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Environmental Impact Statement – Appendix F3: Biodiversity Assessment Report - Construction Area

Warragamba Dam Raising

Reference No. 30012078
Prepared for WaterNSW
10 September 2021

SMEC INTERNAL REF. 30012078

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Report certification

In accordance with section 6.15 of the *Biodiversity Conservation Act 2016*, it is hereby certified that:

- This assessment has been prepared by a person accredited under the *Biodiversity Conservation Act 2016*
- This assessment has been prepared in accordance with the brief provided by the client
- All field workers involved in the preparation of this project were appropriately licensed under the *Biodiversity Conservation Act 2016*
- The information presented in this report is a true and accurate record of the study findings in the opinion of the authors
- As an accredited person, the author recognises the obligations of an accredited person detailed within the Accredited Person Code of Conduct
- This report has been prepared on the basis of the requirements of (and information provided under) the biodiversity assessment method required by the SEARs as at a specified date and that date is within 14 days of the date the report is so submitted.

Signed: Kevin Roberts (BAM Assessor Accreditation No. BAAS17075)

NOTE: The transitional provisions of the Biodiversity Conservation (Savings and Transitional) Regulation 2017 apply to this Project as the application for the Secretary's Environmental Assessment Requirements for the Project was made prior to the commencement of the *Biodiversity Conservation Act 2016*.

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Abbreviations and Acronyms

Term	Description
AHD	Australian Height Datum
BAR	Biodiversity Assessment Report
BBAM	BioBanking Assessment Methodology
BBCC	BioBanking Credit Calculator
BC Act	*Biodiversity Conservation Act 2016* (NSW)
BOS	Biodiversity Offset Strategy
CEEC	Critically Endangered Ecological Community
CMA	Catchment Management Authority
Development site	An area of land that is subject to a proposed Major Project that is under the EP&A Act.
Development footprint	The area of land that is directly impacted on by a proposed Major Project that is under the EP&A Act, including access roads, and areas used to store construction materials. For the purposes of this assessment, the development footprint includes footprint of raised dam spillway, buttress and associated infrastructure.
DFS	NSW Department of Finance and Services
DoE	Commonwealth Department of the Environment (former, now Department of Agriculture, Water and the Environment, DAWE)
DP&E	NSW Department of Planning and Environment (former, now Department of Planning, Industry and Environment, DPIE)
EEC	Endangered Ecological Community
EIS	Environmental Impact Statement
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
FBA	Framework for Biodiversity Assessment
FESM	Fire extent and severity map
FM Act	*Fisheries Management Act 1994* (NSW)
FMZ	Flood Mitigation Zone – the airspace above the Full Supply Level which is used to temporarily capture flood waters.
FSL	Full Supply Level – the maximum level of water in the dam for drinking water supply
GBMWHA	Greater Blue Mountains World Heritage Area
GDE	Groundwater Dependent Ecosystem
GEEBAM	Google Earth engine burnt area map
GIS	Geographic Information System
GL	Gigalitres
GPS	Global Positioning System
IBRA	Interim Biographic Regionalisation for Australia
IDE	Inflow Dependent Ecosystem

Term	Description
LGA	Local Government Area
LEP	Local Environmental Plan
MNES	Matter(s) of National Environmental Significance
NPWS	National Parks and Wildlife Service
NSW	New South Wales
OEH	NSW Office of Environment and Heritage (former, now part of Environment, Energy and Science Group within DPIE)
PCT	Plant Community Type
PMF	Probable Maximum Flood
the Project	Warragamba Dam Raising
RFS	NSW Rural Fire Service
SCA	Sydney Catchment Authority
SEARs	Secretary's Environmental Assessment Requirements
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities (former)
SMEC	SMEC Australia Pty Ltd
SSI	State Significant Infrastructure
Study area	The development site with a 50-metre buffer.
TEC	Threatened Ecological Community
TSC Act	*Threatened Species Conservation Act 1995* (NSW)
WDR	Warragamba Dam Raising

Definitions

Abundance: the quantification of the population of the species or community

Activity: has the same meaning as in the EP&A Act

Avoid: In the development planning process, potential impacts on biodiversity values and the environment are avoided though careful site selection and project design.

Benchmarks: the quantitative measures of the range of variability in vegetation condition in vegetation with relatively little evidence of modification by humans since European (post 1750) settlement. 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 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

BioBanking Credit Calculator: the computer programme that provides decision support to assessors and proponents by applying the FBA, and which calculates the number and type of biodiversity credits required to offset the impacts of a Major Project

Biodiversity Assessment Report: the report that must be prepared in accordance with Section 3.2 of the FBA

Biodiversity values: has the meaning as Section 4A of the TSC Act, but excludes marine mammals, wandering seabirds, and biodiversity that is endemic to Lorde Howe Island

Broad condition state: areas of the same PCT that are in relatively homogenous condition. Broad condition is used for stratifying areas of the same PCT into a vegetation zone for the purpose of determining the site value score

Connectivity: the measure of the degree to which an area(s) of native vegetation is linked with other areas of vegetation

Connectivity value: has the meaning given in Subsection 4.2.3 of the FBA

Conservation status: is regarded as the degree of representation of a species or community in formal conservation reserves

Critical habitat: has the same meaning as the TSC Act

Critically Endangered Ecological Community: an ecological community specified in Part 2 of Schedule 1A to the TSC Act and/or listed under Part 13, Division 1, Subdivision A of the EPBC Act.

Development: has the same meaning as development in section 1.4 of the EP&A Act and includes development as defined in section 5.11 of the EP&A Act

Development footprint: the area of land that is impacted by a proposed Major Project that is under the EP&A Act, including access roads, and areas used to store construction materials. For the purposes of this assessment, the development footprint includes areas directly cleared for construction including raised dam spillway, buttress and associated infrastructure.

Development site: an area of land that is subject to a proposed Major Project that is under the EP&A Act.

Direct impact: an impact on biodiversity values that is a direct result of vegetation clearance from a development

Ecosystem credits: a measurement of the value of EECs, CEECs, and threatened species habitat for species that can be reliably predicted to occur within a PCT. Ecosystem credits measure the loss in biodiversity values at a development site and the gain in biodiversity values at an offset site.

EIS: an environmental impact statement referred to in section 4.12 or section 5.7 of the EP&A Act

Expert: a person who is accredited by the Chief Executive under section 142B(1)(b) of the TSC Act, or if arrangements of accreditation under section 142B(1)(b) are not in place, a person who has the relevant experience and/or qualifications to provide an expert opinion in relation to the biodiversity values to which an expert report relates

Exotic plant cover: exotic plants are vascular plants not native to Australia. Exotic plant cover is measured as total percentage foliage cover of all exotics in all strata

Habitat: an area or areas occupied, or periodically or occasionally occupied by a species, population, or ecological community, including any biotic or abiotic component

Habitat component: the component of habitat that is used by a species for either breeding, foraging, or shelter

Hollow bearing tree: a living or dead tree that has at least one hollow. A tree is considered to have a hollow if:

(a) the entrance can be seen

(b) the minimum entrance width is at least 5 centimetres across

(c) the hollow appears to have depth

(d) the hollow is at least 1 metre above the ground.

IBRA region: a bioregion identified under the Interim Biogeographic Regionalisation for Australia (IBRA) system, which divides Australia into bioregions on the basis of their dominant landscape-scale attributes

IBRA subregion: a subregion of a bioregion identified under the IBRA system and based on major catchment areas

Important area: an area of the CEEC or EEC that is necessary for the entities' long-term persistence and recovery. This may include areas identified in recovery plans, and/or an CEEC or EEC at the limit of the communities' range.

Important wetland: a wetland that is listed in the Directory of Important Wetlands of Australia (DIWA), or is a wetland mapped under State Environmental Planning Policy (Coastal Management) 2018

Individual: in relation to organisms, a single, mature organism that is a threatened species defined in section 4(1) of the TSC Act, or any additional threatened species listed under Part 13 of the EPBC Act

Landscape value: the value given to landscape attributes of a development site after an assessment undertaken in accordance with Section 4.2 of the FBA

Life cycle: the series of reproduction, growth, development, aging, and death of an organism

Linear shaped development: development that is generally narrow in width and extends across the landscape for a distance greater than 3.5 kilometres in length

Local population: the population that occurs within the development footprint. The assessment of the local population may be extended to include individuals beyond the study area if it can be clearly demonstrated that contiguous or interconnecting parts of the population continue beyond the study area. In cases where multiple populations occur on the study area or a population occupies part of the study area, impacts on each subpopulation must be assessed separately.

Local wetland: and wetland that is not identified as an important wetland

Loss: Loss of biodiversity values from the development site

LGA means Local Government Area

Locality is the area within a ten-kilometre radius of the development footprint

Major Catchment Area: the area of operation of a former catchment management authority, as described in Schedule 2 to the *Catchment Management Authorities Act 2003* before its repeal

Major Project: State Significant Development or Sate Significant Infrastructure projects

Minimise: a process applied throughout the development planning and design life cycle which seeks to reduce the avoidable impacts of development on biodiversity values

Mitchell Landscape: landscapes with relatively homogenous geomorphology, soils, and broad vegetation types, mapped at a scale of 1: 250,000

Native ground cover: all native vegetation below 1m in height, including all such species native to NSW (i.e. not confided to species indigenous to the area)

Native vegetation: has the same meaning as in Section 6 of the *Native Vegetation Act 2003*

Offset requirement: the number and type of biodiversity credits that are required to offset the remaining impacts of development on biodiversity values after all reasonable measures have been taken to avoid and minimise impacts

Onsite measures: reasonable measures and strategies that are taken, or are proposed to be taken at a development site to avoid and minimise the direct and indirect impacts of the development on biodiversity values.

Patch Size: an area of native vegetation that

a) occurs on the development site or offset site, and

b) is in moderate to good condition, and

c) includes native vegetation that has a gap of less than 100 m from the next area of moderate to good condition native vegetation (or ≤30 m for non-woody ecosystems).

Patch size may extend onto adjoining land that is not part of the development site.

Percent cleared value: the percentage of a vegetation type that has been cleared within a major catchment area as a proportion of its pre-1750 extent, as identified in the VIS Classification database. The percent cleared value is assigned to the BVT equivalent.

Percent foliage cover: the percentage of ground that would be covered by a vertical projection of the foliage and branches and trunk of a plant or plants.

Percent native vegetation cover: the percent of native vegetation cover in the inner and outer assessment circle, or the development footprint buffer area. Cover estimates are based on the cover of native woody and non-woody vegetation relative to the approximate benchmarks for the PCT, taking into account vegetation condition and extent. Native over storey vegetation is used to determine the percent cover in woody vegetation types, and native ground cover is used to assess cover in non-woody vegetation types.

Plant community type (PCT): a NSW plant community type identified using the PCT classification system.

Plot: an area within a vegetation zone in which site attributes are assessed.

Regeneration: the proportion of over-storey species characteristic of the PCT that are naturally regenerating and have a diameter at breast height

Region has the same meaning as that contained within the TSC Act

Regionally significant biodiversity link: a biodiversity corridor that is important at a regional scale and is identified in a plan approved by the Chief Executive of OEH.

Remaining impact: an impact on biodiversity values after all reasonable measures have been taken to avoid and minimise the impacts of development. Under the FBA, an offset requirement is calculated for the remaining impacts on biodiversity values.

Riparian buffer: an area of land determined according to Appendix 2 of the FBA. Riparian buffer distances must be measured on both sides of the stream from the top of bank, if this is defined, otherwise from the edge of the stream and only from the centre of the stream if the edge is not defined. Where a stream has more than one bank on either side, the bank closest to the main channel must be used, to protect vegetation on and within the stream banks. The riparian buffer distances for various water bodies are set out in Table 7 of Appendix 2 of the FBA. Riparian buffer distances do not include the width of the water body.

Risk of extinction: the likelihood that the local population or CEEC or EEC will become extinct either in the short term or in the long term as a result of direct or indirect impacts on the viability of that population or CEEC or EEC.

Site attributes: the matters assessed to determine site value. They include: native plant species richness, native over-storey cover, native mid-storey cover, native ground cover (grasses), native ground cover (shrubs), native ground cover (other), exotic plant cover (as a percentage of total ground and mid-storey cover), number of trees with hollows, proportion of over-storey species occurring as regeneration, and total length of fallen logs.

Site value: the condition of native vegetation assessed for each vegetation zone against the benchmark for the PCT.

Site value score: the quantitative measure of vegetation condition calculated in accordance with Equation 1 of the FBA (Determine the current site value score for a vegetation zone).

Significant species: means species not listed in the TSC Act but considered to be of regional or local significance

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 Species Profile Database.

Species that cannot withstand further loss: a species identified in the Threatened Species Profile Database as a species that cannot withstand further loss in the major catchment area in which the species occurs because of one or more of the following:

- the species is naturally very rare, has few populations or a restricted distribution
- the species or population is critically endangered
- the species has threats that are beyond control (of the management actions undertaken on an offset site)
- the species' or its habitat's needs/response to management are poorly known.

State significant biodiversity link: a biodiversity corridor that is important at a state scale and is identified in a plan approved by the Chief Executive of OEH.

