosystems for physical and chemical stressors for slightly to moderately disturbed lowland rivers in southeast Australia. The Sydney Harbour and Parramatta River Water Quality and Flow Objectives were also used as a comparison.

3 Results

3.1 Aquatic habitat and riparian condition

3.1.1 Flat Rock Creek

Flat Rock Creek is a first order waterway upstream of the Quarry Creek confluence and a second order waterway downstream. It drains the Flat Rock Creek catchment into Middle Harbour and flows in a general easterly direction from Marlow Road at Artarmon into Middle Harbour at Tunks Park at Cammeray. It is freshwater upstream of its confluence with Quarry Creek and estuarine downstream. There are numerous stormwater outlets along the length of Flat Rock Creek and at the time of inspection these had low or non-existent flow. At the time of inspection, moderate flow was observed downstream of Flat Rock Drive. Low flow was observed at its source but the creek was dry in some of its upper parts (Table 3-1**)**. Flat Rock Creek is comprised of unlined above ground sections, some above ground lined sections and some underground tunnels (**Figure 3-1, Figure 3-2**). The dry areas of the upper parts of the creek were unlined (**Figure 3-1**).

Flat Rock Creek includes a mixture of shallow and deep pools and cascade/riffle zones in its upper and middle reaches before reaching the estuarine section (Table 3-1**, Figure 3-3** to **Figure 3-8**)**.**

Stormwater flows appear to have had a large influence along this waterway, generally scouring the bedrock base and removing coarse and fine sediments. No instream macrophytes were recorded in the creek however, moss was observed in some reaches.

The RCE scores for all of Flat Rock Creek were generally high (Table 3-2**, Figure 3-9** to **Figure 3-10**). Wherever it was not underground or concrete lined, much of Flat Rock Creek has evidence of active bush regeneration and many areas are dominated by native trees and shrubs. Although there are small pockets where exotic vegetation occurs among native plants, the recent efforts of bush regeneration have contributed to much of the creek having riparian condition scores that range between quasi natural or only partly modified (Table 3-2).

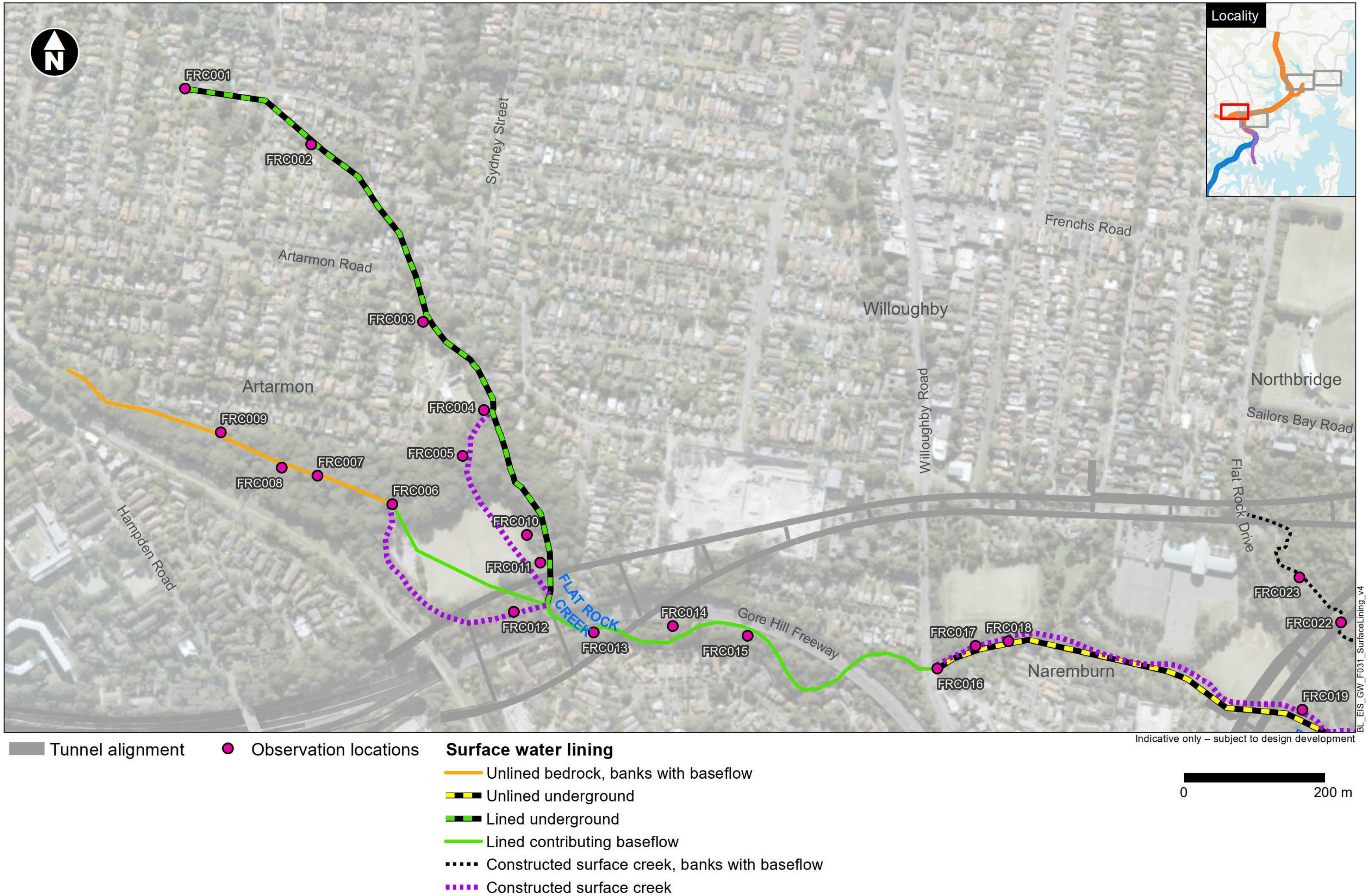


Figure 3-1 Flat Rock Creek (upstream extent) surface lining (Source: Jacobs, 2021)

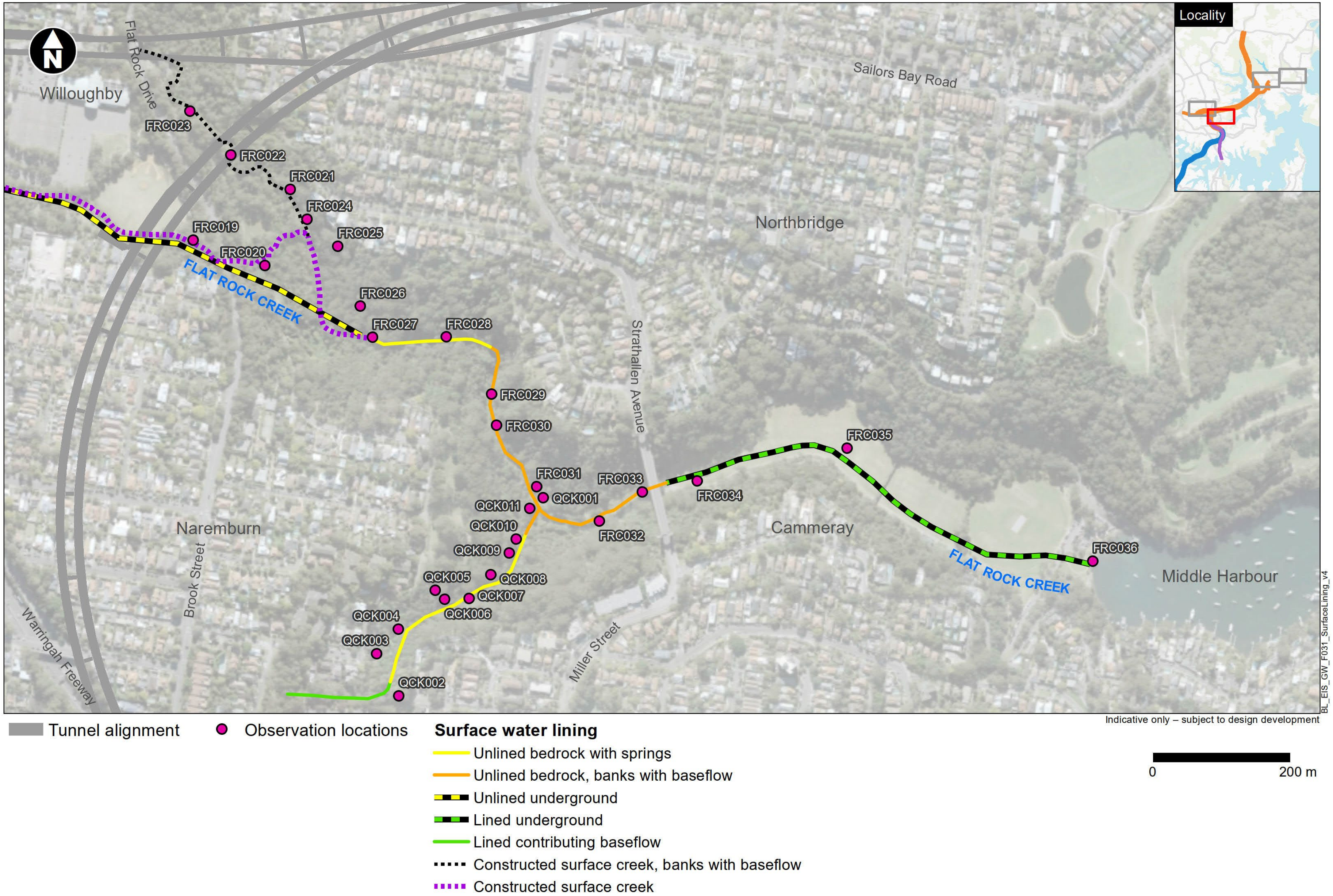


Figure 3-2 Flat Rock Creek (downstream extent) and Quarry Creek surface lining (Source: Jacobs, 2021)

Figure 3-3 Flat Rock Creek concrete lined areas (left) and along the underground channel (right) (Photo date: 27/05/2021).

Figure 3-4 Existing aboveground watercourse within the northern extent of Flat Rock Reserve looking downstream from the Small Street roundabout culvert (Photo date: 27/05/2021).

Figure 3-5 Examples of pools and scoured bedrock along the existing aboveground watercourse within the northern extent of Flat Rock Reserve (Photo date: 27/05/2021).

Figure 3-6 Wilksch Walk crossings along the existing aboveground watercourse of Flat Rock Creek (Photo date: 27/05/2021).

Figure 3-7 Flat Rock Creek at the downstream site looking downstream (left) and upstream (right) (Photo date: 27/05/2021).

Figure 3-8 Flat Rock Creek at the estuarine site looking downstream (left) and looking at the right bank (right) (Photo date: 28/05/2021).

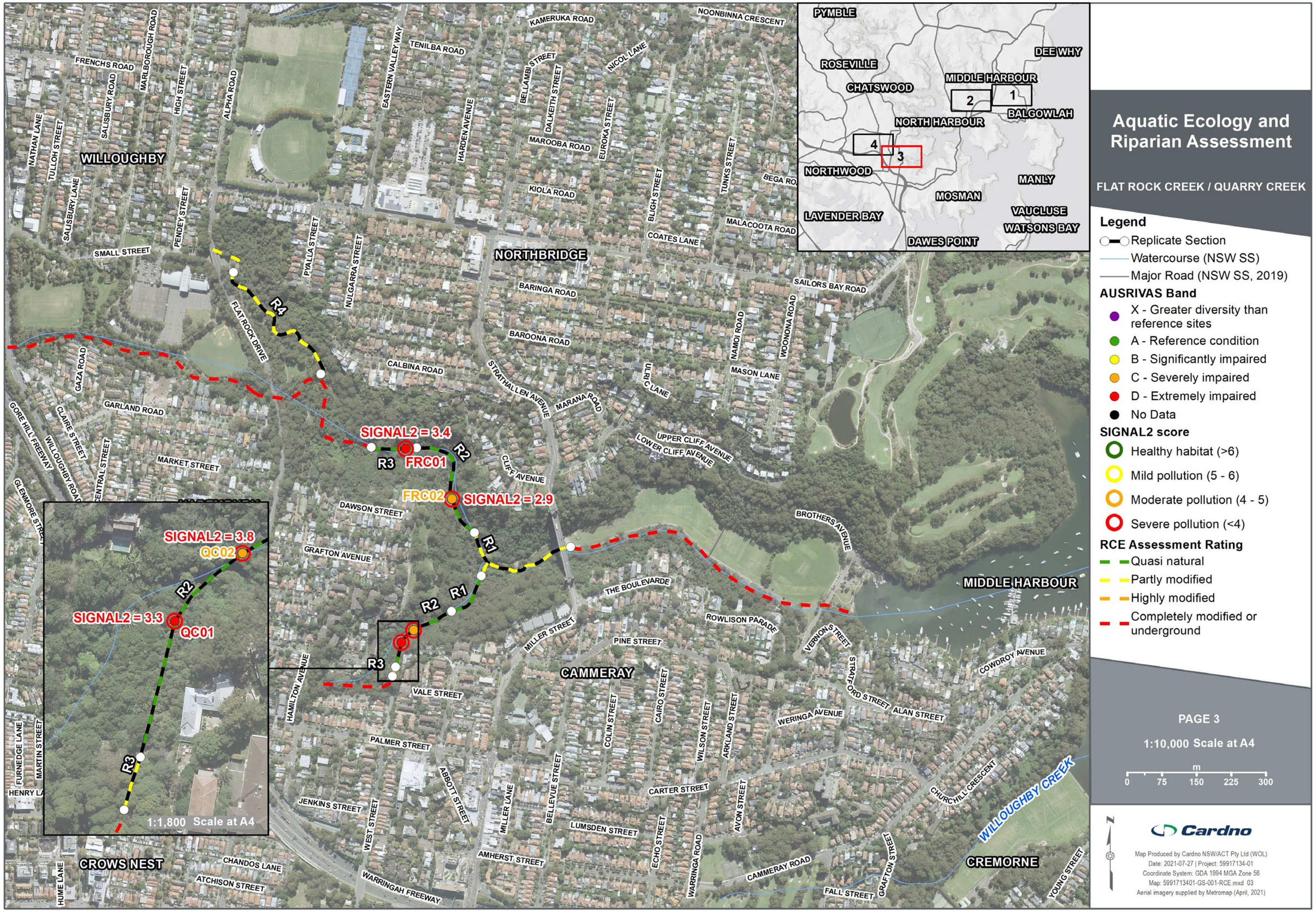


Figure 3-9 Flat Rock Creek and Quarry Creek aquatic ecology and RCE assessment ratings (downstream extent)

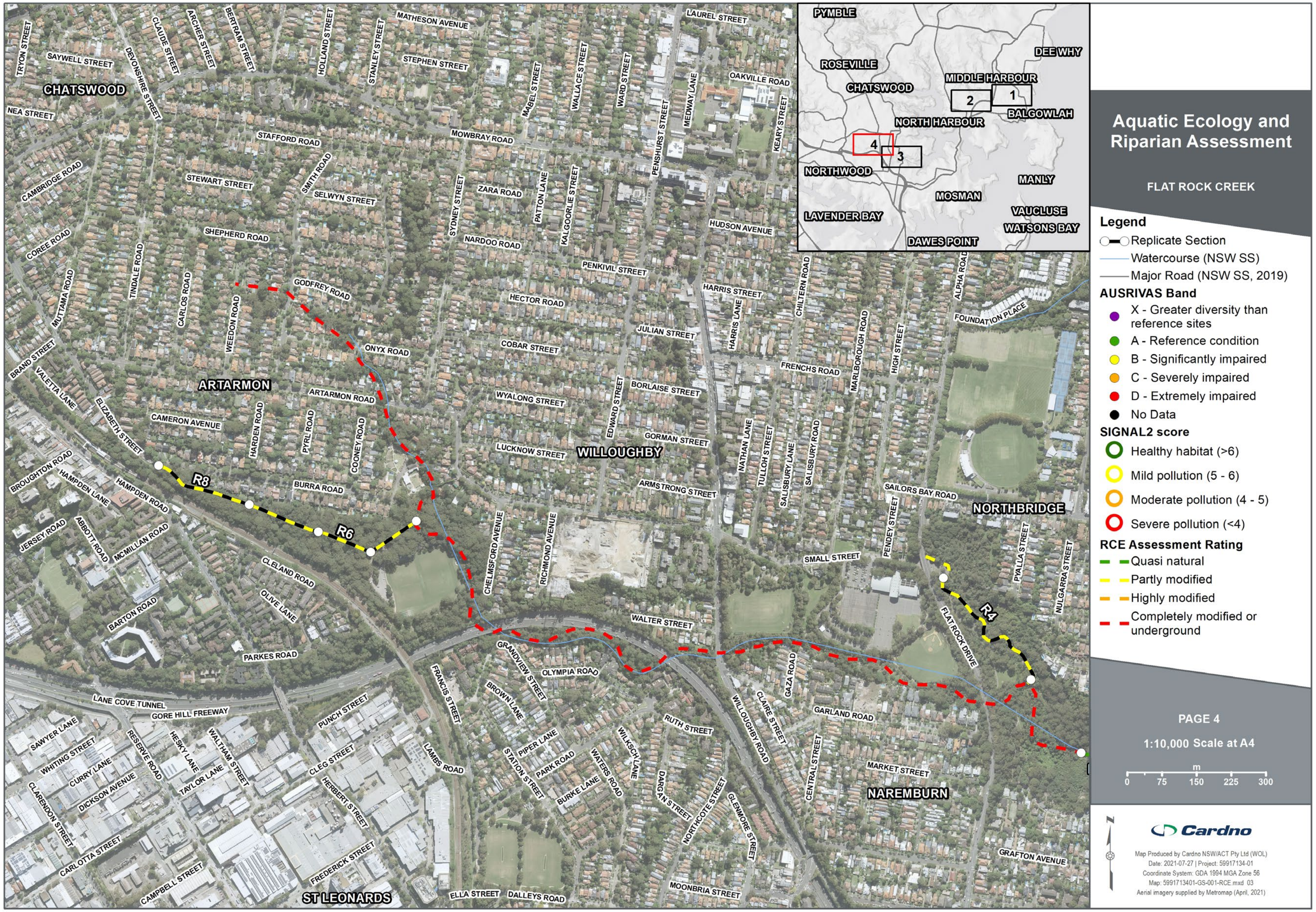


Figure 3-10 Flat Rock Creek aquatic ecology and RCE assessment ratings (upstream extent)

3.1.2 Quarry Creek

Quarry Creek is a second order waterway. It drains into the Flat Rock Creek catchment and further into Middle Harbour. It generally flows in a north-easterly direction from Bridgeview Avenue, Cammeray into Tunks Park, Cammeray. It is estuarine downstream of its confluence with Flat Rock Creek. Quarry Creek is shorter than the other two creeks, has no stormwater outlets along its length and apart from the top section generally flows down a steep gradient. At the time of inspection, moderate flow was observed (Table 3-1). Quarry Creek is generally unlined apart from the far upper part of the creek (**Figure 3-2**).

Quarry Creek generally consists of cascade/riffle zones with few shallow or deep pools (Table 3-1**, Figure 3-11**)**.**

Stormwater flows appear to have had a large influence along this waterway, generally scouring the bedrock base and removing coarse and fine sediments apart from one large deep pool. No instream macrophytes were recorded in the creek, however moss was observed in some reaches.

Most of Quarry Creek is among natural bushland and the RCE scores for all of Quarry Creek were generally good (Table 3-2). Hence the riparian condition of much of the creek is either quasi natural or only partly modified (**Table 3-2, Figure 3-11**).

Figure 3-11 Quarry Creek cascades and boulder instream features (left). Quarry Creek large deep pools upstream of the confluence of Quarry Creek and Flat Rock Creek (right) (Photo date: 28/05/2021).

3.1.3 Burnt Bridge Creek

Burnt Bridge Creek is a first order waterway in the Burnt Bridge Creek catchment which flows in a general easterly direction from Clontarf Street at Seaforth to Kenneth Road where it enters Manly Lagoon. At the time of inspection, low flow was observed at its source. There are numerous stormwater outlets along the length of Burnt Bridge Creek and at the time of inspection these had low or non-existent flow.

Burnt Bridge Creek is generally unlined apart from a small section upstream of the Burnt Bridge Creek Deviation and within the Balgowlah industrial area (**Figure 3-12** and **Figure 3-13**). It includes a mixture of shallow and deep pools and cascade/riffle zones in its upper and middle reaches before flowing into a concrete-lined culvert when it reaches the Balgowlah industrial area (Table 3-1**, Figure 3-14** to **Figure 3-19**)**.**

Stormwater flows appear to have had a large influence along this waterway upstream of the Burnt Bridge Creek Deviation, generally scouring the bedrock base and removing coarse and fine sediments. The gradient of the creek lessens at the middle reach of Burnt Bridge Creek (immediately south of Burnt Bridge Creek Deviation) and here it has been modified and realigned in the past and the upper extent of this reach was defined by one large continuous deep pool behind a weir, with cobble/gravel, silt and detritus substratum (**Figure 3-15**). Established exotic macrophytes lined much of the banks. Downstream of the weir there are pools connected with cascades before Burnt Bridge Creek traverse's north-east underneath the Burnt Bridge Creek Deviation. Further downstream in the Balgowlah industrial area the creek becomes an artificial channel form with no riffle/pool sequence.

The RCE scores for Burnt Bridge Creek ranged from 17 (lower reaches within the Balgowlah industrial area) to 41 (in the upper reaches). Upstream of the Burnt Bridge Creek Deviation the riparian corridor could be considered quasi natural, mostly as a consequence of the results of recent active bush regeneration and weed management in the area (Table 3-2**, Figure 3-21**). The area is dominated by native trees and shrubs with frequent long deep pools, riffles and cascades. The riparian condition of the middle and downstream areas of the creek, where a project exclusion zone occurs, was either partially or highly modified (Table 3-2**, Figure 3-20**). None of the riparian zones of Burnt Bridge Creek are dependent, either entirely or in part, on the presence of groundwater for their health and/or survival (see Appendix S (Technical working paper: Biodiversity development assessment report)).

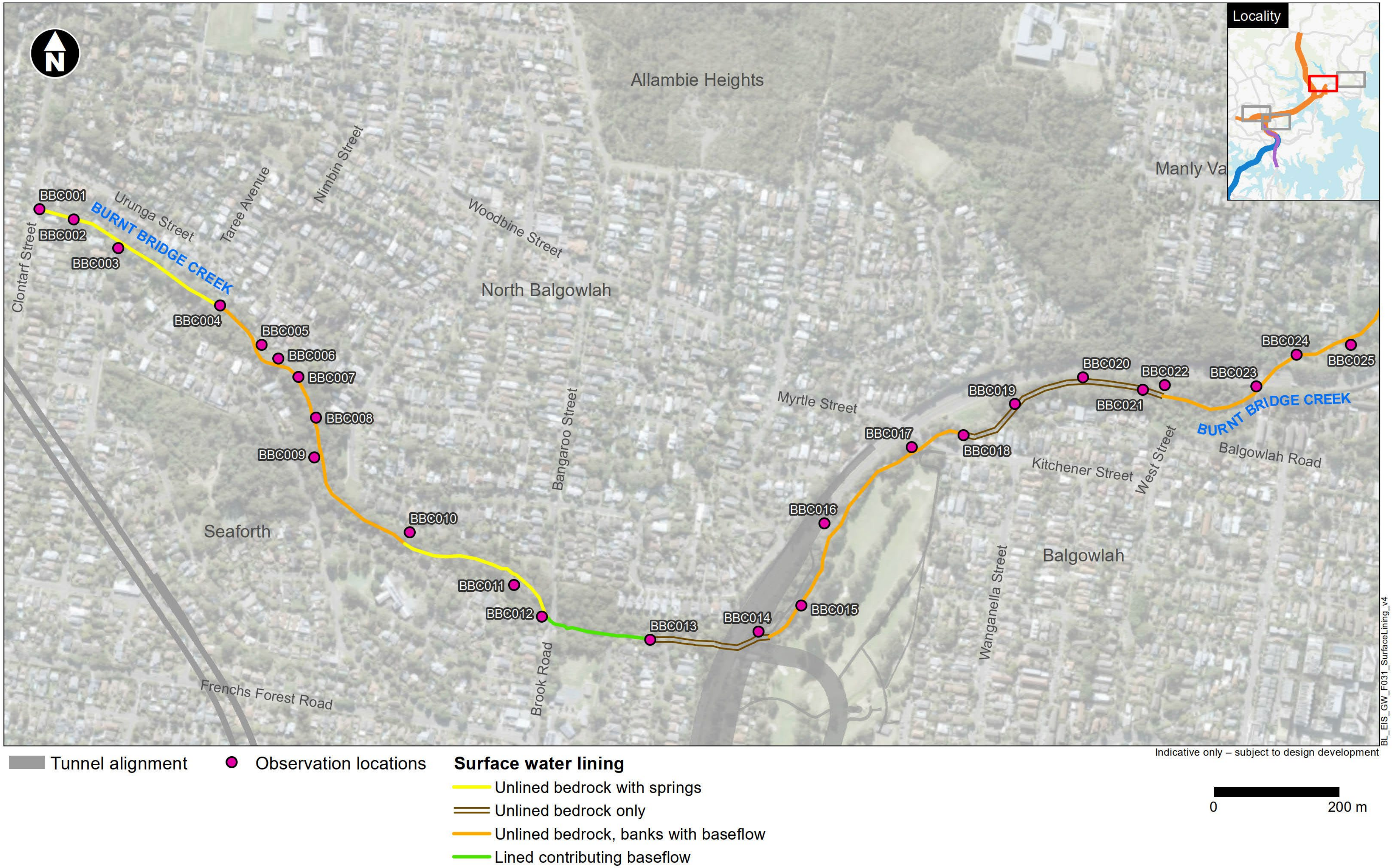


Figure 3-12 Burnt Bridge Creek surface lining (upstream and mid section extent) (Source: Jacobs, 2021)