Stream order: has the same meaning as in Appendix 2 of the FBA. Strahler stream order process where the number begins at the top of a catchment with headwater flow paths assigned number one, where two order one flow paths join, the section downstream of the junction is order two. Where two second order streams join the waterway downstream of the junction is order three, and so on. As a lower order and a higher order waterways join they retain the higher order number (e.g. order one joins order three, the waterway remains a third order).

Study area: the development site with a 50-metre buffer.

Subject species: means those threatened species that are known or considered likely to occur in the study area

TG value: the ability of a species to respond to improvement in site value or other habitat improvement at an offset site with management actions. TG is based on an assessment of effectiveness of management actions, life history characteristics, naturally very rare species, and very poorly known species.

Threatening process: has the same meaning as that contained in the TSC Act; the definition is not limited to KTPs.

Threatened population: has the same meaning as in section 4(1) of the TSC Act.

Threatened species: critically endangered, endangered or vulnerable threatened species and populations as defined in section 4(1) of the TSC Act, or any additional threatened species listed under Part 13 of the EPBC Act as critically endangered, endangered or vulnerable.

Threatened Species Profile Database: is part the BIONET database, is maintained by OEH and can be accessed from the BIONET website at www.bionet.nsw.gov.au/.

Total length of fallen logs: the total length of logs present in a vegetation zone that are at least 10 cm in diameter and at least 0.5 m long.

Transect: a line or narrow belt along which environmental data is collected.

Unavoidable impact: an impact on biodiversity values that cannot be avoided and/or minimised.

Vegetation Benchmarks Database: a database of benchmarks for vegetation classes and some PCTs. The Vegetation Benchmarks Database is maintained by OEH and is part of the VIS Classification Database. It is available at www.environment.nsw.gov.au/research/Visclassification.htm.

Vegetation class: a level of classification of vegetation communities defined in Keith (2004)3 . There are 99 vegetation classes in NSW.

Vegetation formation: a broad level of vegetation classification as defined in Keith (2004)3 . There are 12 vegetation formations in NSW.

Vegetation zone: a relatively homogenous area of native vegetation on a development site that is the same PCT and broad condition state.

VIS Classification Database (NSW Vegetation Information System Classification Database): the master vegetation community-level classification for use in vegetation mapping programs and regulatory biodiversity impact assessment frameworks in NSW. The VIS Classification Database is maintained by OEH and available at www.environment.nsw.gov.au/research/Visclassification.htm.

Viability: the capacity of a species to successfully complete each stage of its life cycle under normal conditions so as to retain long-term population densities.

Wetland: an area of land that is wet by surface water or ground water, or both, for long enough periods that the plants and animals in it are adapted to, and depend on, moist conditions for at least part of their life cycle. Wetlands may exhibit wet and dry phases and may be wet permanently, cyclically or intermittently with fresh, brackish or saline water.

Woody native vegetation: native vegetation that contains an over-storey and/or mid-storey that predominantly consists of trees and/or shrubs.

1 Introduction

1.1 Project application

WaterNSW, a New South Wales (NSW) state owned corporation, is seeking project approval for the Warragamba Dam Raising Project (the Project). The approval is sought under Division 5.2 (section 5.12) (State Significant Infrastructure) of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act).

WaterNSW is proposing to raise the existing Warragamba Dam to facilitate flood mitigation during a flood event and enable the release of downstream environmental flows for river health in non-flood times. To support the Project approval application, an Environmental Impact Statement (EIS) is being prepared. This report is part of the EIS and has been prepared to assess the Project's potential impacts on biodiversity within the construction area of Warragamba Dam. The key objectives of this Biodiversity Assessment Report (BAR) are to address the requirements of the biodiversity matters identified in in the Secretary's Environmental Assessment Requirements (SEARs). The SEARs that this report addresses are listed in Section 1.3. The background to the Project is described in the following section. A more detailed description of the Project is contained in Section 1.4 of this report.

1.2 Project background

The Hawkesbury-Nepean Valley (the valley) in western Sydney has the highest flood risk in New South Wales, if not Australia. The potential for significant flooding of the Hawkesbury-Nepean Valley was known by the local Aboriginal community before the first European settlement of the area in the 1790s. In the early years of European settlement, the risk of flooding was recognised, and a series of proclamations were issued that warned of the risk of flooding. This high flood risk arises from the river being confined by narrow sandstone gorges, creating rapid deep backwater flooding over extensive floodplains. The floodplains are home to a large existing population who would be impacted in a major flood.

During the 1980s and 1990s updated flood investigation techniques and new geological evidence predicted that floods significantly larger than any historically recorded could occur in the Hawkesbury-Nepean Valley. The dam was raised by five metres in the late 1980s to meet modern dam safety requirements. Further investigations into flooding and flood mitigation were undertaken and culminated in 1995 in a proposal to raise Warragamba Dam by 23 metres primarily for dam safety but also to provide for flood mitigation. The 1995 proposal did not proceed. In the late 1990s, major upgrades of Warragamba Dam were undertaken to prevent dam failure during extreme flooding events, to protect Sydney's water supply, and to prevent catastrophic downstream floods from dam failure. This resulted in the construction of the auxiliary spillway. However, these works only dealt with dam safety issues and did not address the major flood risks to the people and businesses in the Hawkesbury-Nepean Valley and the NSW economy.

In 2011, an approximately 1 in 100 chance in a year flood impacted Brisbane, resulting in significant damage, economic costs, and social disruption. The substantial impacts of the 2011 Brisbane flood led the NSW Government to recommence investigations into flood mitigation options for the Hawkesbury-Nepean Valley.

In 2013, the NSW Government in response to the State Infrastructure Strategy and community concerns, initiated the Hawkesbury-Nepean Valley Flood Management Review to consider flood planning, flood mitigation and flood response and recovery in the valley. The Review found that current flood management and planning arrangements could be improved, and no single mitigation option could address all the flood risks present in the valley (Department of Primary Industries (DPI) 2014a). The review concluded that raising Warragamba Dam to capture inflows is the most effective infrastructure measure that could have a major influence on flood levels during those events, when most of the damages occur. Other complementary and non-infrastructure options were also identified to mitigate flood risks (DPI 2014).

Under the direction of Infrastructure NSW (INSW), the Hawkesbury-Nepean Valley Flood Management Taskforce was established to investigate feasible flood options to reduce overall risk to the Hawkesbury-Nepean Valley. In June 2016, the former Premier and Minister for Western Sydney, Mike Baird MP, announced the NSW Government plan to raise Warragamba Dam to significantly reduce the risk of flooding in the Hawkesbury-Nepean Valley. A flood damages assessment for the Warragamba Dam Raising estimated that it would provide a 75 percent reduction in annual average flood damages and reduce current levels of flood damages from $5 billion to $2 billion (2016 dollars).

Raising Warragamba Dam would significantly reduce flood risk; however, it would not eliminate the risk completely. Regardless of the increase in the dam's height, flooding can be generated from catchments other than Warragamba Dam. The raising of Warragamba Dam would therefore be complemented with other non-infrastructure and policy actions. In May 2017, INSW released *Resilient Valley, Resilient Communities*, which outlines the Hawkesbury-Nepean

Valley Flood Risk Management Strategy (the Flood Strategy) (INSW 2017). The Flood Strategy covers the geographic region between Bents Bridge and the Brooklyn Bridge, encompassing areas within the local government areas (LGAs) of Liverpool City, Penrith City, Hawkesbury City, The Hills Shire, Blacktown City, Central Coast, and Hornsby Shire.

The Flood Strategy's objective is to reduce flood risk to life, property and social amenity from floods in the Hawkesbury-Nepean Valley. The strategy includes nine key outcomes; a combination of infrastructure and non-infrastructure initiatives to mitigate the flood risk to the Hawkesbury-Nepean Valley floodplain downstream of Warragamba Dam. Actions include:

- coordinated flood risk management across the Hawkesbury-Nepean Valley now and in the future
- strategic and integrated consideration of flood risk in land use and emergency planning
- engaging and providing flood risk information for an aware, prepared and responsive community.

The Flood Strategy provides the context and policy impetus to mitigate flood risk in the Hawkesbury-Nepean Valley.

1.3 Purpose

This biodiversity assessment report (BAR) has been prepared by SMEC Australia Pty Ltd (SMEC) on behalf of WaterNSW (the Proponent).

The assessment of potential biodiversity impacts of the project has been divided into three areas based upon the different types of impacts and different assessment methodologies applied in each area. These three areas are:

- Upstream of Warragamba Dam – some areas upstream of Warragamba Dam would experience an increase in the extent and duration of temporary inundation during the operation of the Project.
- At Warragamba Dam – the area in and around the existing dam would be subject to clearing, disturbance and other indirect impacts to allow for the construction of the Project.
- Downstream of Warragamba Dam – some areas downstream of Warragamba Dam would experience a decrease in the extent and duration of flooding during the operation of the Project.

This BAR assesses the impacts of the project at Warragamba Dam (the development site) – that is, the impacts of the construction of the Project.

The key objective of this BAR is to meet the requirements of the Framework for Biodiversity Assessment (FBA), developed for Major Projects, and to address the biodiversity matters raised in the Secretary's Environmental Assessment Requirements (SEARs) (See Table 1-1). DPIE has been consulted during the assessment process, through direct meetings and teleconferences. This report conforms to the requirements of DPIE and relevant guidance documents.

Table 1-1. SEARs relevant to biodiversity assessment

Desired performance outcome	Secretary's Environmental Assessment Requirements	Where addressed
6. Biodiversity The project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity. Offsets and/or supplementary measures are assured which are equivalent to any remaining impacts of project construction and operation.	1. The Proponent must assess biodiversity impacts in accordance with the current guidelines including the Framework for Biodiversity Assessment (FBA), unless otherwise agreed by OEH, by a person accredited in accordance with s142B(1)(c) of the *Threatened Species Conservation Act 1995*.	This report is the assessment for the construction area (development site) for the project
	2. The proponent must assess the downstream impacts on threatened biodiversity, native vegetation and habitats resulting from any changes to hydrology and environmental flows. This assessment should address the matters in Attachment B.	Not relevant for this Construction BAR
	3. The Proponent must assess impacts on the following: endangered ecological communities (EECs), threatened species and/or populations, and provide the information specified in s9.2 of the FBA. Specific	Section 7

Desired performance outcome	Secretary's Environmental Assessment Requirements	Where addressed
	environmental requirements are provided in Attachment C.	
	4. The Proponent must identify whether the project as a whole, or any component of the project, would be classified as a Key Threatening Process in accordance with the listings in the *Threatened Species Conservation Act 1997* (TSC Act), *Fisheries Management Act 1994* (FM Act) and *Environment Protection and Biodiversity Conservation Act 2000* (EPBC Act).	Section 7

1.4 Project description

1.4.1 Location

The development site is located about 65 kilometres west of Sydney in a narrow gorge on the lower section of the Warragamba River, 3.3 kilometres upstream of the Nepean River confluence. The Nepean River becomes the Hawkesbury River at the junction of the Grose River at Yarramundi. This entire river system is referred to as the Hawkesbury-Nepean River.

The development site is located adjacent to the township of Warragamba, NSW, within the Wollondilly Local Government Area (LGA). The development site includes:

- the existing dam wall, and the areas in and around the existing Warragamba Dam face and abutment structures
- auxiliary access roads
- associated operational buildings.

1.4.2 The Project

A detailed Project description is provided in Chapter 5 of the EIS (Project description).

Warragamba Dam Raising is a project to provide flood mitigation to reduce the significant existing risk to life and property in the Hawkesbury-Nepean Valley downstream of the dam. This would be achieved through raising the level of the central spillway crest by around 12 metres and the auxiliary spillway crest by around 14 metres above the existing full supply level for temporary storage of inflows. The spillway crest levels and outlets control the extent and duration of the temporary upstream inundation. There would be no change to the existing maximum volume of water stored for water supply.

The NSW Government announcement in 2016 proposed that the dam wall be raised by 14 metres. Subsequently, the revised SEARs required the Project to be designed, constructed and operated to be resilient to the future impacts of climate change and incorporate specific adaptation actions in the design.

Peer reviewed climate change research found that by 2090 it was likely an additional three metres of spillway height would be required to provide similar flood mitigation outcomes as the current flood mitigation proposal. Raising the dam side walls and roadway by an additional three metres may not be feasible in the future, both in terms of engineering constraints and cost. The current design includes raising the dam side walls and roadway by 17 metres now to enable adaptation to projected climate change. Any consideration of raising spillway heights is unlikely before the mid to late 21st century and would be subject to a separate planning approval process.

The 17-metre raising height of the dam abutments (side walls) and roadway have been considered and accounted for in the EIS and design. The potential maximum height and duration of upstream inundation remains consistent with what was originally proposed in 2016.

The Project also includes providing infrastructure to facilitate variable environmental flows to be released from Warragamba Dam.

The Project would include the following main activities and elements:

- demolition or removal of parts of the existing Warragamba Dam, including the existing drum and radial gates
- thickening and raising of the dam abutments
- thickening and raising of the central spillway
- new gates or slots to control discharge of water from the flood mitigation zone (FMZ)
- modifications to the auxiliary spillway
- operation of the dam for flood mitigation
- environmental flow infrastructure.