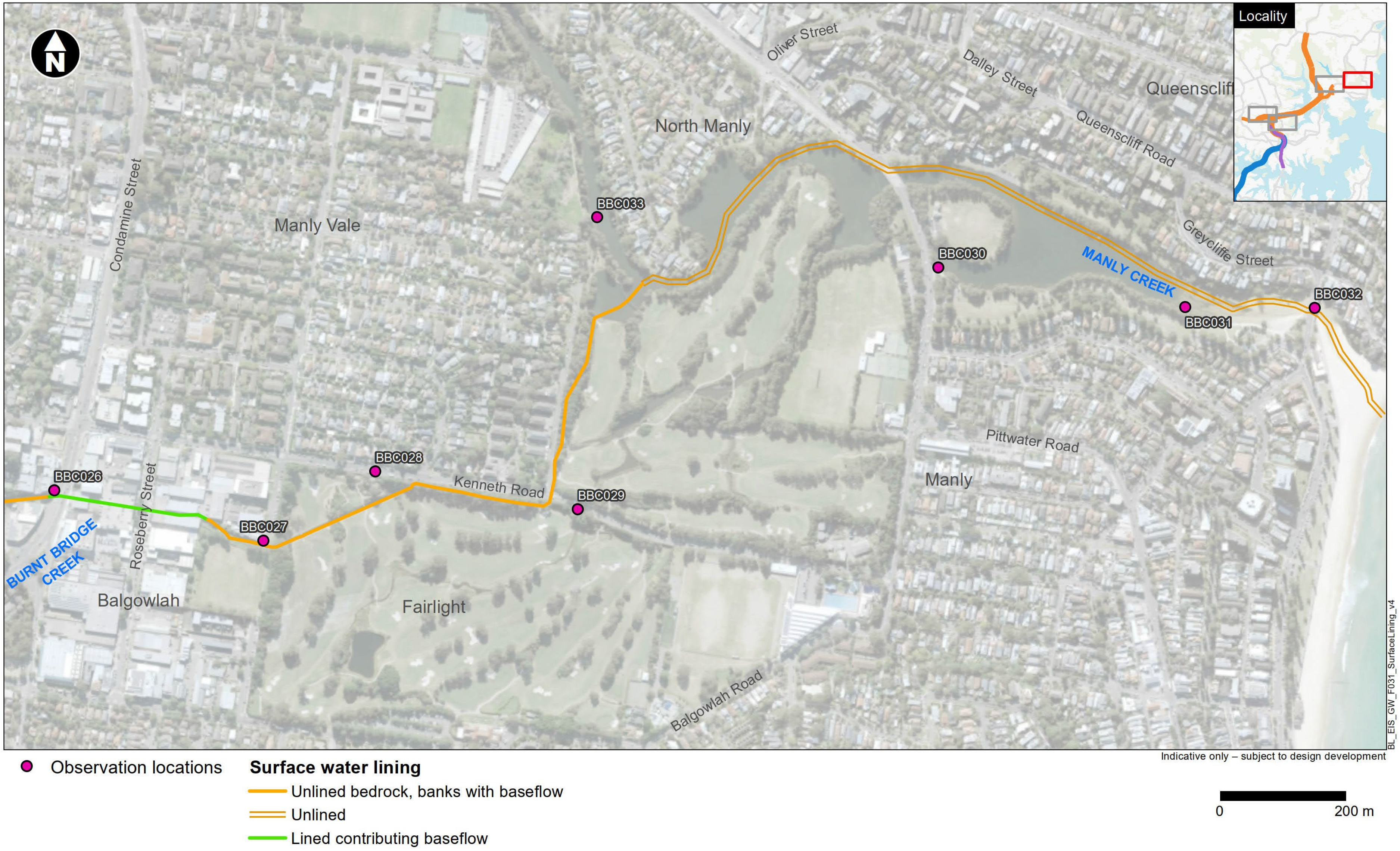


Figure 3-13 Burnt Bridge Creek surface lining (downstream extent) (Source: Jacobs, 2021)

Figure 3-14 AUSRIVAS BB01 sampling site (right). Upstream reach of Burnt Bridge Creek scoured bedrock with cascades (left). Pooled water with aquatic habitat eg cobbles, gravels detritus, macrophytes (right) (Photo date: 26/05/2021).

Figure 3-15 Burnt Bridge Creek spilling weir with deep pool (left). Constricted middle reach downstream (north of Balgowlah Road), heavily constricted by exotic weeds and trees (right) (Photo date: 26/05/2021).

Figure 3-16 Burnt Bridge Creek along the stretch between the culverts at Burnt Bridge Creek Deviation and Kitchener Street looking upstream (left) and downstream (right) (Photo date: 26/05/2021).

Figure 3-17 Highly modified section of Burnt Bridge Creek prior to tracking underground into the Balgowlah industrial area (Photo date: 26/05/2021).

Figure 3-18 Modified sections of Burnt Bridge Creek near Manly Golf Course (Photo date: 26/05/2021).

Figure 3-19 Estuarine sections of Burnt Bridge Creek near Manly Golf Course (Photo date: 26/05/2021).

Figure 3-20 Burnt Bridge Creek aquatic ecology and RCE assessment ratings (downstream extent)

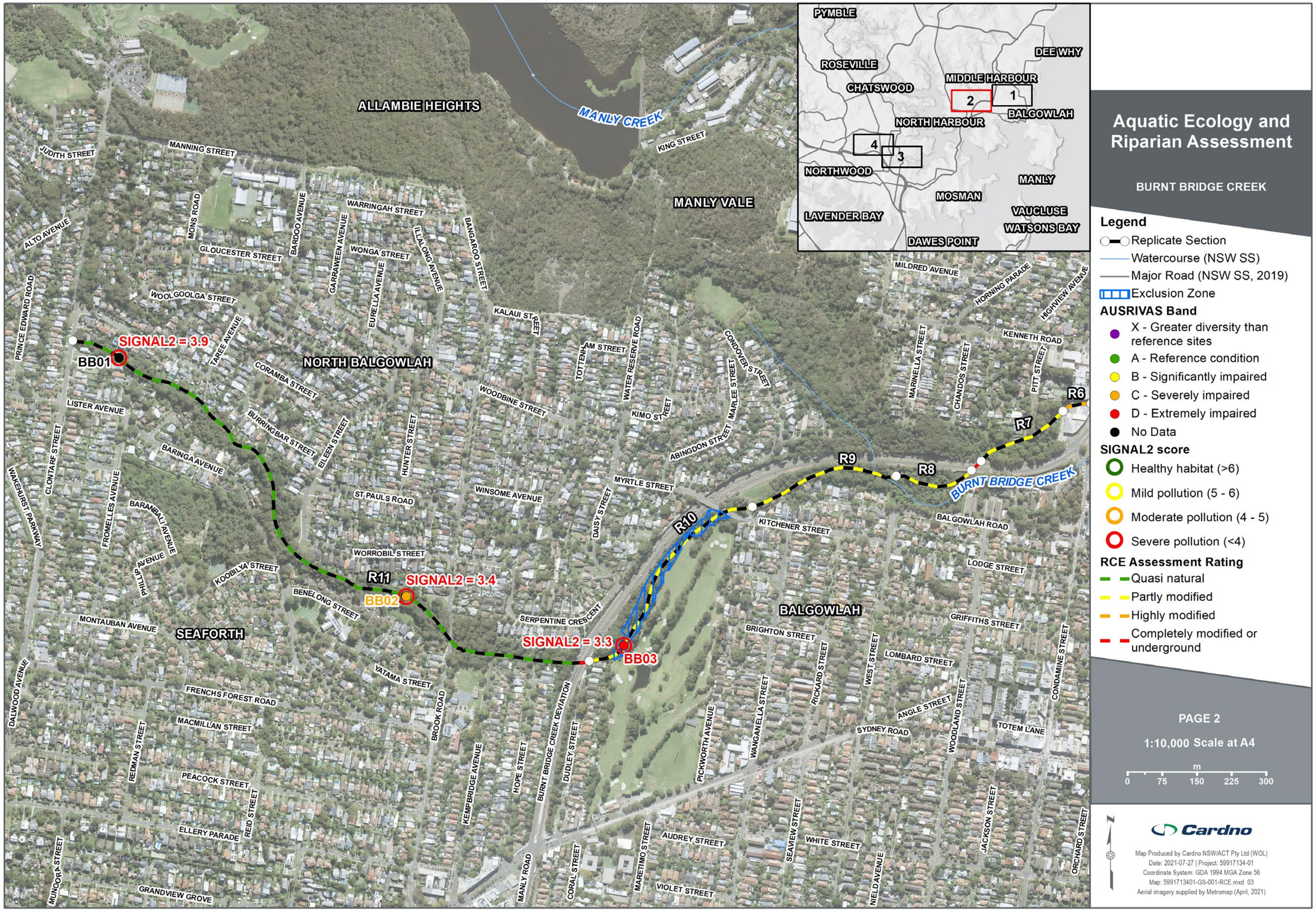


Figure 3-21 Burnt Bridge Creek aquatic ecology and RCE assessment ratings (upstream and mid section extent)

Table 3-1 Instream features and waterway/key fish habitat classification

Creek	Reach	Estuarine or Freshwater	Flow	Instream habitat			Waterway class	KFH level
				Shallow pools (depth <0.2 m)	Deep pools (depth >0.2m)	Cascades / riffles		
Flat Rock Creek	R1	Estuarine	Tidal	-	100%	-	1	1
	R2	Freshwater	Mod	-	50%	50%	3	Not KFH
	R3	Freshwater	Mod	-	20%	80%	3	Not KFH
	R4	Freshwater	Low.	10%	-	80%	3	Not KFH
	R5	Freshwater	Dry	-	-	-	3	Not KFH
	R6	Freshwater	Dry	-	-	-	3	Not KFH
	R7	Freshwater	Low	50%	-	50%	3	Not KFH
	R8	Freshwater	Low	-	60%	40%	3	Not KFH
Quarry Creek	R1	Freshwater	Mod	20%	20%	60%	3	Not KFH
	R2	Freshwater	Mod	-	30%	70%	3	Not KFH
	R3	Freshwater	Mod	10%	-	90%	3	Not KFH
Burnt Bridge Creek	R1-R4	Estuarine	Tidal	-	100%	-	1	1
	R5	Freshwater	Low	100%	-	-	3	Not KFH
	R6	Freshwater	Low	-	100%	-	3	Not KFH
	R7	Freshwater	Low	80%	-	20%	3	Not KFH
	R8	Freshwater	Low	100%	-	-	3	Not KFH
	R9	Freshwater	Low	20%	-	80%	3	Not KFH
	R10	Freshwater	Low	-	100%	-	3	Not KFH
	R11	Freshwater	Low	25%	25%	50	3	Not KFH

Table 3-2 RCE assessment scores

Creek	Reach	RCE score	RCE rating
Flat Rock Creek	R1	39	Partly modified
	R2	44	Quasi natural
	R3	46	Quasi natural
	R4	31	Partly modified
	R5	35	Partly modified
	R6	30	Partly modified
	R7	42	Quasi natural
	R8	35	Partly modified
Quarry Creek	R1	46	Quasi natural
	R2	42	Quasi natural
	R3	34	Partly modified
Burnt Bridge Creek	R1	30	Partly modified
	R2	38	Partly modified
	R3	36	Partly modified
	R4	33	Partly modified
	R5	23	Highly modified
	R6	17	Highly modified
	R7	38	Partly modified
	R8	31	Partly modified
	R9	35	Partly modified
	R10	37	Partly modified
	R11	41	Quasi natural

3.2 Fish

No native fish species were caught or were observed. Schools of the pest species Mosquito Fish (*Gambusia holbrooki)* were caught in the two collapsible bait traps deployed at site BB03 in Burnt Bridge Creek (ie the long, deep pool upstream of the weir, immediately downstream of the Burnt Bridge Creek Deviation).

3.3 Macroinvertebrates

3.3.1 AUSRIVAS samples

The number of macroinvertebrate taxa collected in AUSRIVAS sampling sites ranged between 10 and 36. OE50 refers to the observed to expected ratio of the number of invertebrate families observed at the site to the number of invertebrate families expected at that site. Both the OE50 and SIGNAL2 scores indicated assemblages at all creeks were either severely or extremely impaired and suffered from severe pollution (**Table 3-3** and see **Figure 3-9, Figure 3-10, Figure 3-20, Figure 3-21**).

Table 3-3 AUSRIVAS OE50 scores and SIGNAL2 grades for AUSRIVAS sites

Creek	Site	Band	Autumn OE50 score	SIGNAL2 grade	Number of taxa
Flat Rock Creek	FRC01	D (Extremely impaired)	0.08	3.4 (Severe pollution)	36
	FRC02	C (Severely impaired)	0.19	2.9 (Severe pollution)	16
Quarry Creek	QC01	D (Extremely impaired)	0.09	3.3 (Severe pollution)	25
	QC02	C (Severely impaired)	0.18	3.8 (Severe pollution)	10
Burnt Bridge Creek	BB01	N/A[1]	N/A[1]	3.9 (Severe pollution)	18
	BB02	C (Severely impaired)	0.37	3.4 (Severe pollution)	24
	BB03	D (Extremely impaired)	0.09	3.3 (Severe pollution)	14

1 indicates the site is outside the experience of the model

3.4 Water quality

3.4.1 Rainfall

Rainfall recorded by the bureau of meteorology (BOM) weather station at Observatory Hill (nearest available) is presented in **Table 3-4**. A total of 66.6 mm was recorded in May 2021, with the largest event of 25.4 mm on 6 May 2021. No rainfall was recorded during the survey period, with the most recent period of rainfall occurring between 22 to 25 May 2021 (5.2 mm in total). Mean annual rainfall derived from the BOM indicates the study area receives a mean annual rainfall 1,213.4 mm.

Table 3-4 Rainfall (month prior to survey) (BOM, 2021)

BOM observation Site (ID)	Total May rainfall (mm) / largest event (mm-date)	Most recent rainfall (mm-date)
Observatory Hill (066037)	66.6 / 25.4 - 6/05/2021	5.2 / 22-25/05/2021

3.4.2 Physical and chemical parameters

Some sections of the creeks have undergone significant modifications to the original bedrock channel or alterations from natural channels to artificial, hard (concrete-lined) channels to accommodate higher volumes and flow velocities, after rain, due to an increase in urban, impervious surfaces. This hydrological alteration from natural conditions would be expected to promote the transport of sediments and contaminants to downstream receiving environments (eg Middle Harbour and Manly Lagoon).

Detailed analysis of water quality for Flat Rock Creek, Quarry Creek and Burnt Bridge Creek carried out for the environmental impact statement is given in Appendix O (Technical working paper: Surface water quality and hydrology)**.** In summary, the water quality of these three creeks was considered likely to be substantially influenced by the surrounding urban development. Sources of contaminants, such as suspended sediments, heavy metals and persistent organic pollutants, include stormwater, wastewater overflows and leachate from contaminated lands. Recent investigations in March 2021 (ERM, 2021) of the water quality of Flat Rock Creek and Burnt Bridge Creek, carried out during a period of rainfall, confirmed the presence of some heavy metals and that nutrients (total nitrogen, reactive nitrogen and total phosphorous) were in excess of the ANZECC &

ARMCANZ 2000 default guideline values for slightly to moderately disturbed ecosystems (defined as ecosystems in which "*aquatic biological diversity may have been adversely affected to a relatively small but measurable degree by human activity*" (Chapter 3 of ANZECC, 2000)).

The results of in-situ water quality sampling done for field investigation on 26 - 28 May 2021 (this study) are given in **Table 3-5**. The results indicated exceedances of the default guideline values for the measured parameters only for dissolved oxygen (DO) at AUSRIVAS site BB01.

Table 3-5 Average water quality parameters compared to ANZECC & ARMCANZ 2000 / Sydney Harbour Water Quality Objectives

Creek	Site	pH	EC (uS/cm)	ORP (mV)	DO (%Sat.)	DO (mg/L)	Salinity (ppt)	Turbidity (ntu)	Temp (°C)	Alkalinity (mg/L)[1]
Flat Rock Creek	FC01	7.8	414.5	176.2	91.8	9.6	0.2	19.5	13.3	15
	FC02	7.7	586.5	162.5	**71.7**	7.6	0.3	14	12.7	13
Quarry Creek	QC01	7.6	595	188.1	**83**	8.7	0.3	2.3	13	13
	QC02	7.7	511	196.1	87.2	9.2	0.3	1.9	12.8	13
Burnt Bridge Creek	BB01	7.3	565	142.5	**78.4**	8.2	0.3	0.8	13.4	15
	BB02	7.2	354	136.5	91	9.6	0.2	0.9	13.1	15
	BB03	7.3	357.5	123.8	87.6	9.2	0.2	1.2	12.6	17

Note: Bold indicates exceedance of ANZECC & ARMCANZ 2000 and/or Sydney Harbour Water Quality Objectives for lowland rivers

4 Impact assessment

4.1 Impact of groundwater drawdown to baseflow and total stream flow

As described in **Section 1.1**, modelled changes to baseflow of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek, as given in Appendix N (Technical working paper: Groundwater) informed the predictions of potential ecological impacts in the creeks made in Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report). Discharges from wastewater treatment plants were also considered as to the extent to which these flows would offset reductions to baseflow.

Additional groundwater modelling has since been carried out to refine predictions about the levels to which the project would potentially alter the contribution of baseflow to total stream flow at Flat Rock Creek, Quarry Creek and Burnt Bridge Creek. This additional information is summarised in Table 4-1. These results, which had been measured/derived during a dry period of low rainfall, indicate that, during dry periods, baseflow is generally small (<30 kilolitres per day) for many areas of the creeks. Baseflow makes up only less than one per cent of total stream flow in upstream areas of Flat Rock Creek and generally less than six per cent at and Quarry Creek and Burnt Bridge Creek. In these areas, most of the total stream flow would be expected to be coming from stormwater input from various points. Hence, even though groundwater drawdown from the project is predicted to reduce baseflow by between 25 per cent and 67 per cent, this would only equate to less than three per cent reduction of total stream flow for most parts of Burnt Bridge Creek and the upstream part of Quarry Creek (Table 3-1). Notably, these predictions are indicative of low rainfall periods. After rainfall, given baseflow is likely to be an insignificant proportion of the total stream flow, due to an increased contribution from stormwater runoff any changes from the project to baseflow for upstream parts of Flat Rock Creek and Quarry Creek and for most parts of Burnt Bridge Creek would be negligible.

Along the downstream sections of Flat Rock Creek, baseflows are estimated to comprise larger proportions of total stream flow, at 67 per cent to 79 per cent respectively, meaning that any reductions to baseflow resulting from groundwater drawdown in these areas has potential to be a larger proportion of total stream flow than for upper Flat Rock Creek or for the other two creeks (Table 4-1). Indeed, during dry periods, at the downstream area of Flat Rock Creek and at the weir, groundwater drawdown in dry periods would be expected to reduce total stream flow by 27 per cent and 22 per cent respectively. Notwithstanding this, others factors would potentially mitigate or offset these effects. The high dry period stream flows in these areas mean that reasonable flows would be maintained despite the effects of groundwater drawdown, and, at the weir, where there is an estuarine influence, any changes to stream flow would be inconsequential relative to tidal influence.

Further, Flat Rock Creek would also receive a maximum of 1425 kilolitres per day of treated wastewater from the Gore Hill Freeway operational wastewater treatment plant. Although a portion of this discharge would potentially be directed to Council assets for external use, the reminder would be expected to result in a net increase in total stream flow generally from the project. The discharged wastewater will be treated to meet ANZG (2018) 95 per cent species protection levels for estuarine and lowland river ecosystems for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels, and the draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water), in accordance with environmental management measure WQ17 (refer to Table D2-1 of this submissions report).

Table 4-1 Indicative daily dry period total stream flow (as measured in 2017) and baseflow after 100 years

Creek	Site	Measured (Total) stream flow (kL/d)	Baseflow (kL/d)		Change in baseflow (%)	Baseflow as a % of (Total) stream flow		Change in baseflow as a % of (Total) stream flow
			With no project	After 100 years of operation of the project		With no project	After 100 years of operation of the project	
Flat Rock Creek	Upstream	1589	13	7	-54%	0.8%	0.4%	0.4%
	At the weir	2337	1563	1041	-67%	67%	45%	22%
	Downstream	1908	1503	992	-66%	79%	52%	27%
Quarry Creek	Upstream	178	0.08	0.02	-25%	0.05%	0.01%	0.04%
Burnt Bridge Creek	Mid-section	130	8	4	-50%	6%	3%	3%
	Downstream section	1242	29	9	-31%	2%	1%	1%

4.2 Impact of groundwater drawdown to aquatic ecology

4.2.1 Aquatic ecology

The freshwater sections of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek all have depauperate assemblages of macroinvertebrates, non-existent assemblages of native fish and generally very few, if any, native macrophytes. The AUSRIVAS results suggest the aquatic ecology of the creeks was generally partially or severely impaired and affected by severe pollution. Sensitive macroinvertebrate groups such as Ephemeroptera, Trichoptera and Plecoptera (EPT taxa) were absent from all creeks. This is despite the riparian habitat of many parts of all of the creeks being in reasonable, if not good condition. Hence, although much of the freshwater reaches of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek appear to look good to the 'naked eye', the effect is 'aesthetic only' and the aquatic ecology can be considered to be generally poor.

The reasons for aquatic ecology being in such poor condition are not clear but are likely to be a consequence of the following factors:

> Generally high levels of some nutrients and dissolved metals in the creeks (see Appendix N (Technical working paper: Groundwater))

> Regular scouring after heavy rain from torrents of storm water (eg bare substratum in most shallow pools and a paucity of aquatic habitat for macroinvertebrates in most pools generally, such as fine sand, gravel and detritus)

> The presence of weirs in Flat Rock Creek and Burnt Bridge Creek, and steep cascades in all creeks, that would prevent some species from colonising middle to upper reaches of creeks from downstream areas.

The additional groundwater modelling (**Section 4.1**) has allowed estimates of the project's predicted effects to the baseflow of the creeks to be refined. New estimates indicate baseflow would still be expected to be reduced by as much as 25 per cent – 67 per cent after 100 years, depending on the creek. Notwithstanding this, new information about the relative contribution of baseflow to total stream flow suggests that for the most part, baseflow only represents a small proportion of total stream flow. The exception would be some parts of Flat Rock Creek, but given there is stormwater inflow and an operational discharge into the creek of good quality water from the project's Gore Hill Freeway wastewater treatment plant during operations (see above) there would be a net increase in flow in this creek. Annexure D of Appendix S (Technical working paper: Biodiversity development assessment report) considered that there would still be some (low) flow along the entirety of the creeks between rainfall events and additional studies have confirmed this would be the case after the effects of the project on baseflow are considered. The additional studies presented here also indicate the presence of pool habitats in most reaches of the creeks and that even in periods of low flow in dry periods in summer it would be expected that many of these pools would be deep enough to retain water and hence aquatic habitat. Notwithstanding the finding that assemblages of aquatic macroinvertebrates and fish are generally depauperate in the creeks, even in extremely dry times, some pools would be deep enough to provide refuge for aquatic macroinvertebrates, albeit only those species that are most tolerant to low flows.

Based on the assessment that changes to baseflow caused by groundwater drawdown would not substantially alter the flow regime after 100 years in any of the creeks to the extent that it would alter instream habitat to already depauperate assemblages of aquatic macroinvertebrates, fish and macrophytes it can be concluded that the project would not significantly impact the aquatic ecology of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek.

4.3 Impact of groundwater drawdown on riparian vegetation

Where the creeks are not diverted underground, the general findings of the study indicate the riparian corridors of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek appear to be in good condition, with native vegetation dominating apart from the middle and downstream areas of Burnt Bridge Creek. Ongoing efforts of bush regeneration in the upper parts of Flat Rock Creek and Burnt Bridge Creek appear to have removed much of the weeds that had previously been noted in these areas during investigations for the environmental impact statement. Much of the riparian vegetation of Quarry Creek and in downstream areas of Flat Rock Creek depend on groundwater. It is expected that the additional creek flows from treated water from the construction and operational wastewater treatment plants could partially feed the surrounding groundwater system during construction and ongoing operation.

None of the riparian zones of Burnt Bridge Creek, including the exclusion zone in its middle section (see **Section 3.1.1**), are dependent, either entirely or in part, on the presence of groundwater for their health and/or survival. They are most likely supported by rainfall and hence groundwater drawdown would not be expected to affect these vegetation communities.

A revised assessment of impacts to groundwater dependent ecosystems is provided in Attachment B to Annexure G of this updated biodiversity assessment.

5 References

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Addendum

A

RCE CRITERIA

Descriptor and category	Score	Descriptor and category	Score
1. Land use pattern beyond the immediate riparian zone		8. Riffle / pool sequence	
Undisturbed native vegetation	4	Frequent alternation of riffles and pools	4
Mixed native vegetation and pasture/exotics	3	Long pools with infrequent short riffles	3
Mainly pasture, crops or pine plantation	2	Natural channel without riffle / pool sequence	2
Urban	1	Artificial channel; no riffle / pool sequence	1
2. Width of riparian strip of woody vegetation		9. Retention devices in stream	
More than 30 m	4	Many large boulders and/or debris dams	4
Between 5 and 30 m	3	Rocks / logs present; limited damming effect	3
Less than 5 m	2	Rocks / logs present, but unstable, no damming	2
No woody vegetation	1	Stream with few or no rocks / logs	1
3. Completeness of riparian strip of woody vegetation		10. Channel sediment accumulations	
Riparian strip without breaks in vegetation	4	Little or no accumulation of loose sediments	4
Breaks at intervals of more than 50 m	3	Some gravel bars but little sand or silt	3
Breaks at intervals of 10 - 50 m	2	Bars of sand and silt common	2
Breaks at intervals of less than 10 m	1	Braiding by loose sediment	1
4. Vegetation of riparian zone within 10 m of channel		11. Stream bottom	
Native tree and shrub species	4	Mainly clean stones with obvious interstices	4
Mixed native and exotic trees and shrubs	3	Mainly stones with some cover of algae / silt	3
Exotic trees and shrubs	2	Bottom heavily silted but stable	2
Exotic grasses / weeds only	1	Bottom mainly loose and mobile sediment	1
5. Stream bank structure		12. Stream detritus	
Banks fully stabilised by trees, shrubs etc.	4	Mainly un-silted wood, bark, leaves	4
Banks firm but held mainly by grass and herbs	3	Some wood, leaves etc. with much fine detritus	3
Banks loose, partly held by sparse grass etc.	2	Mainly fine detritus mixed with sediment	2
Banks unstable, mainly loose sand or soil	1	Little or no organic detritus	1
6. Bank undercutting		13. Aquatic vegetation	
None, or restricted by tree roots	4	Little or no macrophyte or algal growth	4
Only on curves and at constrictions	3	Substantial algal growth; few macrophytes	3
Frequent along all parts of stream	2	Substantial macrophyte growth; little algae	2
Severe, bank collapses common	1	Substantial macrophyte and algal growth	1
7. Channel form			
Deep: width / depth ratio < 7:1	4		
Medium: width / depth ratio 8:1 to 15:1	3		
Shallow: width / depth ratio > 15:1	2		
Artificial: concrete or excavated channel	1		

Attachment B. Groundwater dependent ecosystems assessment (Eco Logical Australia, 2021)

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1. Introduction

The Beaches Link and Gore Hill Freeway Connection environmental impact statement was placed on exhibition between 9 December 2020 and 1 March 2021. In the environmental impact statement, specific impacts to groundwater dependent ecosystems (GDEs) were considered in Appendix S (Technical working paper: Biodiversity development assessment report) and Appendix N (Technical working paper: Groundwater).