The Project would take the opportunity during the construction period for the dam raising to install the physical infrastructure to allow for management of environmental flows as outlined in the NSW Government *2017 Metropolitan Water Plan*. However, the actual environmental flow releases themselves do not form part of the Project and are subject to administration under the *Water Management Act 2000*.

Figure 1-1 shows the existing dam with its relevant key features. Figure 1-2 shows the modified dam after the Project works have been completed.

Figure 1-1. Aerial view of existing dam and features

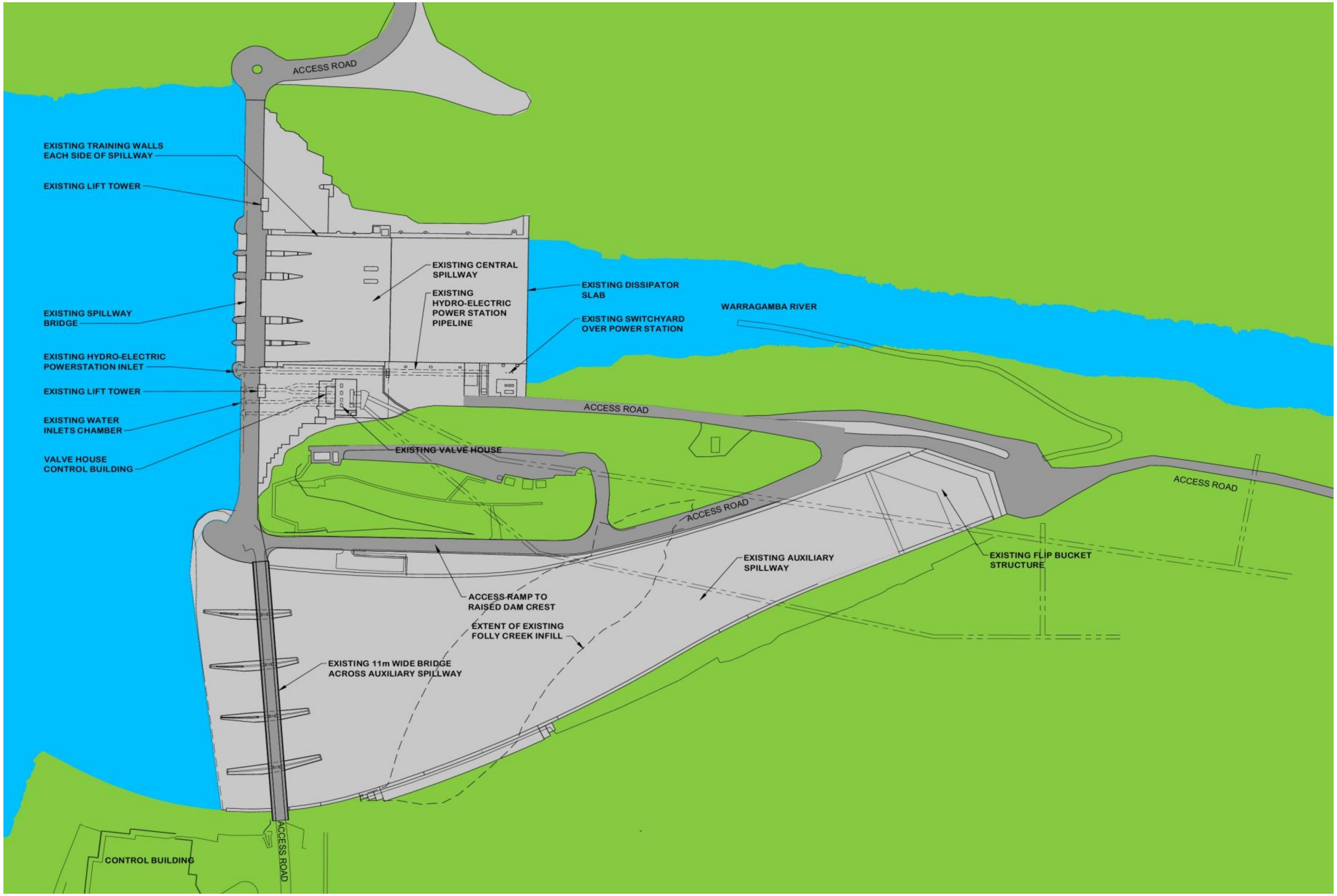
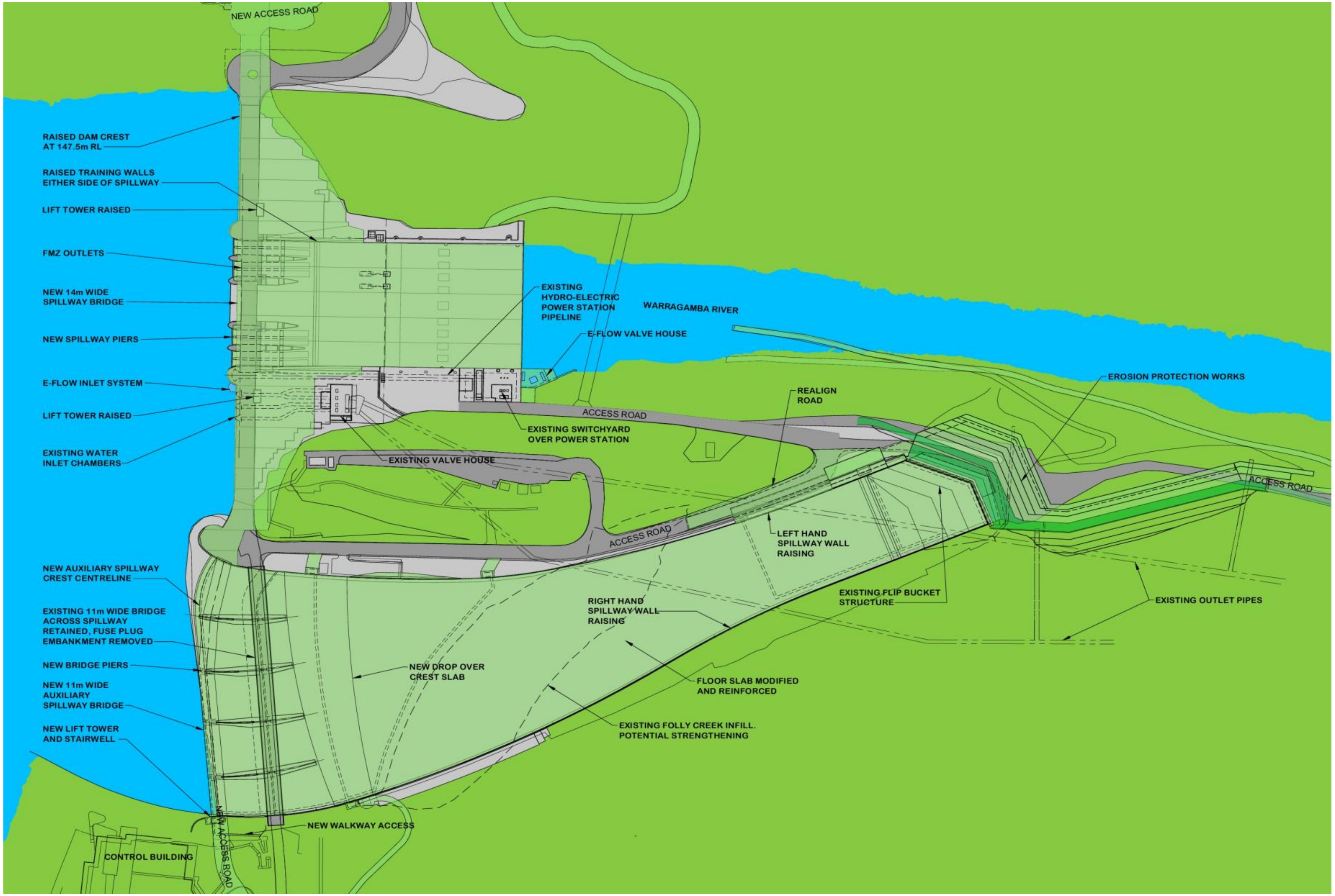


Figure 1-2. Aerial view of modified dam from the Project works



1.4.3 Project construction

If the Project is approved, further detailed construction planning would take place prior to commencement to inform development of a construction environmental management plan (CEMP). This plan would consider methods and the scheduling of activities to minimise impacts on the community and the environment such as noise, access, and amenity, and would detail mitigation and management measures.

1.4.3.1 Construction area

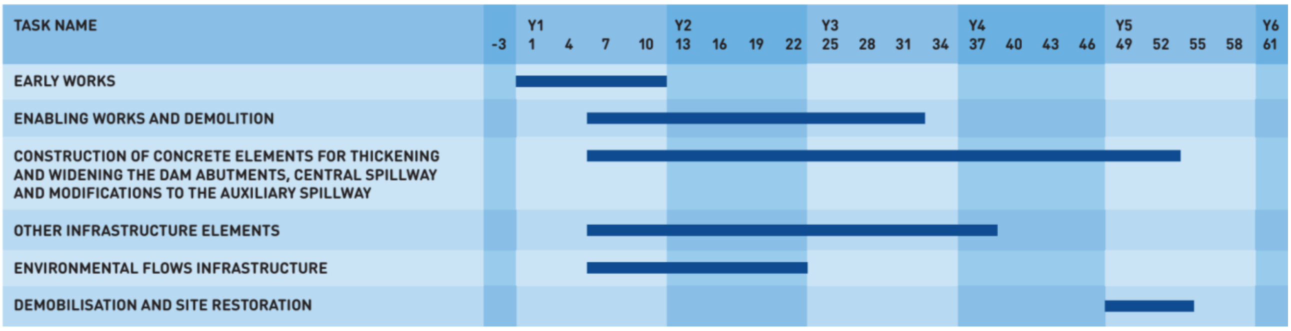
The proposed construction area would include:

- areas directly impacted by construction
- areas where access for construction is required
- concrete batch plants and material storage and handling areas
- offices and worker amenities
- visitor and education centre
- other ancillary sites.

1.4.3.2 Construction program

A preliminary construction program is presented in Figure 1-3 with the Project anticipated to be completed between four and five years from commencement.

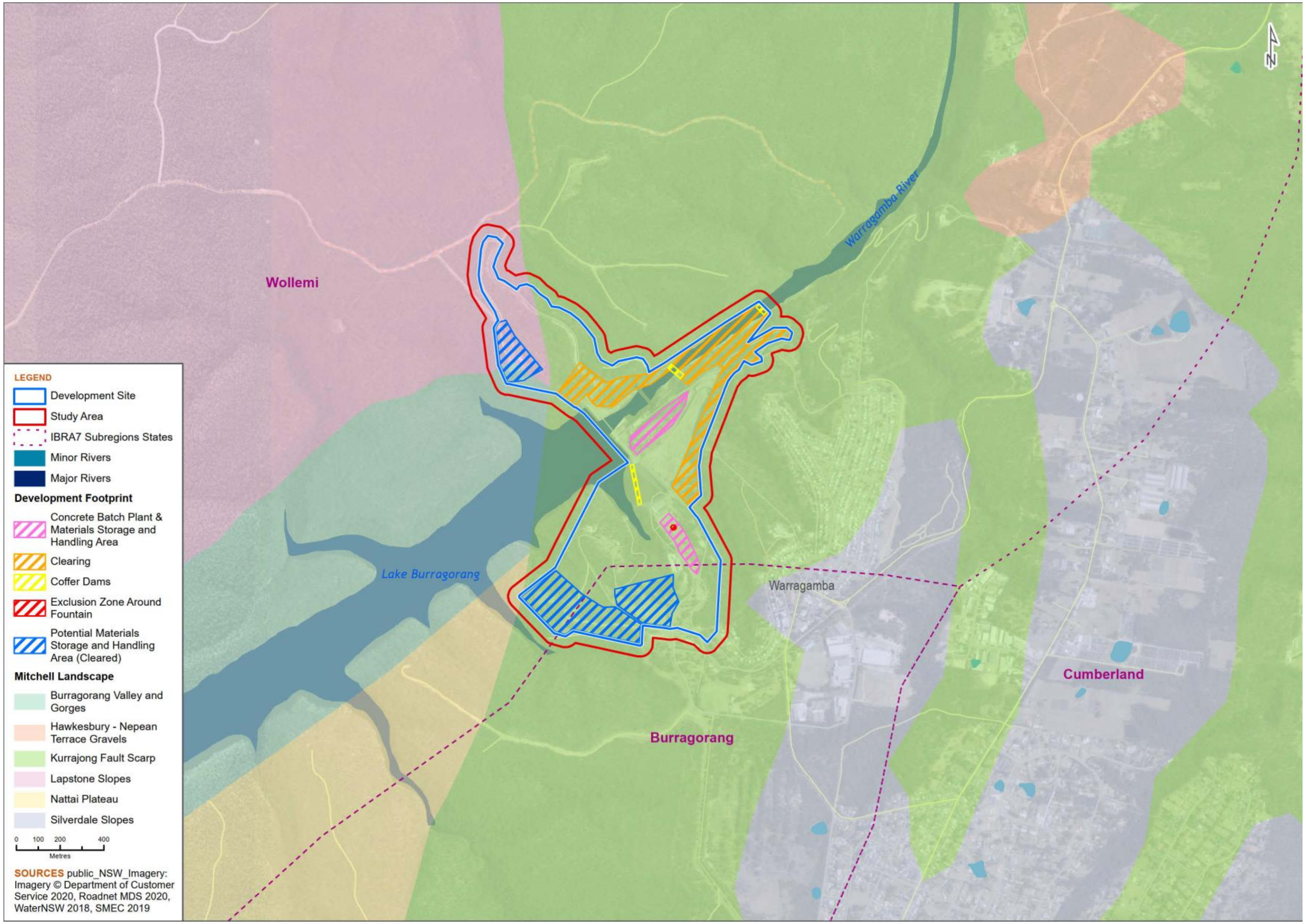
Figure 1-3. Preliminary construction program



1.4.4 Identification of development footprint

The development footprint is shown in Figure 1-4. The development footprint includes areas that would be temporarily impacted by the construction of the Project as well as areas permanently modified for the Project. Areas outside the development that are associated with operational impacts of the Project are addressed in the Upstream operational (FBA) BAR and the Downstream operational BAR.