The Department of Planning, Industry and Environment and other agencies have requested additional consideration of impacts associated with groundwater drawdown and tunnel inflows. Eco Logical Australia Pty Ltd has been engaged by Transport for NSW to provide further assessment on potential impacts to GDEs, specifically with respect to:

- Baseflow reductions in ecologically poor sections of Flat Rock Creek, Quarry Creek, and Burnt Bridge Creek
- Groundwater dependent vegetation communities in moderate ecological condition adjacent to the middle to lower reaches of Flat Rock Creek, including Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest
- A small patch of Coastal Upland Swamp north of Bantry Bay Oval, about 135 metres to the south-east of the construction footprint, which is in relatively poor ecological condition but considered as high ecological value because the community is listed as an endangered ecological community.

This assessment is based on information included in the environmental impact statement, as well as supplementary assessments carried out since the exhibition period in response to agency and Department of Planning, Industry and Environment feedback as follows:

- Longitudinal surveys of Flat Rock Creek, Quarry Creek and Burnt Bridge Creek to confirm the structural nature of reaches along the creeks, specifically whether creek beds were unlined bedrock or lined with concrete, and whether they contained springs
- An update of existing groundwater models to reflect the structural nature of the creek beds (following detailed inspection), and re-run of the base case and null predictive numerical models to predict baseflow reduction and groundwater drawdown, for distinct sections of the creeks
- Revised maps showing the updates in modelled drawdown and baseflow reduction
- An inspection of potential groundwater dependent terrestrial ecology sites carried out by Arcadis on 16 June 2021 (Arcadis, 2021)
- An assessment of potential impacts to aquatic ecology from changes to baseflow (Cardno, 2021).

2. Risk assessment process

This assessment follows the framework outlined in the *Risk Assessment Guidelines for Groundwater Dependent Ecosystems* (Serov et al, 2012), which summarises the steps needed for GDE risk assessment in New South Wales. The assessment also follows the *Information Guidelines Explanatory Note: Assessing groundwater-dependent ecosystems* (Doody et al, 2019). This assessment only considers those impacts relevant to changed groundwater conditions such as groundwater drawdown, flow paths or changes to water quality. Surface activities such as vegetation clearing or altered surface hydrology due to increases in impermeable surfaces, are not likely to impact on GDEs, so are not considered here. More details of impacts to terrestrial ecology are considered in Appendix S (Technical working paper: Biodiversity development assessment report).

The steps used in the GDE assessment process were as follows:

- Identify and classify the GDEs
- Assess the level of dependence on groundwater
- Identify high value ecological components of the GDE and its overall ecological value
- Determine the impact of the project on the aquifer
- Determine risk magnitude to the GDE
- Apply the GDE Risk Matrix
- Determine the appropriate management actions, including mitigation measures.

The GDE Risk Matrix (Table 1) is a method of outlining appropriate management responses for an environmental value under a particular activity.

The matrix consists of a vertical axis that plots ecological value, and a horizontal axis that plots the level of risk of an activity. The ranking of both ecological values and risk is divided into a three-category system of "High, Medium, and Low" values. The comparative terms, low, medium and high are defined in the context of the project and the nature and value of the ecological value. This will also be influenced by the level of data available and confidence in the activity impacts.

Table 1. GDE Risk Matrix (Serov et al., 2012)

	Category 1: Low Risk	Category 2: Moderate Risk	Category 3: High Risk
Category 1: High Ecological Value (HEV) Sensitive Environmental Area (SEA)	A	B	C
Category 2: Moderate Ecological Value (MEV) Sensitive Environmental Area (SEA)	D	E	F
Category 3: Low Ecological Value (LEV)	G	H	I

The Risk Matrix management action table (Table 2) identifies both the level of management action required and the time frame in which this action needs to be implemented (Action Priority). The management action is aligned with ecological value and does not vary with changes in risk (i.e. the rules for the management of high ecological value ecosystems or aquifers are the same whether the risk is high or low). However, the timing of the management action is aligned with and determined by the level of risk and specific actions will be determined on a site by site basis.

Table 2. Risk Matrix Management Actions (Serov et al., 2012)

Risk Matrix Box	Descriptor	Management action		
		Short term	Mid-term	Long term
A	High value/Low risk	Protection measures for aquifer and GDEs.	Continue protection measures for aquifers and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Periodic monitoring and assessment.	
B	High value/Moderate Risk	Protection measures for aquifer and GDEs.	Protection measures for aquifer and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation action.	Monitoring and periodic assessment of mitigation.	
C	High Value/High Risk	Protection measures for aquifer and GDEs.	Protection measures for aquifer and GDEs.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring. Mitigation.	Monitoring and annual assessment of mitigation	
D	Moderate Value/Low Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline Risk monitoring.	Baseline Risk monitoring.	
E	Moderate Value/Moderate Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline risk monitoring.	Monitoring and periodic assessment of mitigation.	
F	Moderate Value/High Risk	Protection of hotspots.	Protection of hotspots.	Adaptive management. Continue monitoring.
		Baseline risk monitoring. Mitigation action.	Monitoring and annual assessment of mitigation.	
G	Low value/Low risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline risk monitoring.	Baseline risk monitoring.	
H	Low Value/Moderate Risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline risk monitoring. Mitigation action.	Monitoring and periodic assessment of mitigation.	
I	Low Value/High Risk	Protect hotspots (if any).	Protect hotspots (if any).	Adaptive management. Continue monitoring.
		Baseline risk monitoring. Mitigation action.	Monitoring and periodic assessment of mitigation.	

3. Current environment

3.1. Summary of groundwater condition

A detailed account of the geology and hydrogeology of the project area is given in Appendix N (Technical working paper: Groundwater). Information relevant to GDEs present in the project area is summarised below.

The majority of the project area is underlain by Hawkesbury Sandstone, with a small amount of localised fill or Quaternary sediment near Flat Rock Creek that consists of silty to peaty quartz sand, silt and clay.

The Hawkesbury Sandstone was deposited in a fluvial paleo-environment, likely by a large braided river and as such is highly stratified. Localised perched water tables occur as a result of the stratified nature of the sandstone, which can be interspersed with lenses of low permeability that restrict the downward draining of water. This can mean that at some locations throughout the study area there are shallow perched water tables overlying deeper water table (e.g. near Wakehurst Parkway, Jacobs, 2020).

Fractures in the sandstone create preferential flow paths for groundwater. Shallow or perched groundwater systems may discharge to surface water via shallow fracture networks or, may emerge from the sides of bare sandstone as springs.

The Hawkesbury Sandstone is thus an unconfined aquifer at the surface, but becomes increasingly confined with depth because of the highly stratified nature of the sandstone and interbedded shales. Groundwater flow occurs mostly via secondary permeability, fractures and along bedding planes.

The regional water table generally mimics, but in a subdued fashion, the surface topography, with groundwater moving from high topographic areas to low areas where it discharges to surface drainage lines. The water table varies from close to ground surface in topographic lows to 100 metres below ground level beneath hills.

3.2. Groundwater dependent ecosystems identified in the project area

The following GDEs were identified in the environmental impact statement as part of Appendix S (Technical working paper: Biodiversity development assessment report) and the Appendix N (Technical working paper: Groundwater).

The National Atlas of GDEs (BOM, 2018) was used to identify the location of GDEs for the region and these are shown in relation to the project in Figure 1. However, only those in or close to the project assessment area were considered further. These include:

- Coastal Sandstone Gully Forest
- Sandstone Riparian Scrub
- Coastal Sand Forest
- Coastal Sandstone Plateau Heath
- Illawarra Gully Wet Forest
- Estuarine Fringe Forest in the middle to lower reaches of Flat Rock Creek, approximately 280 metres south-east of the tunnel alignment and the Flat Rock Drive construction support site (BL2).

These vegetation communities are mapped as having a moderate to high potential for groundwater dependence, and occur in isolated patches throughout the Sydney region.

- A small patch of Coastal Upland Swamp in the Sydney Basin Bioregion, which is an Endangered Ecological Community (EEC) under the *Biodiversity Conservation Act 2016* and the *Environment Protection and Biodiversity Conservation Act 1999,* whilst not mapped in the National Atlas of GDEs, is potentially sensitive to changes in groundwater flow (Arcadis, 2020). Three patches occur in the assessment area: two approximately 95 metres west of Wakehurst Parkway in Garigal National Park, and one north of Bantry Bay Oval, about 135 metres south-east of the construction footprint.

In addition to these identified communities, varying levels of groundwater discharge contributes to river baseflow ecosystems in Flat Rock Creek, Quarry Creek, and Burnt Bridge Creek (Jacobs, 2020). These are described in Section 3.3.1.

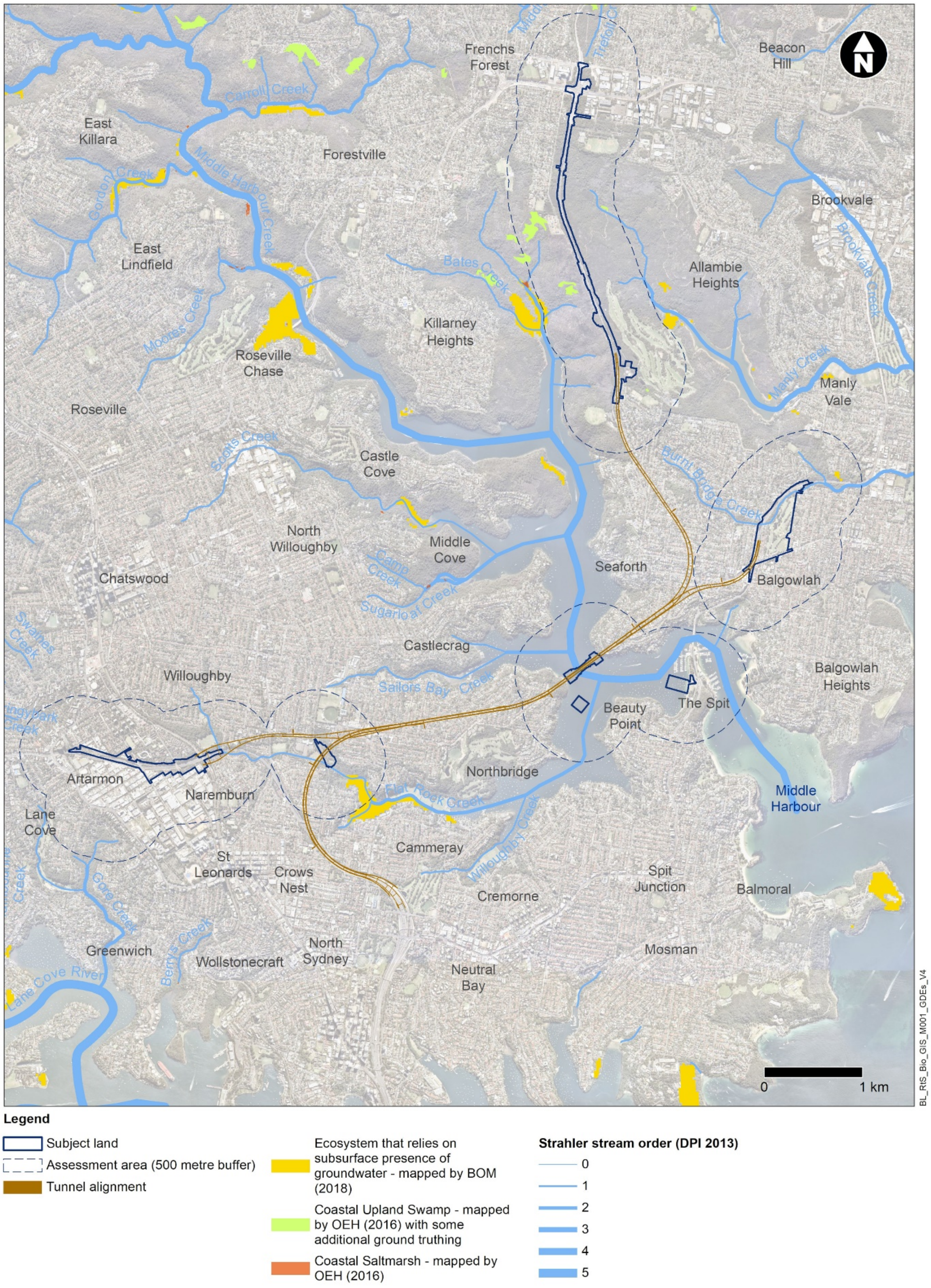

Figure 1. Location of regional groundwater dependent ecosystems represented in the National Atlas of GDEs (from Arcadis, 2020)

3.3. Level of groundwater dependence in ecosystems

3.3.1. River baseflow ecosystems

Streamflow is made up of a number of components, principally including baseflow, sourced from groundwater aquifers, and quickflow, sourced from surface runoff. River channel precipitation and evapotranspiration also contributes to the overall flow in waterways, but are generally small and indistinguishable from other components of streamflow. Distinguishing between each of these sources of water is difficult in practice and is commonly derived through modelling.

Strict definitions of baseflow are difficult to formulate. Conceptually, however, baseflow represents river flow sourced from groundwater aquifers. Groundwater and surface water interaction varies spatially and temporally and can occur from the stream to groundwater, vice versa or in both directions at different times and places, depending on relative river and groundwater levels and hydrogeologic conditions.

Groundwater is recognised to contribute to the baseflow component of stream flow in Flat Rock, Quarry and Burnt Bridge Creeks.

Flat Rock Creek

Flat Rock Creek intersects the groundwater table near where it is crossed by the M1 at Artarmon, approximately at 54 meters AHD, and groundwater interacts with the stream for most of its length downstream, including in the estuarine reaches. In the upstream reaches of Flat Rock Creek, near Willoughby Road, baseflow is estimated to contribute 0.8 per cent to the entire volume of streamflow, with the remaining contribution from surface runoff and direct rainfall. Further downstream at Flat Rock Creek reserve the baseflow contribution is 79 per cent, and at Flat Rock Creek Weir it is 67 per cent. However, overall flow in Flat Rock Creek is dominated by stormwater contribution and this has a stronger influence over aquatic ecology than groundwater.

Groundwater is likely to enter the creek channel, either through springs or as diffuse seepage through porous bedrock, when the stream bed or banks intersect the water table. Figure 2 indicates that Flat Rock Creek is currently a gaining stream (i.e. receives upwelling groundwater) downstream of Hampden Road and Artarmon Park. Most flow in this reach of Flat Rock Creek, upstream of Flat Rock Drive, originates from overland flow or from shallow groundwater in perched aquifers emerging as springs, rather than from the regional Hawkesbury Sandstone aquifer which is predicted to be affected by drawdown during development.

Immediately upstream of Willoughby Road, Flat Rock Creek is lined, though is still able to receive baseflow through cracks and seepage (Figure 4). Downstream of Willoughby Road, the creek is unlined and flows underground for about 900 metres before emerging as an unlined bedrock channel with springs and baseflow. Downstream of Strathallen Avenue it becomes a lined underground channel until it flows into Middle Harbour (Figure 5).

Quarry Creek

Quarry Creek is a gaining stream for its entire length and connected to groundwater (Figure 2). The upper 200 metres is lined, but is still able to receive groundwater contributions to baseflow (Figure 5). For this reach, baseflow makes up approximately 0.5 per cent of stream flow. Unlined bedrock with springs occur along most of its length, until just before its confluence with an unlined reach of Flat Rock Creek. The percentage of groundwater baseflow in the lower reaches is likely to be approximately 79 per cent - similar to that of the mid-reach of Flat Rock Creek.

Burnt Bridge Creek

The upper reach of Burnt Bridge Creek is unlined bedrock with springs and baseflow until Brook Road, where is becomes lined for approximately 200 metres but still receives baseflow contributions (Figure 3, Figure 6). For 200 metres downstream of this point, the creek is an unlined bedrock channel with no baseflow, however baseflow contributions resume for most of the length downstream to Manly Creek (Figure 7). The mid-section of Burnt Bridges Creek, near Baringa Ave, baseflow contributes six per cent to streamflow. This decreases to two per cent downstream of the Balgowlah Golf Course.

Figure 2. Areas of lined, gaining and losing sections of Flat Rock and Quarry Creeks

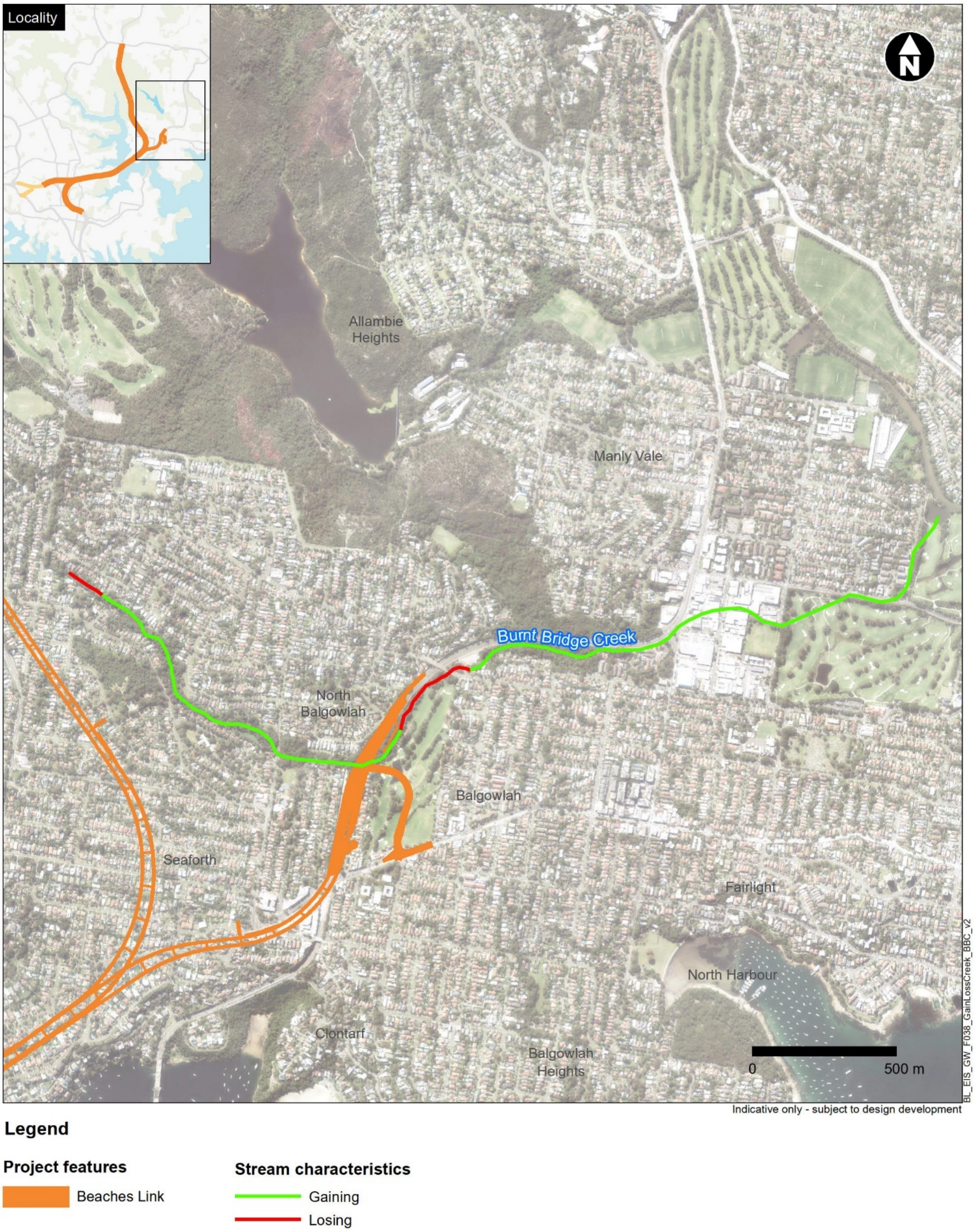

Figure 3. Areas of gaining and losing sections of Burnt Bridge Creek

Figure 4. Waterway lining type- upper to mid reaches of Flat Rock Creek

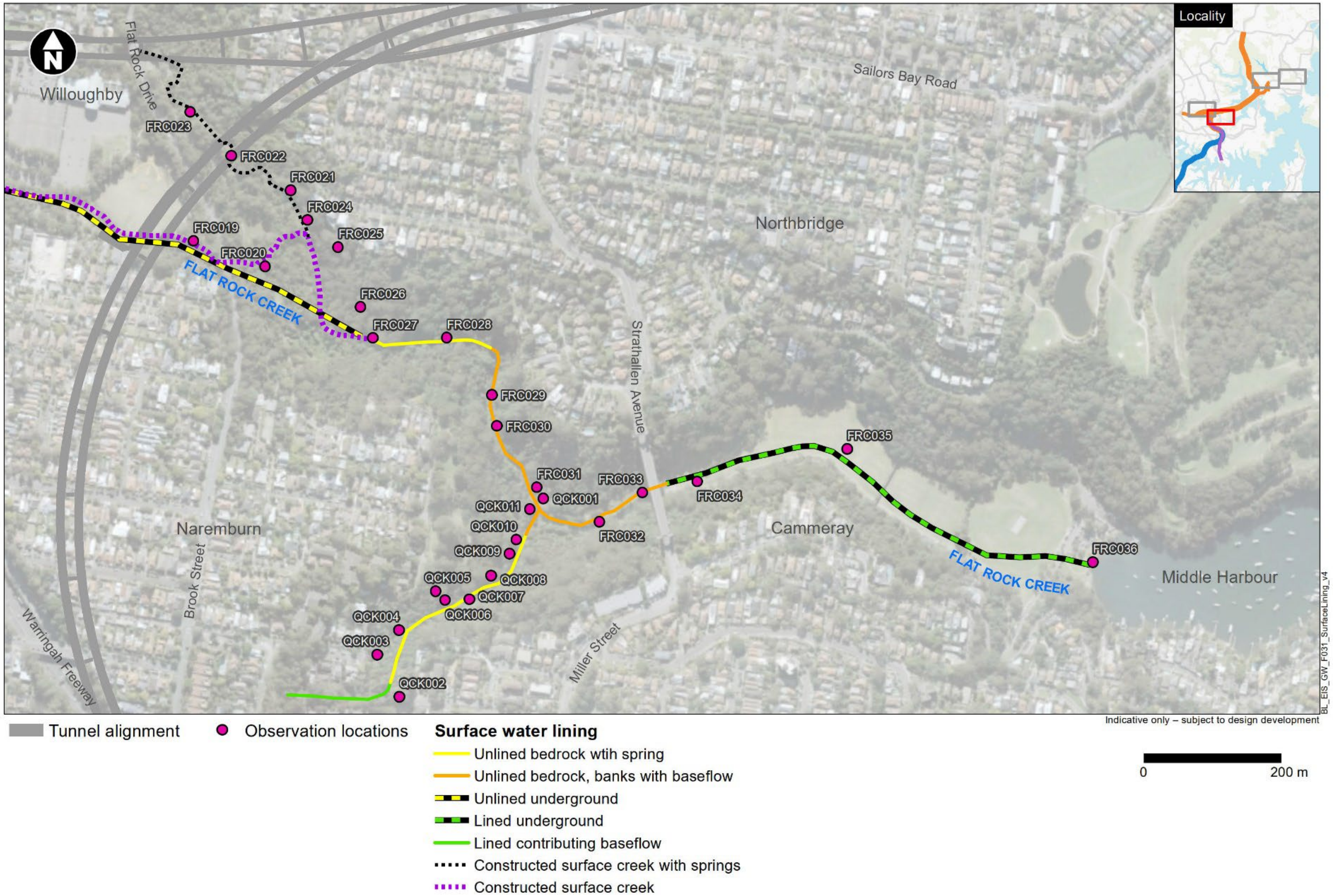

Figure 5. Waterway lining type- mid to lower reaches of Flat Rock Creek, including Quarry Creek

Tunnel alignment

Observation locations

Surface water lining

Unlined bedrock wtih spring

Unlined bedrock only

Unlined bedrock, banks with baseflow

Lined contributing baseflow

Indicative only – subject to design development

0 200 m

Figure 6. Waterway lining type- upper reach of Burnt Bridge Creek

Figure 7. Waterway lining type - lower reach of Burnt Bridge Creek

3.3.2. Groundwater dependent vegetation

Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest in the middle to lower reaches of Flat Rock Creek are all mapped on the National Atlas of GDEs (Figure 8; BOM, 2018) as having a moderate to high potential for groundwater interaction (Figure 9; BOM, 2018). Vegetation upstream of Long Gully Bridge is mapped as having a moderate likelihood of groundwater interaction, while vegetation on the southern sides of the gully overlooking Tunks Park, is mapped as having a high potential for groundwater interaction (Figure 9).

Vegetation upstream of Long Gully Bridge extends from elevations of 4 metres AHD close to Flat Rock Creek, up to 40 metres AHD on the gully slopes[1]. The extent of interaction with the regional water table in these vegetation communities is likely to become less with increasing distance up the gully slope. Vegetation in elevated areas is more likely to depend on perched aquifers and water stored in fractures, since fractures are required for root penetration of the rock. Examples of fracturing in the Hawkesbury Sandstone near the Flat Rock Drive construction support site (BL2) are shown in Figure 10.

[1] Measured with www.maps.six.nsw.gov.au

Figure 8. Groundwater dependent vegetation communities as mapped by Groundwater Dependent Ecosystems Atlas (Arcadis 2021)

Figure 9. Potential for groundwater interaction as mapped by the Groundwater Dependent Ecosystem Atlas (Arcadis 2021)

Figure 10. Examples showing horizontal fractures and stratification in Hawkesbury Sandstone, Tunks Park

3.3.3. Coastal Upland Swamp

Coastal Upland Swamp mainly occurs on impermeable sandstone plateau where there are shallow groundwater aquifers, impeded drainage lines, and on benches with seepage moisture (Jacobs, 2020). A small section of Coastal Upland Swamp south of the Wakehurst Golf Course sits at an elevation of approximately 110 metres AHD[2]. At this location, the modelled composite groundwater contour is approximately 40 metres AHD (Jacobs, 2020). A larger section of swamp occurs in Garigal National Park to the west of Wakehurst Parkway at an altitude of 110 metres AHD. Beneath the swamp the composite groundwater contour is between 100 and 110 metres AHD.

The level of groundwater dependence at these swamps is unclear. The swamp near Wakehurst Golf Course does not appear to be connected to the regional water table, but may be dependent on shallow perched water tables. The swamp west of Wakehurst Parkway sits above a shallower section of groundwater table and may be connected, although neither of these swamps are mapped on the National Atlas of GDEs (BOM, 2018).

3.4. Baseline ecological value and ecological condition

The value of a GDE is determined by the biota it supports, as well as the processes performed by the ecosystem (Serov et al., 2012). Biota includes the flora, fauna and microbiota, while the processes performed include nutrient processing, hydrological filtration, and other biological, hydrological, physical and chemical processes.