Figure 1-4. Project location showing development site, study area, IBRA Subregion-Sydney Basin, and Mitchell Landscapes



1.5 2019-2020 bushfire event

Following the completion of field surveys for this biodiversity assessment, New South Wales, including the catchment of Lake Burragorang, experienced severe wild bushfire between 2019 and 2020. These bushfires are described as unprecedented in their extent and intensity affecting at least 5.4 million hectares (seven percent of NSW) including 27 percent of the national park estate, more than 81 percent of the Greater Blue Mountains World Heritage Area and 54 percent of the NSW components of the Gondwana Rainforests of Australia World Heritage property (DPIE 2020a). The most affected ecosystems were rainforests (37 percent of their state-wide extent), wet sclerophyll forests (50 percent) and heathlands (52 percent) (DPIE 2020a). The fires affecting the study area began in late October 2019 in remote bushland near Lake Burragorang, near Yerranderie, and in the Kanangra-Boyd National Park. Due to the extreme isolation of the area and rugged inaccessible terrain, the fire spread and merged to eventually become the Green Wattle Creek Fire on 27 November 2019. This fire rapidly affected the Lake Burragorang catchment where it burnt out of control for at least nine weeks. A total of 278,700 hectares in the Wollondilly area were affected by this fire until it was officially declared as 'contained' on 30 January 2020. The fire was declared as 'extinguished' by the NSW Rural Fire Service (RFS) on 10 February 2020 following a torrential rain event over the preceding week.

The NSW DPIE Remote Sensing and Landscape Science team has, in collaboration with other organisations, developed fire mapping and modelling of the 2019-2020 bushfire event in order to determine the extent, severity, and impact of the bushfires on native vegetation. There are two fire maps:

- Google Earth engine burnt area map (GEEBAM), was developed in collaboration with University of NSW, as a rapid mapping approach which detected how badly the tree canopy had burnt by measuring the change in colour in vegetation before and after fire (DPIE 2020b). GEEBAM's rapid assessment of vegetation post-fire made information quickly available on the likely impacts of the fire event on biodiversity, supporting important conservation and environmental management decisions (DPIE 2020b).
- Fire extent and severity map (FESM), was developed in collaboration with RFS as a semi-automatic approach to mapping fire extent and severity through a machine learning framework based on Sentinel 2 satellite imagery (DPIE 2020c). Machine learning uses algorithms and statistical models to understand patterns in the data. FESM has a standardised classification system of fire severity and can predict and compare the severity of fires across different landscapes (DPIE 2020c). The finalised version of the FESM for the 2019-2020 bushfire season was produced in April 2020. A further update was issued in December 2020.

The NSW DPIE Remote Sensing and Landscape Science team has recommended that FESM be used over the rapid GEEBAM product for assessing the impacts of the fire event within the study area. The FESM classifies the fire severity into five burn severity classes. A description of each class is provided in Table 1-2.

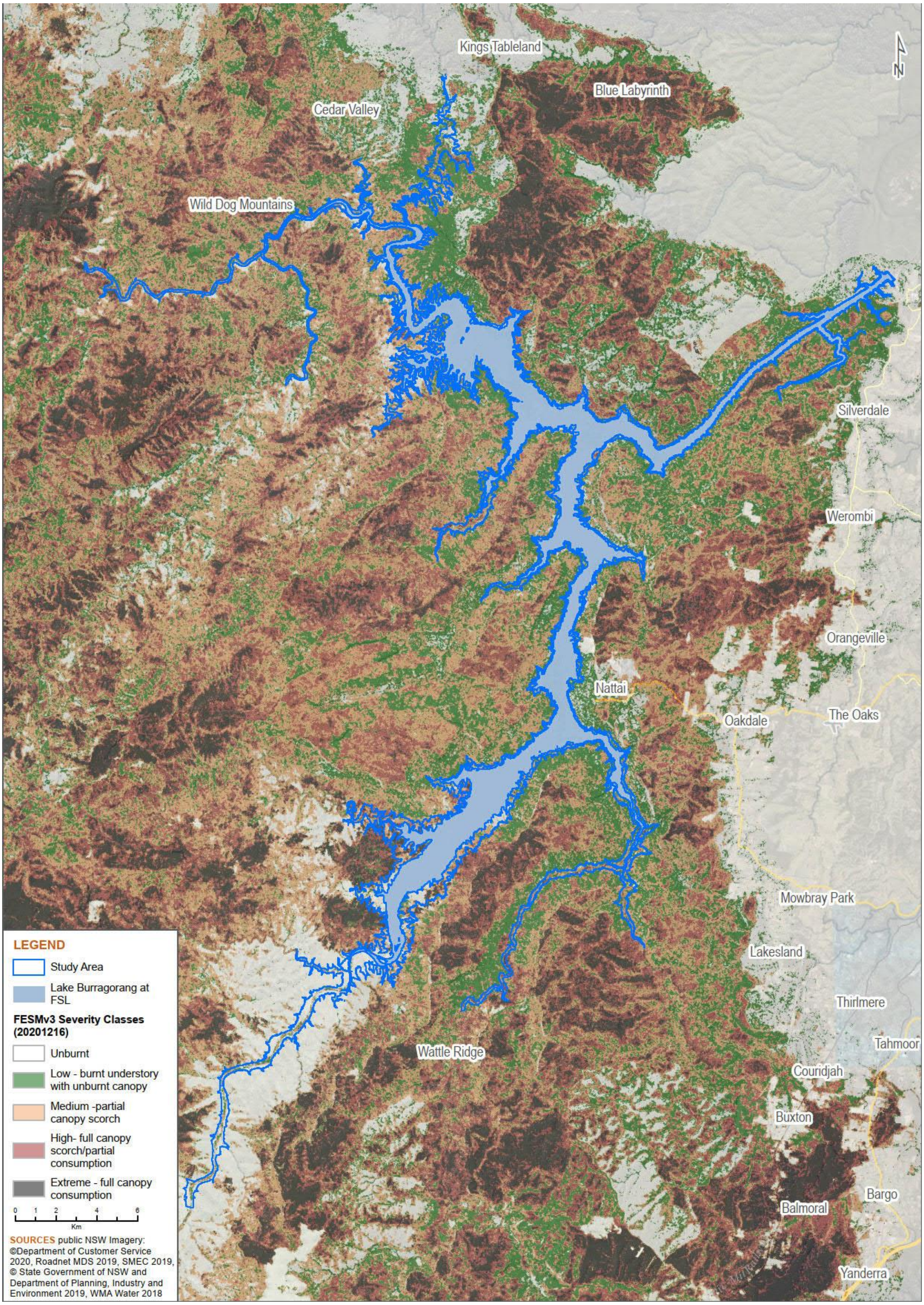
Table 1-2. FESM burn severity classes

Severity class	Description	Percent foliage fire affected
Unburnt	Unburnt surface with unburnt canopy	0% canopy and understory burnt
Low	Burnt understory with unburnt canopy	>10% burnt understory >90% green canopy
Medium	Partial canopy scorch	20-90% canopy scorched
High	Full canopy scorch/partial consumption)	>90% canopy scorched <50% canopy consumed
Extreme	Full canopy consumption	>50% canopy biomass consumed

The FESM shows an area of fire activity within the development site, immediately north of the dam wall. However, the area is not shown on the GEEBAM mapping as being affected by fire. Updated aerial imagery and drone video footage, the area in question confirm that the development site was not burnt. Consequently, it appears that the fire activity on the FESM within the development site is an artefact of the image processing.

The extent of the fires and the burn severity is shown in Figure 1-5. The mapping provided by DPIE includes areas below FSL; the mapping has been modified to show only areas above FSL.

Figure 1-5. Extent of 2019/2020 bushfires



The 'NPWS Fire History – Wildfires and Prescribed Burns' is a mapping layer released by DPIE on the history of fire in national parks based on data captured by the RFS and Forestry Corporation NSW (DPIE 2020d). According to this mapping, the majority of the study area has been affected by wildfire historically and at least 30 percent of the extent has been subjected to a prescribed burn. Wildfires have affected the catchment variably since 1964-65 however none has been as extensive in size as the 2019-2020 fire. Historically, the catchment has experienced at least four major wildfire events: 1964-65 1994-95 1997-98 and 2001-02 (DPIE 2020d).

The effects of the 2019-2020 bushfires on the environment, including the ecological consequences, are not yet fully understood. Though bushfires are not uncommon in Australia, they are usually of a lower scale and intensity that only affect small parts of the overall distribution of ecosystems and habitats. Post-fire studies have found that a number of species (both threatened and not currently threatened) have had their entire populations burnt in the 2019-2020 fires. This includes some species and ecological communities that are known to be sensitive to severe fire (DPIE 2020e).

The long-term fire regime including fire frequency, intensity and seasonality influence the ecosystem in various ways, including having both positive and negative effects. If fires are too frequent, plants may be killed before they have matured or before they have set sufficient seed to ensure population recovery. Alternatively, infrequent fires can impact negatively on plants that rely on fire to regenerate. If fire is too infrequent, these species can grow old and die, and their seeds rot in the soil before germinating. In this way, plant community species richness and composition can be shaped by the fire regime. Some plant species have no or limited natural fire tolerance and may significantly reduced in density over their affected ranges. Other ecological inputs following fire, in particular, widespread and intense fires, can have additional effects on post-fire ecology. These inputs may include recurrent fire, drought, intense rainfall, flood, erosion and predation.

Notwithstanding, a number of threatened ecological communities, threatened species, and non-threatened species are considered to have been disproportionately impacted by the 2019-2020 bushfires. Consequently, the Department of the Environment and Energy (DoEE) has released an initial list of threatened and migratory species which have more than 10 percent of their known or predicted distribution in areas affected by bushfires in southern and eastern Australia from 1 August 2019 and 13 January 2020. Examples of species on this list that were recorded during current field surveys, or predicted to occur based on habitat preferences, within the development site, include:

- *Pomaderris brunnea* (50 to <80 percent)
- Regent Honeyeater (10 to <30 percent)
- Koala (10 to <30 percent)
- Brushtail Rock Wallaby (30 to <50 percent)
- Broad-headed Snake (50 to <80 percent)

In addition to the above, DoEE has released an initial list of fauna species which require urgent management intervention (DoEE 2020). The Regent Honeyeater and the Koala are on the initial list and were predicted to occur based on habitat preferences, within the development site.

In March 2020, DPIE released a set of guidelines relating to carrying out biodiversity assessments, specifically BAM assessments, at severely burnt sites. The guidelines aim to provide assessors with a reasonable, evidence-based and transparent process for identifying severely burnt native vegetation and provides a range of approaches for applying the BAM on land impacted by severe bushfire as identified on the GEEBAM. As the development site is not severely affected by fire as identified on the GEEBAM, the guidelines do not need to be applied.

1.6 Information sources

1.6.1 Database analysis

The following information sources were used in the preparation of this report:

- Aerial maps, project layers and environmental layers provided by WaterNSW and OEH.
- Department of the Environment and Energy Species Profiles and Threats database (SPRAT) (DoEE n.d.b)
- Department of Environment and Climate Change NSW *Landscapes (Mitchell) of NSW- Version 3* GIS dataset (DECCW 2010a)
- Department of the Environment and Energy Protected Matters Search Tool (DoEE 2015)
- Matters of National Environmental Significance Significant Impact Assessment Guidelines (DoE 2013)
- NSW BioBanking credit calculator (OEH n.d.a)

- NSW Atlas of NSW Wildlife (OEH 2017b)
- NSW Threatened Species Profiles (OEH 2017d)
- Mitchell Landscapes with percent cleared estimates (DECCW 2010a)
- Framework for Biodiversity Assessment (OEH 2018a)
- NSW Biodiversity Offsets Policy for Major Projects (OEH 2014)
- VIS 2.1 Vegetation Classification Database (OEH 2017c)
- Bureau of Meteorology (BOM) Atlas of Groundwater Dependent Ecosystems (BOM 2019)
- NSW Government Biodiversity Values Map and Threshold Tool (OEH 2019a)
- *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge 2003).

1.6.2 Literature review

Several biodiversity investigations have been previously undertaken for the different components of the dam and its infrastructure. A review of ecological literature relevant to the site was undertaken as part of this assessment to evaluate the biodiversity values associated with the development site.

The following reports were reviewed in preparation of this report:

- Warragamba Dam EIS - Dam Site Environmental Studies, Fauna and Flora (Mount King Ecological Surveys 1992)
- Warragamba Dam Raising Preliminary Environmental Assessment (BMT WBM Pty Ltd 2016)
- Warragamba Dam Auxiliary Spillway Project – Construction Environmental Management Plan Framework (Australian Water Technologies and SKM 2003)
- Safeguarding Warragamba Dam: proposed auxiliary spillway (Sydney Water 1996)
- *Eucalyptus benthamii* Inundation Experiment – Reporting on stand health and soil properties over a 12-month monitoring period (Bush *et al*. 2018)
- Glasshouse evaluation of inundation tolerance of Camden White Gum (*Eucalyptus benthamii)* (Marcar 1995)
- The Native Vegetation of the Warragamba Special Area, Part A: Technical Report (NPWS 2003)
- Terrestrial Vertebrate Fauna of the Greater Southern Sydney Region: Volume 1 - Background Report (DECC 2007a)
- Threatened and pest animals of Greater Southern Sydney (DECC 2007b).

In addition to the literature review of previous biodiversity investigations listed above, the following sources of information were reviewed as part of the assessment:

- Soil Landscapes of the Penrith 1:100,000 Sheet map and report, Soil Conservation Service of NSW, Sydney (Bannerman and Hazelton 1990)
- Descriptions for NSW (Mitchell) Landscapes, Version 2 (DECC 2002)
- *Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands*, Version 1.0 (Tozer *et al*. 2010).

1.6.3 Aerial photography

SIX maps imagery (Department of Finance and Services 2017) was utilised for vegetation mapping and in the production of figures for this report. The SIX maps aerial details are provided in Table 1-3.

Table 1-3. SIX maps specifications - 21 November 2018

Parameter	Details
BlockName	Penrith
BlockType	ADS40_SC
BlockStartDate	19-09-2013
BlockEndDate	n/a

2 Legislation and policies

2.1 Commonwealth

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) is the Commonwealth Government's principal piece of environmental legislation and is administered by the Department of Agriculture, Water, and the Environment (DAWE)[1]. The EPBC Act is designed to protect national environmental assets, known as matters of national environmental significance (MNES), which include threatened species of flora and fauna, endangered ecological communities (EECs) and migratory species, as well as other protected matters.

Among other things, the EPBC Act defines the categories of threat for threatened flora and fauna, identifies key threatening processes and provides for the preparation of recovery plans for threatened flora, fauna and EECs. This piece of legislation would only become relevant if it was considered that an impact on an MNES was likely, thus providing a trigger for referral of the Project to DAWE.

Matters of national environmental significance identified in the Act are:

- World Heritage properties
- national heritage places
- Ramsar wetlands
- nationally threatened species and communities
- migratory species protected under international agreements
- the Commonwealth marine environment
- nuclear actions.

The Protected Matters search tool (search date: 26 April 2019) for the development site with a 10-kilometre buffer resulted in the following biodiversity-related MNES that may occur in, or may relate to, this area:

- 12 threatened ecological communities
- 78 threatened species
- 16 migratory bird species.

The following MNES species were identified as having a moderate or high likelihood of occurring within the development site, or were recorded during surveys:

- Giant Burrowing Frog (*Heleioporus australiacus*) – Vulnerable
- Littlejohn's Tree Frog (*Litoria littlejohni*) – Vulnerable
- Regent Honeyeater (*Anthochaera phrygia*) – Critically Endangered
- Australasian Bittern (*Botaurus poiciloptilus*) – Endangered
- Painted Honeyeater (*Grantiella picta*) – Endangered
- White-Bellied Sea-Eagle (*Haliaeetus leucogaster*) – Migratory
- White-throated Needletail (*Hirundapus caudacutus*) – Migratory
- Swift Parrot (*Lathamus discolor*) – Critically Endangered
- Dural Land Snail (*Pommerhelix duralensis*) – Endangered
- Large-Eared Pied Bat (*Chalinolobus dwyeri*) – Vulnerable
- Spotted-Tailed Quoll (*Dasyurus maculatus*) – Endangered
- Brush-Tailed Rock-Wallaby (*Petrogale penicillata*) – Vulnerable
- Koala (*Phascolarctos cinereus*) – Vulnerable
- Grey-Headed Flying-Fox (*Pteropus poliocephalus*) – Vulnerable
- Broad-headed Snake (*Hoplocephalus bungaroides*) – Vulnerable
- *Acacia bynoeana* – Vulnerable

[1] DAWE was established on 1 February 2020. Prior to this date the EPBC Act was administered by the Department of the Environment and Energy.

- *Asterolasia elegans* – Endangered
- *Cryptostylis hunteriana* – Vulnerable
- *Melaleuca deanei* – Vulnerable
- *Persoonia acerosa* – Vulnerable
- *Persoonia hirsuta* – Endangered
- *Pomaderris brunnea* – Vulnerable.

The preliminary environmental assessment (BMT WBM Pty Ltd 2016) of the MNES present within the development site indicated that there is likely to be impacts on areas of White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland CEEC and Shale-sandstone Transition Forest in the Sydney Basin Bioregion CEEC as well as individuals of Camden White Gum (*Eucalyptus benthamii*), Kowmung Hakea (*Hakea dohertyi*) and Few-seeded Bossiaea (*Bossiaea oligosperma*). In addition, the Project may have additional impacts on suitable habitat for a number of other EPBC Act listed species and as such, a referral to DoEE was required for further consideration.

The project has been deemed a controlled action (ref 2017/7940) as it has the potential to significantly impact on MNES, and as such requires assessment under the EPBC Act. In accordance with the Bilateral Agreement reached between the NSW and Commonwealth Governments, an Environmental Impact Statement (EIS) under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for State Significant Infrastructure (SSI) can also be used for an EIS under the EPBC Act for a controlled action, where directed by the Commonwealth Minister. The direction was given for the Project to be assessed under the Bilateral Agreement on 17 July 2017. The Project will be assessed by relevant NSW departments in the first instance followed by assessment by the Commonwealth Minister for final determination.

2.2 New South Wales

2.2.1 Environmental Planning and Assessment Act 1979

The EP&A Act is the overarching planning legislation in NSW that provides for the creation of planning instruments that guide land use. The EP&A Act also provides for the protection of the environment, including the protection and conservation of native animals and plants. This includes threatened species, populations and ecological communities, and their habitats of biodiversity values, as listed in the NSW *Threatened Species Conservation Act 1995* (TSC Act) and NSW *Fisheries Management Act 1994* (FM Act).

The protection of the environment is addressed in Division 5.2, subdivision 2 of the EP&A Act – Environmental assessment and approvals of infrastructure for SSI. Specifically, this section provides guidance on significant effect on species, populations or ecological communities or their habitats. It is noted that the *Biodiversity Conservation Act 2016* (BC Act) came into effect on 25 August 2017, repealing and replacing the TSC Act, but retaining the threatened species listings. Preliminary work on the EIS commenced prior to the date that the BC Act came into effect, triggering consultation with DPIE for clarity on the appropriate planning pathway. Consequently, in accordance with Part 7, clause 29 of the *Biodiversity Conservation (Savings and Transitional) Regulation 2017*, WaterNSW is obliged to continue to apply the former planning provisions.

WaterNSW, as the Proponent and a determining authority for the Project within the meaning of Part 5 of the EP&A Act, has formed the view that the impact of the Project is likely to significantly affect the environment and, therefore, would require the preparation of an EIS. On this basis, the project is declared to be SSI under section 5.12(2) of the EP&A Act. The effect of the EP&A Act and the relevant state environmental planning policies (SEPPs) is that WaterNSW would have been the determining authority for the Project under Part 4 of the EP&A Act, were it not for the application of section 5.12(2) of the EP&A Act. In this instance, section 5.12(2) of the EP&A Act is triggered by reason of the operation of clause 14 and Schedule 3 of the *State and Regional Development SEPP*.

Accordingly, the Project is subject to assessment under Division 5.2 of the EP&A Act and requires the approval of the NSW Minister for Planning and Public Spaces under section 5.14 of Division 5.2. Further information on the assessment process is available on the DPIE website (www.planning.nsw.gov.au).

The SEARs for the Project were issued by the NSW Department of Planning and Environment (DP&E) on 30 June 2017 and updated on the 13 March 2018. The provisions that are relevant to this BAR are reproduced below.

The EIS must address the following specific matters that relate to the Project:

- The Project design considers all feasible measures to avoid and minimise impacts on terrestrial and aquatic biodiversity.

- Offsets and/or supplementary measures are assured which are equivalent to any remaining impacts of project construction and operation.
  1. The Proponent must assess biodiversity impacts in accordance with the current guidelines including the FBA, unless otherwise agreed by OEH, by a person accredited in accordance with s142B(1)(c) of the *Threatened Species Conservation Act 1995.*
  2. The Proponent must assess any impacts on biodiversity values not covered by the FBA as specified in s2.3.
  3. The Proponent must assess impacts on the following: endangered ecological communities (EECs), threatened species and/or populations, and provide the information specified in s9.2 of the FBA. Specific environmental requirements are provided in Attachment A.
  4. The Proponent must identify whether the project as a whole, or any component of the project, would be classified as a Key Threatening Process in accordance with the listings in the *Threatened Species Conservation Act 1997* (TSC Act), *Fisheries Management Act 1994* (FM Act) and *Environment Protection and Biodiversity Conservation Act 2000* (EPBC Act).

An assessment of the type and magnitude of impacts that would result from the Project on biodiversity values and measures to avoid and mitigate these impacts at the development site are presented within this BAR. A separate biodiversity offset strategy (BOS) to address offset measures has been prepared for the Project and is provided as part of the EIS documentation.

2.2.2 Biodiversity Conservation (Savings and Transitional) Regulation 2017

The BC Act and its supporting regulations commenced on 25 August 2017. The BC Act repeals the TSC Act along with other natural resource management legislation, while retaining the TSC Act species list.

The BC Act sets out the environmental impact assessment framework for threatened species, threatened ecological communities and Areas of Outstanding Biodiversity Value (formerly critical habitat) for Major Projects (amongst other types of development).

However, the transitional provisions of the Biodiversity Conservation (Savings and Transitional) Regulation 2017 apply to the Project as the SEARs for the Project were issued prior to the commencement of the new BC Act. Consequently, the Project has been assessed in accordance with the TSC Act.

When referring to the planning assessment provisions used for this assessment, the report uses the TSC Act. When referring to threatened species, populations, or ecological community listings, this report uses the BC Act.

2.2.3 Threatened Species Conservation Act 1995

The TSC Act was repealed when the BC Act commenced on 25 August 2017. However, transitional arrangements allow SSI projects to be considered under previous legislation if the SEARs were issued before 25 August 2017. Initial SEARs for the project were issued in June 2017 and consequently the TSC Act applies to the project. Updated SEARs for the project were reissued on 13 March 2018.

The TSC Act was the key piece of legislation in NSW relating to the protection and management of biodiversity and threatened species. The TSC Act aimed to protect and encourage the recovery of threatened species, populations and ecological communities of plants and animals that were listed under the Act through threat abatement and species recovery programs.

The Schedules to the TSC Act identified endangered or vulnerable subjects and the processes likely to be affecting them. This was achieved through the declaration and mapping of habitats that are critical to the survival of the relevant species, populations and ecological communities (critical habitats). Further, the TSC Act also set out the methods of assessment, management and regulation of actions that may damage critical or other habitat or otherwise significantly affect threatened species, populations and ecological communities. Provision was made for the preparation of recovery plans to mitigate and manage key threatening processes.

2.2.4 Fisheries Management Act 1994

The objectives of *Fisheries Management Act 1994* (FM Act) are to conserve, develop and share the fishery resources of NSW for the benefit of present and future generations. More detailed objectives relevant to the Project include:

(a) to conserve fish stocks and key fish habitats

(b) to conserve threatened species, populations and ecological communities of fish and marine vegetation

(c) to promote ecologically sustainable development, including the conservation of biological diversity.

Certain separate approvals under the FM Act are not required if the Project is approved under Division 5.2 of the EP&A Act. Other requirements of the FM Act would need to be considered including impacts on threatened fish and aquatic species and key fish habitat. Key threatening processes to aquatic ecosystems and species needs to be considered. A separate Aquatic Ecology assessment (Appendix F4) assesses these issues.

Section 218 of the FM Act requires projects involving alteration of a dam, weir or reservoir or involving blockage to fish passage to conduct an assessment to identify the potential impacts. The project must also be referred to the Minister responsible for the FM Act and, if requested, involve inclusion of a suitable fishway or bypass.

A number of activities require consultation and approval from NSW Fisheries under the FM Act. Construction as part of the proposed works may require consent from NSW Fisheries for the harming of marine vegetation and impacting on key fish habitat. This may require a permit under Part 7 of the FM Act.

2.2.5 National Parks and Wildlife Act 1974

The *National Parks and Wildlife Act 1974* (NPW Act) provides for the protection of Aboriginal sites and designated conservation areas as well as the flora and fauna within conservation areas. Conservation areas declared under the NPW Act that are within the development site include:

- Warragamba Special Area (see Section 2.2.8 regarding the *Water NSW Act 2014* (Water NSW Act))
- Blue Mountains National Park.