A GDE with high ecological value is one that is in a natural or near-natural state and meets the following criteria (Serov et al., 2012):

[2] As indicated in topographic mapping on www.maps.six.nsw.gov.au

- Groundwater dependent communities where a slight to moderate change in groundwater hydrology would result in a substantial change in distribution, species composition or health
- Ecosystems that have already been identified as important by other State, Commonwealth, or International agencies, or are a recognised high conservation area
- Any GDE that is habitat for endemic, relictual, rare, or endangered plant of animal as listed under the *Biodiversity Conservation Act 2016*, *Fisheries Management Act 1994*, or the *Environment Protection and Biodiversity Conservation Act 1999*.

The ecological conditions of GDEs in the project area have been determined from information contained in Appendix S (Technical working paper: Biodiversity development assessment report) and information gathered subsequently by Arcadis during a site inspection (Arcadis, 2021).

3.4.1. River baseflow ecosystems

Flat Rock Creek

Flat Rock Creek is a first order fresh waterway upstream of the Quarry Creek confluence, and an estuarine second order creek downstream of the confluence. In the upstream reaches, the channel is modified and alternates between above- and below-ground sections and has reaches where the channel is lined with either concrete or bedrock. In addition, this area is dominated by stormwater flows which have shaped the creek form. This part of the creek is not considered key fish habitat (Cardno, 2020; Cardno, 2021). The channel is natural as it flows through Flat Rock Reserve, with the bed made of sandstone in the upstream section of reserve, and alluvium downstream. There are occasional ripples and pools, and the banks are steep in places, ranging from 3 to 10 metres above the creek bed. The invertebrate fauna of Flat Rock Creek consists of 16-36 taxa and indicates that the creek is either severely or extremely impaired.

Riparian vegetation is densely vegetated with generally native overstorey and an understorey of native and exotic species. Vegetation consists of PCT 1841 Smooth-barked Apple-Turpentine-Blackbutt tall open forest on enriched sandstone slopes and gullies of the Sydney region, with infestations of weeds and exotics in disturbed areas. The vegetation is likely to only provide marginal quality habitat for disturbance-tolerant species of amphibians, reptiles, mammals, invertebrates and birds (Cardno, 2020). There are numerous impediments to fish passage including underground sections, bedrock bars, and narrow pipe culverts, and there is limited fauna habitat present in the form of logs, leaf litter or rocks. In the lower reaches of the creek immediately upstream of the Quarry Creek confluence there is a small amount of instream timber that may provide fish habitat.

Given the depauperate invertebrate community, and considering the poor quality of habitat present, Flat Rock Creek is considered to be in poor ecological condition (Cardno, 2021), and therefore it is a **low ecological value** GDE.

Downstream of Quarry Creek confluence, Flat Rock Creek becomes estuarine and continues to receive stormwater discharge (as do the mid to upper reaches). The bed consists of unconsolidated sediments and there is some channel and bank erosion. It remains aboveground until Strathallen Avenue, then flows underground though a lined channel into Middle Harbour.

Quarry Creek

Quarry Creek is a short (500 metres) waterway that joins Flat Rock Creek at Flat Rock Reserve. Quarry Creek begins at an altitude of 50 metres AHD and descends over a distance of 300 metres to an altitude of 10 metres AHD. The creek crosses the modelled water table contour (Jacobs, 2020) at an altitude of 30 metres AHD, indicating that the final 300 metres of the creek is fed to varying degrees by groundwater.

Upstream of the confluence, Quarry Creek is a first order waterway that flows through an underground culvert reach into a natural bedrock channel as part of Flat Rock Reserve. Vegetation along Quarry Creek is similar to that along Flat Rock Creek. Quarry Creek has a depauperate community of aquatic macroinvertebrates (10-25 taxa), with those taxa present indicating extreme or severe levels of impact on the ecology (Cardno, 2021). The creek is therefore considered to be a **low ecological value** GDE.

Burnt Bridge Creek

Burnt Bridge Creek is a first order waterway that is intermittent and receives stormwater input from multiple locations. It was not identified as being groundwater dependent in the GDE Atlas, but receives some of its contribution from groundwater (Jacobs, 2020). The creek has low dissolved oxygen concentration and elevated heavy metal and nutrient concentrations (Cardno, 2020). The channel consists of bedrock with sand and silt patches and rocky outcrops. Pools are partially connected and contain exotic in-stream vegetation and moderate riparian shading. Burnt Bridge Creek provides only marginal quality habitat suitable for disturbance tolerant species. There is minimal structural habitat (rocks, logs, leaf litter) and water quality is poor (Cardno, 2020). The aquatic ecology of Burnt Bridge Creek is severely or extremely impaired, with 14-24 taxa (Cardno, 2021), and is therefore considered to be of **low ecological value** GDE.

Riparian vegetation ranges in width from 0 to 30 metres and consists of Water Gum-Coachwood riparian scrub that has a mix of native and exotic species. The area has been significantly disturbed and contains weeds and large areas of exposed ground.

3.4.2. Groundwater dependent vegetation communities of Flat Rock Reserve

Patches of Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest extend for approximately one kilometre in the middle to lower reaches of Flat Rock Creek. The vegetation is in moderate to good condition and contains mostly native species (*Eucalyptus* sp., *Angophora costata*, *Allocasuarine littoralis*) which grow on the upper or mid-slopes, but is dominated by exotic species in the flatter areas beside the creek (Arcadis, 2021). Vegetation in the gully closer to the creek is sheltered and appears to be in good condition with no signs of stress (Arcadis, 2021). Palms and ferns occur on the lower flat beside the creek. This GDE is considered to be a **moderate ecological value** GDE.

3.4.3. Coastal Upland Swamps

Coastal Upland Swamps in the Sydney Basin Bioregion are listed as an EEC under the *Biodiversity Conservation Act 2016* and the *Environment Protection and Biodiversity Conservation Act 1999*. Therefore, this GDE is considered to be a **high ecological value** GDE. This vegetation community occurs on poorly permeable sandstone plateaux in low relief headwater valleys of streams and on sandstone benches with abundant seepage moisture (OEH, 2017). Coastal Upland Swamps generally occur in small patches of less than a hectare (OEH, 2017). There is a small patch of swamp located west of Wakehurst

Parkway in Garigal National Park, and another small patch north of Bantry Bay oval. During a site visit to this swamp in 2021, Arcadis ecologists found it difficult to delineate the swamp from the surrounding heathland (Arcadis, 2021).

4. Potential impacts

4.1. Creek baseflow loss

Assessments of baseflow loss determined for the Beaches Link and Gore Hill Freeway Connection environmental impact statement are likely to be overestimates as groundwater models were developed using a conservative approach that assumed tunnels were fully unlined and that there is full hydraulic connectivity between the deep tunnels and surface. In reality, tunnels would be lined with shotcrete at a minimum, grouting would be carried out to limit groundwater inflows to within approval limits and stratification and fracturing of sandstone would result in actual hydraulic conductivity in the rocks being less than that used for modelling purposes.

Further, under the environmental management measures, the project is required to limit groundwater inflows into the tunnel to less than 1L/km/s during operation. Additional modelling was carried out to account for the different creek linings, which are shown in Figure 4 toFigure 4 Figure 7.

While Flat Rock Creek, Quarry Creek, and Burnt Bridge Creek are predicted to lose some water from the baseflow component of their streamflow, the ecology of all three creeks is already highly disturbed, and the taxa present are considered to be robust and able to tolerate small changes in flow volume. There are no sensitive species present and it is expected that there would be negligible impact on aquatic communities.

4.1.1. Flat Rock Creek

Groundwater modelling estimates a maximum fall in groundwater level of 27 metres beneath Flat Rock Creek near Artarmon at the (approximate) start of the gaining reach of Flat Rock Creek shown in Figure 11. However, at this location, the current contribution to streamflow is only estimated as 0.8 per cent. Drawdown continues to affect the creek for most of the distance downstream, reducing to between 3 and 5 metres at Flat Rock Reserve, and 1 metre where Flat Rock Creek reaches Quarry Creek (Figure 11). This drawdown regime results in an average reduction in baseflow of 30 per cent across the whole creek, comprised of a reduction in streamflow of 0.4 per cent in the upstream reaches, 27 per cent at Flat Rock Reserve, and 22 per cent at Flat Rock Creek Weir (Jacobs, 2021).

This estimated drawdown is based on the conservative modelling approach considering the tunnel being unlined and having no mitigation measures to limit inflow. Considering the modelled drawdown, the point at which Flat Rock Creek intersects the groundwater table would migrate downstream due to the project. Without supplemental flow or storm water input, this means that Flat Rock Creek may become more ephemeral for this reach, and experience longer and more frequent periods of low or no flow. However, the impacts of this would be offset by supplemental flows from the project operational water treatment plant that discharges into Flat Rock Creek in the Artarmon area (refer to Section 17.5.3 of the environmental impact statement). These supplemental flows would prevent the creek from drying out and provide enough connectivity between pools for aquatic habitats in the creek to be sustained.

4.1.2. Quarry Creek

Drawdown beneath the gaining reaches of Quarry Creek is predicted to be approximately 13 metres (Figure 11) in the upper section and one metre just upstream of the Flat Rock Creek confluence. This drawdown would result in a loss of 63 per cent of baseflow contribution to the creek (Jacobs, 2021). In the upstream reaches of Quarry Creek, the predicted loss in baseflow would equate to a decline in stream flow of 0.04 per cent (Jacobs, 2021).

Most flow in the upper reaches of Quarry Creek comes from surface contribution. A reduction of 0.04 per cent is not expected to have a significant impact on aquatic ecology. In the downstream reaches, where Quarry Creek flows through a small floodplain and into Flat Rock Creek, the impact to baseflow is expected to be minor. This is because the alluvial floodplain aquifer would be recharged from water released from the project operational water treatment plant discharging into Flat Rock Creek at Artarmon. Therefore, the resultant impact to aquatic ecology would be negligible.

4.1.3. Burnt Bridge Creek

Drawdown beneath Burnt Bridges Creek is predicted to be between one and three metres for most of the reach upstream of Kitchener Street, and less than one metre downstream (Figure 12). This equates to an overall baseflow reduction of 60 per cent along the whole creek (Jacobs, 2021) and a reduced total streamflow of three per cent in the mid-section and two per cent in the downstream section.

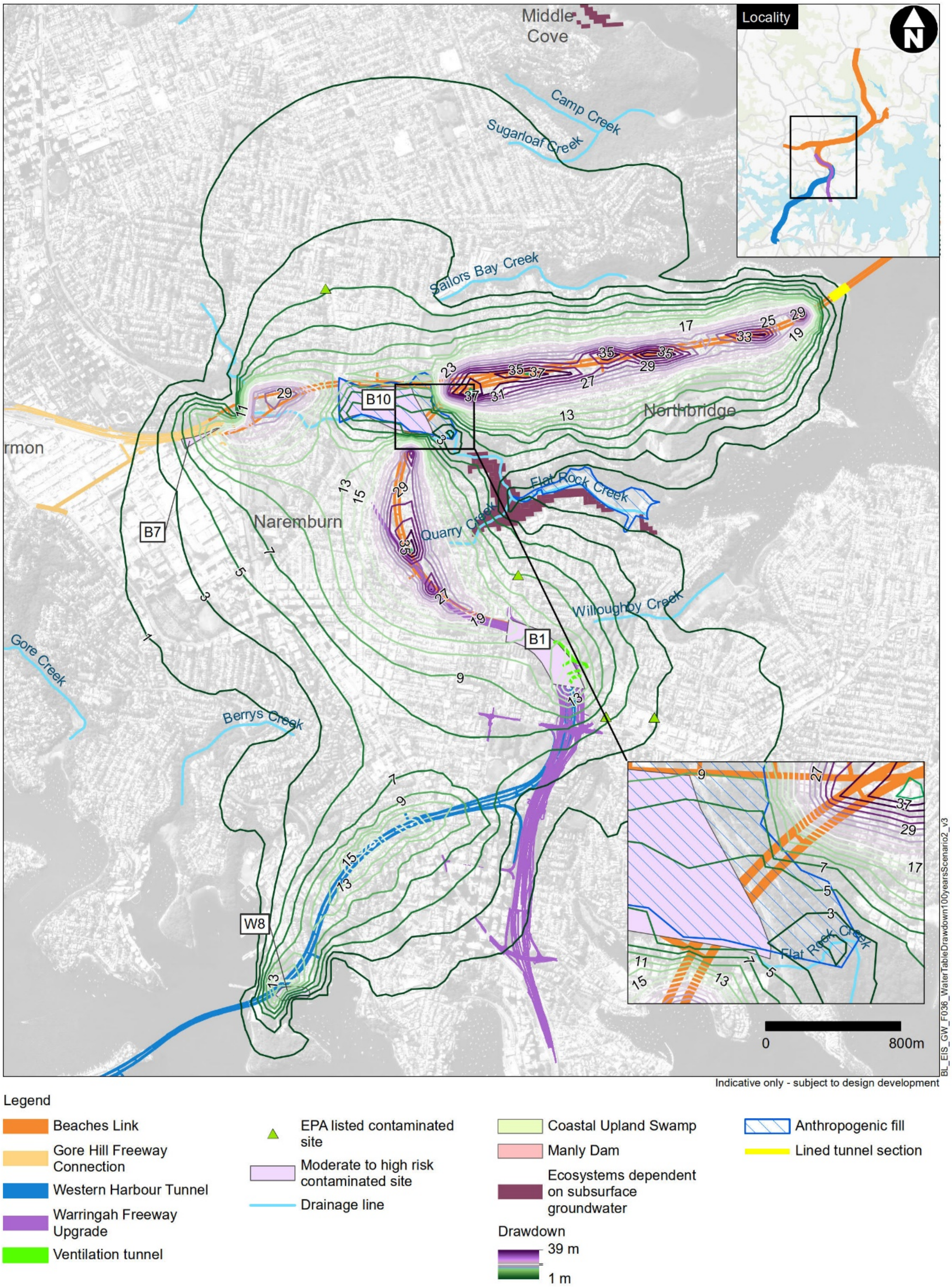

Figure 11. Water table drawdown beneath Flat Rock and Quarry Creeks after approximately 100 years of operation for the Western Harbour Tunnel and Beaches Link program