The works for the Project would be undertaken only within the Warragamba Special Area. As WaterNSW jointly manages the Special Area with the National Parks and Wildlife Service (NPWS) it has authority under the Water NSW Act to undertake works associated with Warragamba Dam, subject to approval under the EP&A Act. Consequently, no permit or other approval is required in relation to any national park, state conservation area or regional park as no works are planned within these areas.

While works associated with the Project would not occur directly in any conservation area declared under the NPW Act, conservation areas both upstream and downstream may be impacted by changes in temporary inundation and flooding. The impacts of any changes in inundation and flooding due to the project on conservation areas are assessed in Chapter 20 (Protected and sensitive lands) and Chapter 21 (Socio-economic, land use and property) of the EIS.

Under section 153 of the NPW Act, the relevant Minister is prohibited from granting a lease, licence, easement or right of way for the purposes of inundation of any land which is protected under the NPW Act and is land to which the *Sydney Water Catchment Management Act 1998* applies. However, the Water NSW Act was amended in October 2018 to exclude the need for a lease, licence, easement or right of way under the NPW Act from the relevant Minister for temporary inundation of the Warragamba Catchment. This is further discussed in Section 2.2.8.

Impacts to wild rivers have been assessed in Chapter 15 of the EIS (Flooding and hydrology). As part of preparation of the EIS, the Minister administering the NPW Act has been consulted in regard to potential impacts from all aspects of the Project, including changes of flow patterns in the Kowmung River, Colo River and Grose River.

Issues raised by and advice from the Minister is detailed in Chapter 6 of the EIS (Consultation).

2.2.6 Biosecurity Act 2015

The *Biosecurity Act 2015* (Biosecurity Act) replaced the *Noxious Weeds Act 1993* on 1 July 2017. The Biosecurity Act is a wide-ranging legislation that outlines the requirements of government, councils, private landholders, and public authorities in the management of biosecurity matters. Priority weeds are regulated under the Biosecurity Act with a general biosecurity duty to prevent, eliminate or minimise any biosecurity risk they may pose. Some priority weeds have additional management obligations which may apply generally, or under specific circumstances. Any person who deals with any plant, who knows (or ought to know) of any biosecurity risk, has a duty to ensure the risk is prevented, eliminated, or minimised as is reasonably practicable.

2.2.7 NSW Biodiversity Offsets Policy for Major Projects 2014

The NSW *Biodiversity Offsets Policy for Major Projects* was adopted in September 2014 and applies to SSI designated under the EP&A Act. The policy provides a standard method for assessing impacts of major projects on biodiversity and determining offsetting requirements (OEH 2014). The policy is underpinned by six principles, all of which must be considered when assessing offsets for major projects.

These principles are:

1. Before offsets are considered, the impacts must first be avoided, and unavoidable impacts minimised through mitigation measures. Only then should offsets be considered for the remaining impacts.
2. Offset requirements should be based on reliable and transparent assessment of losses and gains.
3. Offsets must be target by the biodiversity values being lost or to higher conservation priorities.
4. Offsets must be additional to other legal requirements.
5. Offsets must be enduring, enforceable and auditable.
6. Supplementary measures can be used in lieu of offsets.

The FBA has been developed in conjunction with the policy to provide a method for determining the cumulative magnitude of impacts. The FBA provides rules and software for calculating the number and type of credits that a development site will require in order to offset its impacts and thus improve or maintain biodiversity values. ‘Credits’ are the currency used within FBA and they are not specifically area measurements. Rather, they are a measure of the current quality of habitat.

The FBA requires the preparation of the following documents:

- Biodiversity Assessment Report: To describe the biodiversity values present within the development site and the impact of the project on these values.
- Biodiversity Offset Strategy: To outline how the proponent intends to offset the impacts of the project.

Submission of these reports is required as part of the EIS.

As the FBA applies predominantly to terrestrial biodiversity, the NSW Offsets Policy for Major Projects and FBA refers to the *NSW Department of Primary Industries Policy and Guidelines for Fish Habitat Conservation and Management* (Fairfull 2013) for guidance on assessing and offsetting aquatic impacts. Offsets for identified key fish habitats are required once avoidance and mitigation measures have been implemented.

2.2.8 Water NSW Act 2014

The Water NSW Act enabled provisions for WaterNSW establishment as a legal entity. Under the Act, the former State Water Corporation became WaterNSW and with full transference of functions from the previous Sydney Catchment Authority. As a result, WaterNSW is the responsible authority for, and owner of, Warragamba Dam. It should be noted that Water NSW is the official legal entity and WaterNSW is the trading name of the same entity.

Under the Water NSW Act, WaterNSW has the power to operate and modify works within its control (including Warragamba Dam) for the purposes of catchment management, subject to approval under the EP&A Act. The Water NSW Act also allows dams and their catchments to be declared as Catchment Areas, Special Areas and Controlled Areas. These declared areas are established to provide the appropriate water management authority, the Minister and/or NSW Parliament powers to control development, access, and ownership of land in and around water supply dams. The Warragamba Dam site and a large part of its catchment have been declared a Special Area under the provisions of the Act.

2.2.9 State Environmental Planning Policy (Koala Habitat Protection) 2020

State Environmental Planning Policy (Koala Habitat Protection) 2020 (Koala Habitat Protection SEPP) commenced on 30 November 2020 replacing State Environmental Planning Policy (Koala Habitat Protection) 2019 which in turn had replaced State Environmental Planning Policy No 44—Koala Habitat Protection.

The SEPP aims to encourage the proper conservation and management of areas of natural vegetation that provide habitat for koalas to ensure a permanent free-living population over their present range and reverse the current trend of koala population decline:

- by requiring the preparation of plans of management before development consent can be granted in relation to areas of core koala habitat, and
- by encouraging the identification of areas of core koala habitat, and
- by encouraging the inclusion of areas of core koala habitat in environment protection zones.

The Project is being assessed under Part 5 of the EP&A Act and the provisions of the Koala Habitat Protection SEPP therefore do not apply to the Project.

3 Landscape features

3.1 General description of the development site

3.1.1 Landform, geology, and soils

The development site is 104.85 hectares and is located at and adjacent to Warragamba Dam. The elevation within the development site is varied, ranging between 21 metres AHD at its lowest point and 195 metres AHD at its highest point. The development site slopes from the top of the gorge down to the dam and Warragamba River.

The mean rainfall for Lake Burragorang is 840 millimetres per year, with the highest rainfall occurring in the warmer months, particularly during the month of February (WaterNSW 2015).

The Soil Landscapes of Penrith 1:100,000 soil landscape sheet (Bannerman and Hazelton 1990) has mapped four soil landscapes within the outer assessment circle as outlined in Table 3-1.

Table 3-1. Soil landscape description

Name	Landscape	Soils	Limitations
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 m, slopes 10-15%. Rock outcrop 25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop with broken scarps.	Shallow to moderately deep (30-100 cm) yellow earths and earthy sands on crests and on insides of benches; shallow siliceous sands on leading edges of benches; localised gleyed podzolic soils and yellow podzolic soils on shale lenses; shallow to moderately deep (<100 cm) siliceous sands and leached sands along drainage lines.	Steep slopes, water erosion hazard, rock outcrop, localised rockfall hazard, localised non-cohesive soils, shallow highly permeable soil, very low soil fertility.
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces on Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop.	Shallow (<50 cm) earthy sands and yellow earths; some siliceous sands/lithosols associated with rock outcrop.	Shallow, highly permeable soil, localised non-cohesive soils, very low soil fertility, localised water erosion hazard, localised rick outcrop.
Hawkesbury	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200 m, slopes >25%. Rock outcrop >50%. Narrow crests and ridges, narrow incised valleys, steep side slopes with rocky benches, broken scarps and boulders.	Shallow (<30 cm) discontinuous lithosols/ siliceous sands, associated with rock outcrop; earthy sands, yellow earths and some locally deep sands on inside of benches and along joins and fractures; localised yellow and red podzolic soils associated with shale lenses, siliceous sands and secondary yellow earths along drainage lines.	Steep slopes, mass movement hazard, rockfall hazard, water erosion hazard, shallow soils, rock outcrop, non-cohesive soils (localised), stony, highly permeable soils of low fertility.
Blacktown	Gently undulating rises on Wianamatta Group shales. Local relief to 30 m, slopes usually >5%. Broad rounded crests and ridges with gently inclined slopes.	Shallow to moderately deep (>100 cm) hard setting mottled texture contrast soils, red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and drainage lines.	Localised seasonal waterlogging, localised water erosion hazard, moderately reactive highly plastic subsoil, localised surface movement potential.

3.1.2 Vegetation

The total area of vegetation in the development site is 55.23 hectares. Vegetation within the development site can be classified into three native vegetation classes:

- Sydney hinterland dry sclerophyll forests
- Sydney coastal dry sclerophyll forests
- Northern hinterland wet sclerophyll forests.

Of the total area within the development site, 53 percent is mapped as native vegetation, with the balance containing a mix of dam-related infrastructure, buildings, roads, and landscaped areas. Figure 3-1 shows the vegetation within the development site as mapped by broadscale vegetation mapping.

Portions of the development site have been previously disturbed during dam construction and upgrade. The majority of these areas have been revegetated with cultivated native species and also contain a level of indigenous regeneration, whilst in other areas, where soil disturbance was minimal, the vegetation was regenerated with minor alterations to species richness and diversity. These areas have been included as native vegetation within this assessment.

3.1.3 Hydrology

Lake Burragorang is the dominant hydrological feature of the development site. Created by damming the Warragamba River and flooding the Burragorang Valley, Lake Burragorang is four times the size of Sydney Harbour and is currently managed as Sydney's water supply dam (WaterNSW 2015).

Downstream of the dam is the Warragamba River. Water is discharged into the Warragamba River when the dam spills. Water is also released into the Warragamba River (downstream of Warragamba Weir) to provide a secure water supply to the population of North Richmond. Warragamba River is a 9th order Strahler stream and there are several small, unnamed ephemeral tributaries within the development site.

3.1.4 Land uses

The development footprint is located on land zoned as SP2 Infrastructure (Water Supply) under the Wollondilly Local Environmental Plan 2011 (Table 3-2). This land around the dam serves as operational support for the existing dam and consists of cleared and vegetated areas, dam support facilities, access roads and parks. The proposed works would be permissible within this land zone type and construction activities would be contained within this zone. As a result, there is no overarching land use change expected.

Table 3-2. Land zones at the development site

Land zone	Objectives	Permissibility
SP2 – Water Supply	▪ To provide for infrastructure and related uses. ▪ To prevent development that is not compatible with or that may detract from the provision of infrastructure.	Permitted

Figure 3-1. Location Map -– Vegetation communities

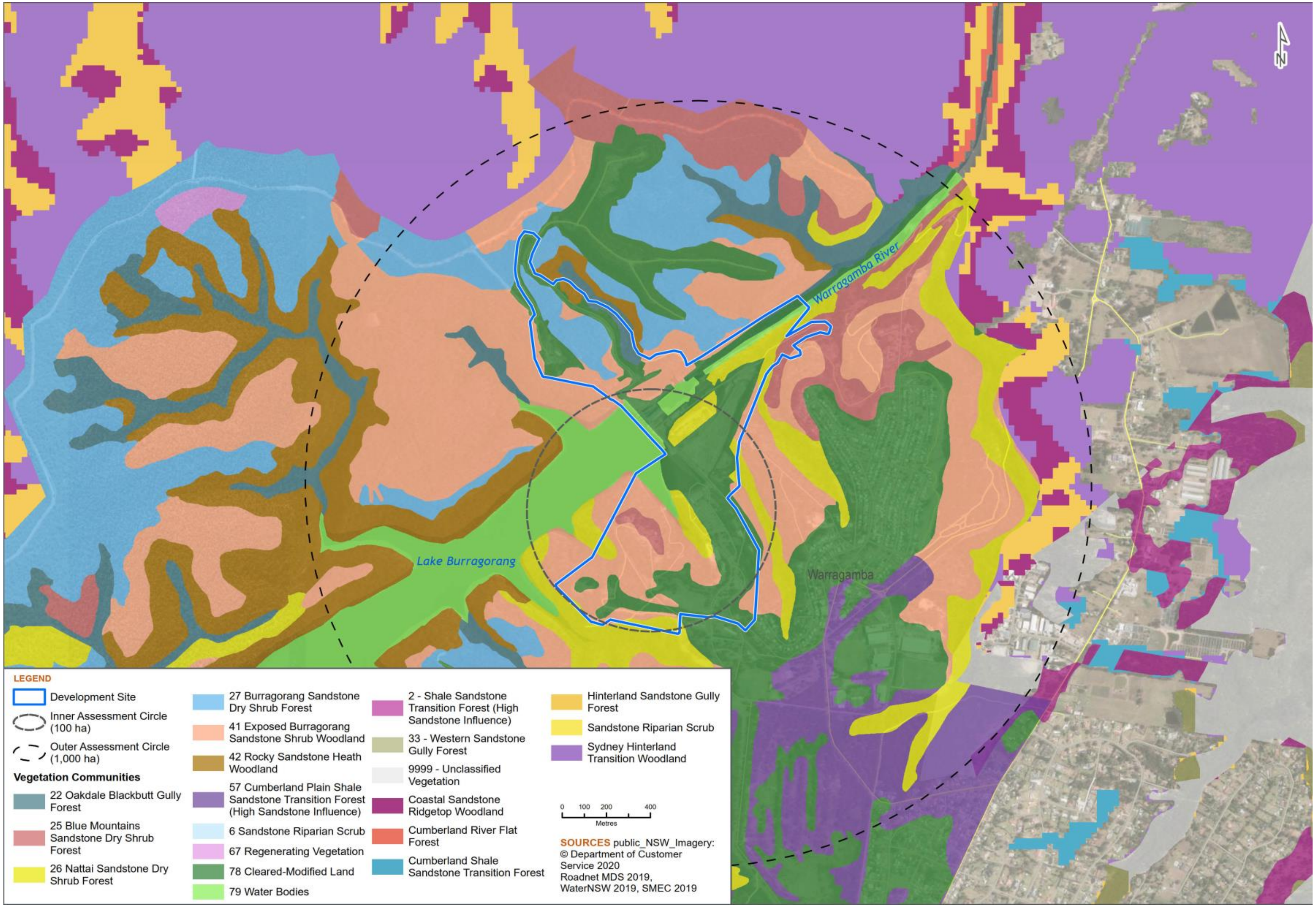
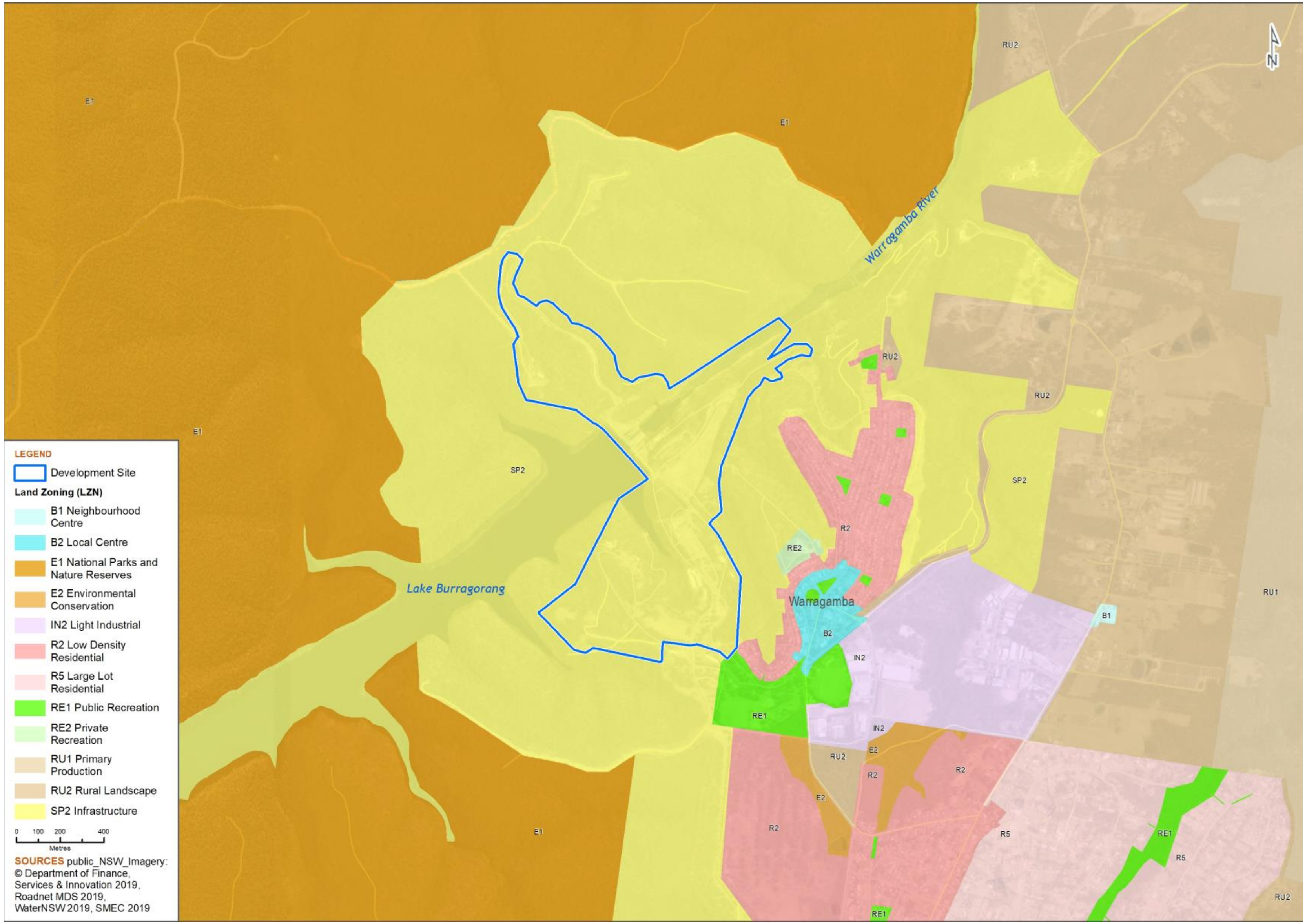


Figure 3-2. Land use zones



3.2 IBRA bioregions and IBRA subregions

Bioregions are large, geographically distinct areas of land with common characteristics such as geology, landform patterns, climate, ecological features and plant and animal communities.

Bioregions and subregions are the reporting unit for assessing the status of native ecosystems and their level of protection. Bioregions and subregions are used in the FBA to assist the assessment of landscape scale impacts of a development and predictions for distribution of threatened species.

3.2.1 Bioregions

The development site is located within the Sydney Basin (SYB) Bioregion (DoEE 2018). OEH (2016) provides the following information on the SYB Bioregion.

The Sydney Basin Bioregion lies on the central east coast of NSW and covers an area of approximately 3.6 million hectares, which is the equivalent of 4.5 percent of NSW. The SYB Bioregion is one of two bioregions contained wholly within the state. It consists of a geological basin filled with near horizontal sandstones and shales of Permian to Triassic age that overlie older basement rocks of the Lachlan Fold Belt. The sedimentary rocks have been subject to uplift with gentle folding and minor faulting during the formation of the Great Dividing Range. Erosion by coastal streams has created a landscape of deep, cliffed gorges and remnant plateaux across which an east-west rainfall gradient and differences in soil control the vegetation of eucalypt forests, woodlands and heaths. The Sydney Basin Bioregion includes coastal landscapes of cliffs, beaches and estuaries.

The frontal slope of the Blue Mountains (where the site is located) is formed along the Lapstone monocline. A secondary flexure and similar escarpments occur at the coast forming the Hornsby Plateau and the Illawarra Escarpment. These structural features combine with different rock types and strong trends in joint patterns to control drainage patterns and the distribution of gorges and swamps.

3.2.2 Subregions

The development site is located across two IBRA subregions (DoEE 2018):

1. Burragorang subregion
2. Wollemi subregion.

The Cumberland subregion is located close to the development site and is considered in the landscape assessment in Section 3.10. The Wollemi, Burragorang, and Cumberland subregions are described by Morgan (2001), with a summary of this description being provided in Table 3-3.

The extent of the subregions within the development site is shown in Figure 1-4.

Table 3-3. Description of the subregions within Sydney Basin Bioregion occurring within the development site

Subregion	Geology	Characteristic landforms	Typical Soils	Vegetation
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. There are also a number of scattered volcanic necks distributed throughout the Wollemi subregion.	Characterised by the highest part of the Blue Mountains and other sandstone plateaux with benched rock outcrops.	Typically, soils are thin sands or deep yellow earths on plateaux, with thin texture contrast soils on shale benches. Organic sands in line swamps and joint crevices, while slope debris are found below cliffs, and sandy alluvium in pockets along the streams. On basalts, soils are red brown structured loams.	*Corymbia gummifera*, *Corymbia eximia*, *Angophora floribunda*, *Angophora costata*, *Eucalyptus sclerophylla*, and *Eucalyptus punctata* with diverse shrubs and heaths on plateau. Additionally, *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus agglomerata*, and *Syncarpia glomulifera* subsp. *glomulifera* and gully rainforests are present in gullies and canyon heads. *Eucalyptus viminalis* and Blaxland's Stringybark on basalt. *Casuarina cunninghamiana* is found along main streams.
Burragorang	Comprised of Permian and Triassic sandstones and shales on the western edge of the Sydney Basin.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley	Typically, soils include rocky outcrops, texture contrast soils and uniform sands on sandstone. Cliff bases are generally pillowed with a sandy, clay matrix, alluviums contain rich loams.	Heath, shrubland and woodland with *Eucalyptus sieberi*, *Eucalyptus sclerophylla*, *Eucalyptus piperita* and *Corymbia gummifera* on sandstone similar to other parts of the Basin. *Eucalyptus deanei*, *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerata* immediately below escarpment passing to *Eucalyptus punctata*, *Eucalyptus crebra* and *Eucalyptus eugenioides* on rocky slopes. *Casuarina cunninghamiana* along main streams below the plateaux.
Cumberland	Triassic Wianamatta group shales and sandstones, which are intruded by a small number of volcanic vents and partly covered by Tertiary river gravels and sands. There is quaternary alluvium along the mains streams.	Low rolling hills and wide valleys in a rain shadow area below the Blue Mountains. Volcanics from low hills in the shale landscapes. Swamps and lagoons on the floodplain of the Nepean River.	Typically, soils include a mixture of clays on volcanics, poor stony soils on older gravels, and high-quality loams on floodplain alluvium.	*Eucalyptus moluccana, Eucalyptus tereticornis, Eucalyptus crebra* woodland with some *Corymbia maculata* on the shale hills. *Eucalyptus sclerophylla, Angophora floribunda*, and *Banksia serrata* on alluvial sands and gravels. *Angophora subvelutina, Eucalyptus amplifolia* and *Eucalyptus tereticornis* with abundant *Casuarina glauca* on river flats. Tall spike rush, and juncus with *Eucalyptus parramattensis* in lagoons and swamps.

3.3 NSW landscape regions (Mitchell landscapes)

Mitchell landscapes were developed by the then DECC (2002) to provide a more detailed description of the landscape than bioregions and sub regions. They include consideration of landscape features such as geology and geomorphology to reflect common landscape features.

Mitchell landscapes are used in the FBA to assist the assessment of landscape scale impacts of a development and predictions for distribution of threatened species. The development site is located across four landscape regions:

- Kurrajong Fault Scarp
- Lapstone Slopes
- Burragorang Valley and Gorges
- Nattai Plateau.

The extents of the Mitchell Landscapes within and adjacent to the development site are shown in Figure 1-4. Kurrajong Fault Scarp occurs over the majority of the development site (as measured by area) followed by Lapstone Slopes, Burragorang Valley and Gorges, and Nattai Plateau. Descriptions of each Mitchell Landscape (DECC 2002) are provided in Table 3-4.

Table 3-4. Description of the Mitchell Landscapes

Mitchell landscape	Description
Kurrajong Fault Scarp	Dissected and broken slopes on Triassic Quartz sandstone and shale across the Lapstone monocline and Kurrajong fault scarp. Local dips on the sedimentary rocks up to 300 m, general elevation 100 to 250 m, local relief 100 m. Abundant rock outcrop with pockets of yellow-brown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of: *Eucalyptus agglomerata*, *Syncarpia glomulifera* subsp. *glomulifera*, Red *Corymbia gummifera*. *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus radiata*, *Eucalyptus punctata*, *Eucalyptus pilularis* and *Allocasuarina* sp. Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered *Eucalyptus tereticornis*, *Angophora floribunda* and *Eucalyptus globoidea* on the margins.
Lapstone Slopes	The frontal slope of the Blue Mountains formed by folding and faulting of Triassic quartz sandstone and shale with a veneer of Tertiary river gravels. A southern extension of the Kurrajong Fault Scarp landscape. Larger streams cut through the structural ridge in deep gorges, but smaller streams have accumulated organic sands in swamps and lagoons on the western side of the flexure. General elevation 50 to 300 m, local relief 180 m, steep dip slopes on the eastern face and benched faulted slopes on the west. Extensive rock outcrop, thin sandy soils with gravel and occasional white or yellow clay subsoils. Pockets of deep sand in some streams. *Corymbia gummifera*, *Corymbia eximia*, *Eucalyptus punctata*, *Allocasuarina torulosa*, *Eucalyptus sieberi*, *Eucalyptus radiata* with diverse shrubby understorey.
Burragorang Valley and Gorges	Deep steep sided benched slopes and gorge of the Wollondilly and Coxs Rivers incised into mostly horizontal Triassic quartz sandstone conglomerate, siltstone, and shale, cliffs to 150m high with waterfalls, general elevation 50 to 220 m, local relief 150 m. The gorge widens upstream and exposes underlying Permian chert, mudstones and conglomerate. Very extensive rock outcrop, thin yellow to yellow-brown silty sand and gravel with occasional white clay layers forming either shallow yellow earths or gleyed texture-contrast profiles. *Corymbia gummifera*, *Syncarpia glomulifera*, and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliffs upstream with *Eucalyptus tereticornis*, *Eucalyptus macrorhyncha*, *Eucalyptus crebra*, and *Eucalyptus mannifera*. Moist protected environments with *Eucalyptus saligna*, *Eucalyptus cypellocarpa*, *Eucalyptus muelleriana* and *Eucalyptus smithii*. Gallery forest of *Casuarina cunninghamiana* with *Eucalyptus deanei* and *Eucalyptus benthamii* along the main streams.
Nattai Plateau	Steeply dissected plateau remnants on lower Triassic lithic sandstone, shale and tuff, abundant rock outcrop and cliffs, steep debris slopes, general elevation 600 to 700 m, local relief 80 m. Shallow sand and occasional yellow texture-contrast soils. Forests of *Eucalyptus eugenioides*, *Eucalyptus fibrosa* subsp. *fibrosa*, *Callitris rhomboidea*, *Eucalyptus sieberi*, *Eucalyptus blaxlandii*, *Eucalyptus fastigata* and *Eucalyptus viminalis*.
Silverdale Slopes	Moderately undulating slopes descending to the east on gently dipping Triassic shales and sandstones. General elevation 230 to 630 m, local relief 200 m. Brown to yellow-brown texture-contrast soils. Woodland to forest with a shrubby understorey, common species; *Eucalyptus punctata*, *Eucalyptus albens*, *Eucalyptus paniculata*, *Eucalyptus crebra*, *Eucalyptus fibrosa*, *Eucalyptus moluccana*, *Allocasuarina torulosa*, *Eucalyptus eugenioides*, and occasional *Syncarpia glomulifera*.