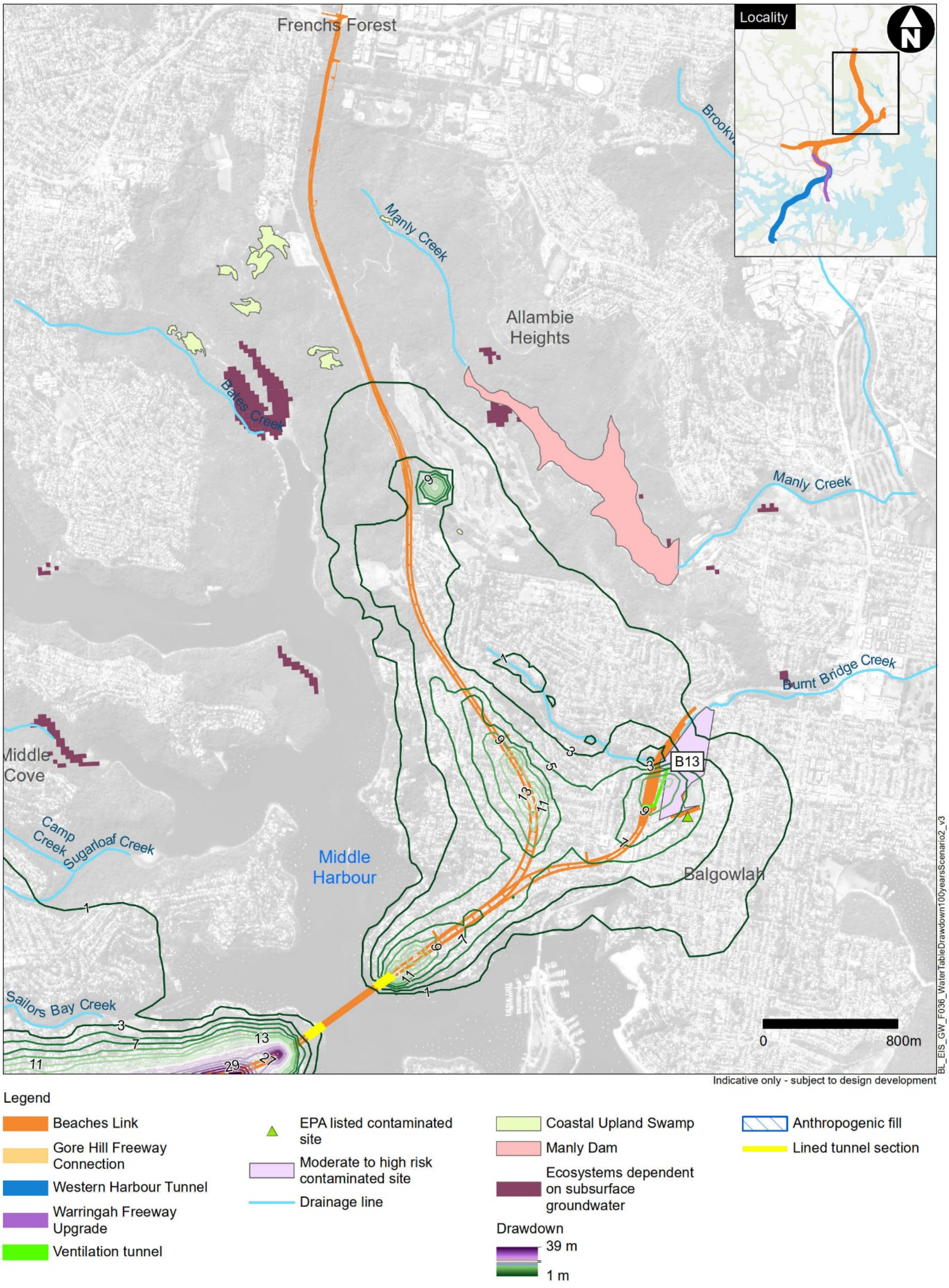

Figure 12. Water table drawdown beneath Burnt Bridge Creek after approximately 100 years of operation for the Western Harbour Tunnel and Beaches Link program.

4.2. Groundwater dependent vegetation communities of Flat Rock Creek

Approximately 10.5 hectares of Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest is within the area predicted to experience drawdown around Flat Rock Creek. Drawdown beneath this vegetation is modelled to be less than five metres at the upstream end, and less than one metre downstream of the Quarry Creek confluence (Figure 11).

Vegetation growing on the upper slopes of the sandstone ridges are likely to be supported by perched aquifers that are isolated from the regional water table. These are constrained by the stratification and fracturing in the Hawkesbury Sandstone. Drawdown in the regional aquifer is therefore likely to have minor spatial impacts on vegetation health, so the magnitude of risk is small given that the vegetation community is not solely dependent on regional groundwater.

The small alluvial aquifer of Flat Rock Creek and at the Quarry Creek confluence would also be recharged by releases from the project water treatment plant into Flat Rock Creek at Artarmon. This is expected to replace any baseflow losses and sustain vegetation communities dependent on groundwater in the shallow alluvium.

4.3. Coastal Upland Swamp

Groundwater drawdown beneath the section of coastal upland swamp beside Wakehurst Golf Course is modelled to be less than three metres. This regional water level is approximately 50 metres below ground level, so this swamp is likely to be connected to perched water tables, rather than the regional aquifer. Perched aquifers are predominantly fed by localised rainwater, or from downward drainage from upslope aquifers. It is therefore unlikely that this section of upland swamp would be affected by drawdown from the project.

Drawdown beneath the swamp west of Wakehurst Parkway is modelled to be between zero and one metre by 2028 and for the subsequent 100 modelled years. The groundwater dependence of this swamp is uncertain, as the water level is currently approximately 10 metres below ground level. The water table beneath this swamp may be affected by drawdown, but it is likely that the swamp receives water from surface runoff and subsurface drainage from upslope perched aquifers, and that the availability of this water to support the swamp would not be affected.

5. Risk assessment

The aquatic ecosystems supported by Flat Rock, Quarry, and Burnt Bridge Creeks are all highly modified and support a depauperate aquatic biota, typical of highly-disturbed small streams in the Sydney region (Cardno, 2021). The biological community of these creeks are robust and would not be impacted by the anticipated levels of disturbance expected from the project. There are few aquatic macrophytes in the creeks and the native fish communities are in poor condition. As such, these creeks have a **low ecological value**.

The local Coastal Upland Swamps, however, are listed as endangered, hence the two patches of this ecosystem are considered to have a **high ecological value**.

Modelled baseflow losses are estimated at between 30 and 63 per cent across the three creeks predicted to be impacted by the project. This constitutes approximately 2 to 27 per cent of daily total stream flow. Most of the water in these creeks is thus derived from surface runoff and stormwater discharge, so would be minimally affected by groundwater drawdown. The percentage of potential baseflow loss can be considered as posing a **low level of risk** in Quarry and Burnt Bridge Creeks, and a **moderate level of risk** in Flat Rock Creek.

Drawdown of the regional groundwater table beneath the Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest along Flat Rock Creek, and beneath the Coastal Upland Swamp, is not expected to negatively affect these vegetation communities because they are likely supported by rainfall and shallow, perched aquifers. They are considered of **moderate ecological value** and at a **low level of risk**.

Outcomes against the GDE risk matrix are presented in Table 3, and the associated recommended management actions are discussed in Section 6 below.

Table 3. Risk Matrix assessment characteristics for GDEs

Potential GDE	Ecological Value	Level of Risk	Risk Matrix outcome
Flat Rock Creek	Low	Moderate	H
Quarry Creek	Low	Low	G
Burnt Bridge Creek	Low	Low	G
Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest	Moderate	Low	D
Coastal Upland Swamp	High	Low	A

6. Proposed management actions and mitigation measures

For ecosystems in category H (low value/moderate risk) and G (low value/low risk) of the GDE Risk Matrix, the recommended management actions include protecting hotspots (if any) and monitoring ecological condition. As there are no areas of high biodiversity that could be considered hotspots in any of the creeks affected by baseflow loss, there are no sections that need particular protection. The ecological condition of the creeks is already very poor, so is not likely to be impacted further by the potential baseflow loss. Ongoing ecological monitoring of these waterways would not be sensitive enough to detect the minor (if any) impacts from reduced baseflow, so this is not recommended.

Environmental management measures as listed in the environmental impact statement and submissions report would be sufficient to maintain the current ecological condition of all groundwater dependent ecosystems in the project area. Specifically, releases from wastewater treatment plants will replace and augment local streamflows.

The release of water into Flat Rock Creek from the Gore Hill Freeway operational wastewater treatment plant at Artarmon would compensate for any water lost due to groundwater drawdown. Prior to release, water will be treated to comply with the relevant physical and chemical stressors from ANZECC/ARMCANZ (2000) and the ANZG (2018) 95 per cent species protection levels for toxicants generally, with the exception of those toxicants known to bioaccumulate, which would be treated to meet the ANZG (2018) 99 per cent species protection levels, and the draft ANZG default guideline values for iron (in fresh and marine water) and zinc (in marine water), in accordance with environmental management measure WQ17 (refer to Table D2-1 of the submissions report). This would ensure that pool and riffle habitats in middle reaches of Flat Rock Creek are able to persist and maintain their ecological functions. Water released down Flat Rock Creek would also recharge the shallow alluvial aquifer of the creek and support riparian vegetation on the narrow floodplain at the bottom of Flat Rock Gully.

Baseflow loss in Burnt Bridge Creek would be supplemented by discharges from the wastewater treatment plant only during the construction phase. During the operational phase, the current modelled reduction in streamflow due to groundwater drawdown is only 2-3 per cent. These figures are based on the conservative scenario of tunnels being unlined with no mitigation measures in place to limit groundwater inflows. Once the construction contractor has a detailed tunnel design, which includes inflow mitigation measures at strategic locations, it is likely that revised groundwater modelling would indicate an even lesser impact on streamflow. Given the level of disturbance already apparent in Burnt Bridge Creek, the small reduction in streamflow is unlikely to have a significant impact, so no monitoring is considered necessary.

For Coastal Sandstone Gully Forest, Sandstone Riparian Scrub, Coastal Sand Forest, Coastal Sandstone Plateau Heath, Illawarra Gully Wet Forest and Estuarine Fringe Forest ecosystems, classified as D under the risk matrix, the recommended management actions include the protection of hotspots, ongoing monitoring, and adaptive management. There is a very low risk that these ecosystems would be impacted by groundwater drawdown, particularly the vegetation growing close to the creeks where flow is supplemented from the water treatment plant.

Vegetation communities on the sandstone slopes of Flat Rock Gully are likely to be buffered against the impacts of groundwater drawdown by water received from shallow perched aquifers. These aquifers are recharged by rainfall and surface runoff, and in the upper slopes of the gully are likely disconnected from the deeper regional aquifer. Given the highly disturbed condition of the vegetation community, it would be difficult to attribute any decline in vegetation condition to a decline in regional groundwater level.

For the Coastal Upland Swamps, the risk management matrix outcome was A, as they are considered EECs. Management actions for these ecosystems include the protection of the GDE and aquifer and monitoring to detect potential impacts. However, the extent of dependence on the potentially impacted regional aquifer for both of these patches of swamp is uncertain, and it is difficult to determine if there would be any impact from regional water table drawdown. Coastal Upland Swamps generally occur on areas of poorly permeable sandstone (OEH, 2017), so at least some of the water they rely on is expected to come from overland flow or rainfall that is prevented from draining away by rock beneath the swamp.

The area of swamp north of Bantry Bay Oval is also surrounded by a modified landscape, including a sportsground that drains directly into the swamp area. For the area of Coastal Upland Swamp in Garigal National Park, meanwhile, the predicted drawdown of less than 1 metre is unlikely to have a significant impact on the vegetation community. Given the likelihood that the two patches of Coastal Upland Swamp are not dependent on the regional groundwater table, and the low likelihood that they would be impacted by the project, no specific monitoring of these ecosystems is recommended.

Environmental management measure SG2 (refer to Table D2-1 of the submissions report) specifies that, "during the development of the detailed design and once a contractor is engaged, additional geotechnical investigations and groundwater monitoring would be completed". This information would be used, along with the updated detailed tunnel design, to carry out any additional groundwater modelling, which would provide more detailed predictions of groundwater drawdown. If the updated predictions indicate that the impacts would be greater that those presented in the environmental impact statement, additional mitigation measures should be developed.

As current modelling is conservative and assumes that the tunnels are unlined with no mitigation measures in place to limit groundwater inflows, and assumes there would be continuous saturation (and hence hydraulic connectivity) between the tunnel and the water table, the incorporation of more refined geotechnical information and inflow mitigation measures at strategic locations into the models is expected to reduce the predicted level of groundwater drawdown.

Following completion of any updated modelling, environmental management measure SG6 (refer to Table D2-1 of the submissions report) requires "a focussed study, in consultation with Department of Planning, Infrastructure and Environment, to confirm potential groundwater drawdown and baseflow reduction in the three creeks due to tunnelling, and confirm potential impacts on freshwater ecology in the affected watercourses and nearby GDEs". This would entail further, detailed hydrological and geological studies and would provide improved appreciation of potential impacts to GDEs in the project area. If unacceptable impacts are predicted, appropriate additional mitigation measures would be identified to address these impacts.

7. References

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