3.4 Rivers and streams

The development site falls within the Warragamba Catchment. Bordered on the west by the Great Dividing Range, the catchment stretches from north of Lithgow at the head of the Coxs River in the Blue Mountains, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River (WaterNSW n.d.).

The proposed construction area includes areas of Lake Burragorang, the dam spillway and the Warragamba River. Up to the dam, Lake Burragorang is considered to be a 9th order stream in accordance with the Strahler stream ordering method. According to the aquatic ecology and water quality assessment undertaken by BMT for the EIS, the current geomorphological condition at the dam is characterised by altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplains.

The Project would impact upon all of the riparian buffers within the development site. The extents of the streams are shown in Figure 1-4.

3.5 Wetlands

Lake Burragorang and part of the Warragamba River downstream of the dam wall have been mapped as NSW wetland within the development site within the NSW wetland shapefile (OEH 2010). No important or local wetlands occur within the development site. There are a number of smaller dams mapped to the east of the development site, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 kilometres of the development site.

3.6 Native vegetation

The development site is 104.85 hectares in size, which includes 55.23 hectares of native vegetation. The extent of native vegetation within the development site is shown in Figure 4-2. This extent has been determined through aerial photograph interpretation and field surveys as described in Section 4.2. It is considered that there are no differences between the mapped vegetation extent and the vegetation indicated by the aerial imagery.

The development site is centred around Warragamba Dam which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, the vegetation surrounding Lake Burragorang is not typical riparian or floodplain vegetation. Instead, much of the development site is comprised of vegetation typical of ridgetops on skeletal soils. The majority of the development site supports dry sclerophyll forest of shrubby sub-formation, as well as an area of wet sclerophyll forest. To the west of Warragamba Dam, to both the north and south of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenioides*, *Eucalyptus sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest which extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the shale/sandstone transition forest critically endangered ecological community (CEEC).

WaterNSW has recently carried out approved vegetation clearing around built structures for the purposes of asset protection in relation to bushfire risk. This clearing has reduced the area of vegetation mapped by SMEC by 0.15 hectares.

3.7 State or regionally significant biodiversity links

State significant biodiversity links, regionally significant biodiversity links, very large area biodiversity links, large area biodiversity links or local area biodiversity links are defined in the FBA. To date, no biodiversity corridor plans have been approved by DPIE.

Appendix 2 of the FBA outlines the riparian buffer widths required for each order of stream classified in accordance with the Strahler system. The Project would impact upon the 50-metre riparian buffer for an 9th order stream. Under the FBA, riparian buffers for 6th order streams or higher are considered to be a state significant biodiversity link. Consequently, the Project would be impacting upon a state significant biodiversity link.

3.8 Biodiversity values map

The Biodiversity Values (BV) map identifies land with high biodiversity value that is especially sensitive to impacts from development and clearing. Land types included on the BV map include:

- Declared Ramsar wetlands defined by the EPBC Act

- Land containing threatened species or threatened ecological communities identified as potential serious and irreversible impacts (SAII) under section 6.5 of the BC Act
- Protected riparian land
- High conservation value grasslands or groundcover
- Old growth forest identified in mapping developed under the National Forests Policy Statement but excluding areas not meeting the criteria published jointly by the Minister for the Environment and the Minister for Primary Industries
- Rainforest identified in mapping developed under the National Forests Policy Statement but excluding areas not meeting the criteria published jointly by the Minister for the Environment and the Minister for Primary Industries
- Declared areas of outstanding biodiversity value (listed critical habitat)
- Council nominated areas with connectivity or threatened species habitat that the Minister for the Environment considers will conserve biodiversity at bioregional or state scale
- Any other land that in the opinion of the Environment Agency Head is of sufficient biodiversity value to be included.

No areas of biodiversity value were identified on the BV Map as occurring within the development site.

3.9 Other landscape features

No other landscape features within the development site or landscape buffer were identified in the SEARs.

3.10 Landscape value score components

A BioBanking credit assessment was completed for this Project. The Project ID for the assessment is 174/2019/4968MP and the assessment type was selected as 'Major Project'. This section summarises the values entered into the landscape values section of the BioBanking Credit Calculator (BBCC).

3.10.1 Method applied

For the development site, the 'site-based development' module was selected in the BBCC version 4.0. A 100-hectare inner assessment circle and 1,000-hectare outer assessment circle were used r to calculate the current and future native vegetation cover extent and patch size score in accordance with the FBA methodology. Combined with the connectivity value score the BBCC calculates a landscape value score. The landscape value score is entered into the BBCC as part of the credit calculations.

The development footprint crosses the polygon boundaries within the IBRA subregion and Mitchell Landscape spatial datasets. The dataset selected for the assessment was Wollemi IBRA sub-region and Kurrajong Fault Scarp Mitchell Landscape as the majority of the development site and impacts occur with this IBRA sub-region and Mitchell Landscape.

3.10.2 Percent native vegetation cover in the landscape

To map the extent of native vegetation within the development site, the Warragamba_VISmap_2380 shapefile was overlain on a 2016 aerial image available through the SIX Maps application. The extent of native vegetation cover was confirmed and revised, where necessary, through surveys of the development site conducted by SMEC from December 2017 to October 2018. Amendments to the extent of native vegetation were made using Geographic Information System (GIS), ArcGIS 10.6. The boundaries of native vegetation were reduced in areas that have been cleared since the previous vegetation mapping was prepared. Conversely, the boundaries of native vegetation were extended in areas where the previous vegetation mapping indicated the land was cleared but has subsequently been mapped or can be predicted to contain native vegetation using aerial imagery.

Native vegetation occurring in the inner and outer assessment circle is shown in Figure 3-1. Native vegetation occupies approximately 61 percent of the inner assessment circle, and 75 percent of the outer assessment circle. Native vegetation within the landscape buffer is predominately large, intact patches of native forest of at least three vegetation formations. The remaining land within the inner and outer assessment circles is comprised of parkland as well as recreational areas and infrastructure associated with tourism at Warragamba Dam. It is considered that there are currently no differences between the mapped vegetation extent and aerial imagery used by this assessment.

Construction of the Project would result in the loss of 22.42 hectares of native vegetation within the development site. A summary of the current and future percentage of native vegetation cover in the landscape buffer area is provided in Table 3-5. Based on these values, the Project has a native vegetation cover score of 1.2 as calculated by the BBCC.

3.10.3 Connectivity value

A 'Riparian buffer of a 6th order stream of higher' has been identified as being impacted by the proposed construction activities. In accordance with Appendix 4 of the FBA, this is considered a 'State significant biodiversity link' with a connectivity value score of 12 as calculated by the BBCC.

3.10.4 Patch size

As the Project is a site-based development, patch size has been determined in accordance with Appendix 4 to the FBA. The Kurrajong Fault Scarp is the Mitchell landscape within which most of the Project is located. The native vegetation within the development site has been identified in Section 3.6 of this report. Of this vegetation, the largest patch of native vegetation (of which a large portion occurs within the development site) is greater than 1000 hectares in size. Based on this, the patch size class is categorised in accordance with the FBA as 'Extra Large' which has a corresponding patch size score of 12.

3.10.5 Summary of landscape value score components

A summary of the landscape value score components is provided in Table 3-5.

Table 3-5. Summary of landscape value score components

Components	Inner assessment circle	Outer assessment circle
Current native vegetation cover extent	61%	75%
Future native vegetation cover extent	49%	72%
Connectivity value	Riparian buffer around a 9th order stream	
Patch size	>1000	
Landscape value score	25.20	

4 Native vegetation

4.1 Review of existing data

A review of existing vegetation data was undertaken prior to any field surveys being undertaken. The following primary sources of information were consulted as part of a desktop assessment of the native vegetation within the development site:

- BioNet Vegetation Classification System (OEH 2017c)
- SIX Maps viewer (Department of Finance and Services 2017)
- The Native Vegetation of the Warragamba Special Area (NPWS 2003)
- Warragamba_VISmap_2380 (NPWS 2003)
- The Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands. Version 1.0 (Tozer *et al*. 2010).

The following secondary sources were reviewed:

- Preliminary Environmental Assessment – Warragamba Dam Raising (BMT WBM Pty Ltd 2016)
- Proposed Warragamba Flood Mitigation Dam – Environmental Impact Statement (ERM Mitchell McCotter 1995)
- Warragamba Dam EIS – Dam Site Environmental Studies Flora and Fauna Report (Mount King Ecological Surveys 1992).

Information obtained during the review of existing data was used in conjunction with field data collected by SMEC to assess native vegetation within the site.

4.2 Surveys

4.2.1 Overview

Surveys of the vegetation within the development site and adjoining land were conducted between October 2017 and October 2018. The first round of surveys was conducted to obtain an overview of the nature and extent of vegetation not just within the development site, but also within adjacent lands. Another objective of the first round of surveys was to map the extent of vegetation communities and establish the number of floristic plots required for the assessment. Once the likely plant community types (PCTs) were identified, full floristic plots and plot and transect surveys were conducted to verify the PCTs and collect site value data from the identified vegetation zones.

These surveys were designed to meet the requirements of the FBA. Areas of native vegetation were delineated using a handheld global positioning system (GPS) unit, aerial photograph interpretation and site notes.

For the purposes of assigning PCTs to native vegetation communities, plot based full floristic survey was undertaken in accordance with Table 3 of the FBA at 13 sites across the development site. These same sites were also used for plot and transect surveys of each vegetation zones.

The PCTs occurring within the development site were initially stratified into areas represented by the locally-defined vegetation communities. These were subsequently divided into different condition classes, which resulted in the creation of five vegetation zones, as shown in Table 4-1.

The field survey requirements and effort for this assessment have been carried out as part of the broader field survey requirements and effort for the upstream assessment. As such, some of the survey effort (for example plots 9-13) has been undertaken outside of the development site boundary.

4.2.2 Plot-based full floristic survey

Thirteen floristic plots were surveyed within the development site and adjoining land. The following information was collected at each of the 20 x 20 metre full floristic plots, in accordance with Table 1 of the FBA:

- Stratum (and layer): the stratum and layer in which each species occurs
- Growth form: the growth form for each species recorded
- Species name: scientific and common name

- Cover: a measure or estimate of the appropriate cover measure for each recorded species, from 1–5 percent and then to the nearest 5 percent. If the cover of a species is less than 1 percent and the species is considered important, then the estimated cover should be entered, for example, 0.4 percent
- Abundance rating: a relative measure of the number of individuals or shoots of a species within the plot. Use the following intervals: numbers above about 20 are estimates only: 1 2, 3, 4, 5, 6, 7, 8, 9 10 20, 50 100, 500, or 1,000, or specify a number greater than 1,000 if required.

The locations of these plots are shown in Figure 4-1. The locations of the full floristic plots were determined by pacing a random distance into the vegetation zone that would enable an appropriate assessment of expected environmental variation. Areas considered not suitable for assessment include ecotones, vehicle tracks and their edges, and disturbed areas which are readily distinguishable from the broad condition state of the vegetation zone.

4.2.3 Plot and transect surveys

Thirteen plots and transects were surveyed within the development site and adjacent land have been used in this assessment. The following information was collected at each 20 x 50 metre plot and transect sites in accordance with Section 5.3.2 of the FBA:

- native species richness recorded within each stratum of a 20 x 20 metre sub-plot
- native overstorey cover recorded at 10 points along a 50 metre transect
- native midstorey cover recorded at 10 points along a 50 metre transect
- native ground cover recorded at 50 points along a 50 metre transect for three life forms (shrubs, grasses and other)
- exotic plant cover expressed as a total percent cover across all strata (each stratum measured using the same method for native overstory, midstorey and ground cover)
- number of trees with hollows visible from the ground within the 20 x 50 metre plot
- the total length of fallen logs greater than 10 centimetres in diameter within the 20 x 50 metre plot
- the proportion of regenerating overstory species within the vegetation zone.

The locations of the plot and transect sites are shown in Figure 4-1.

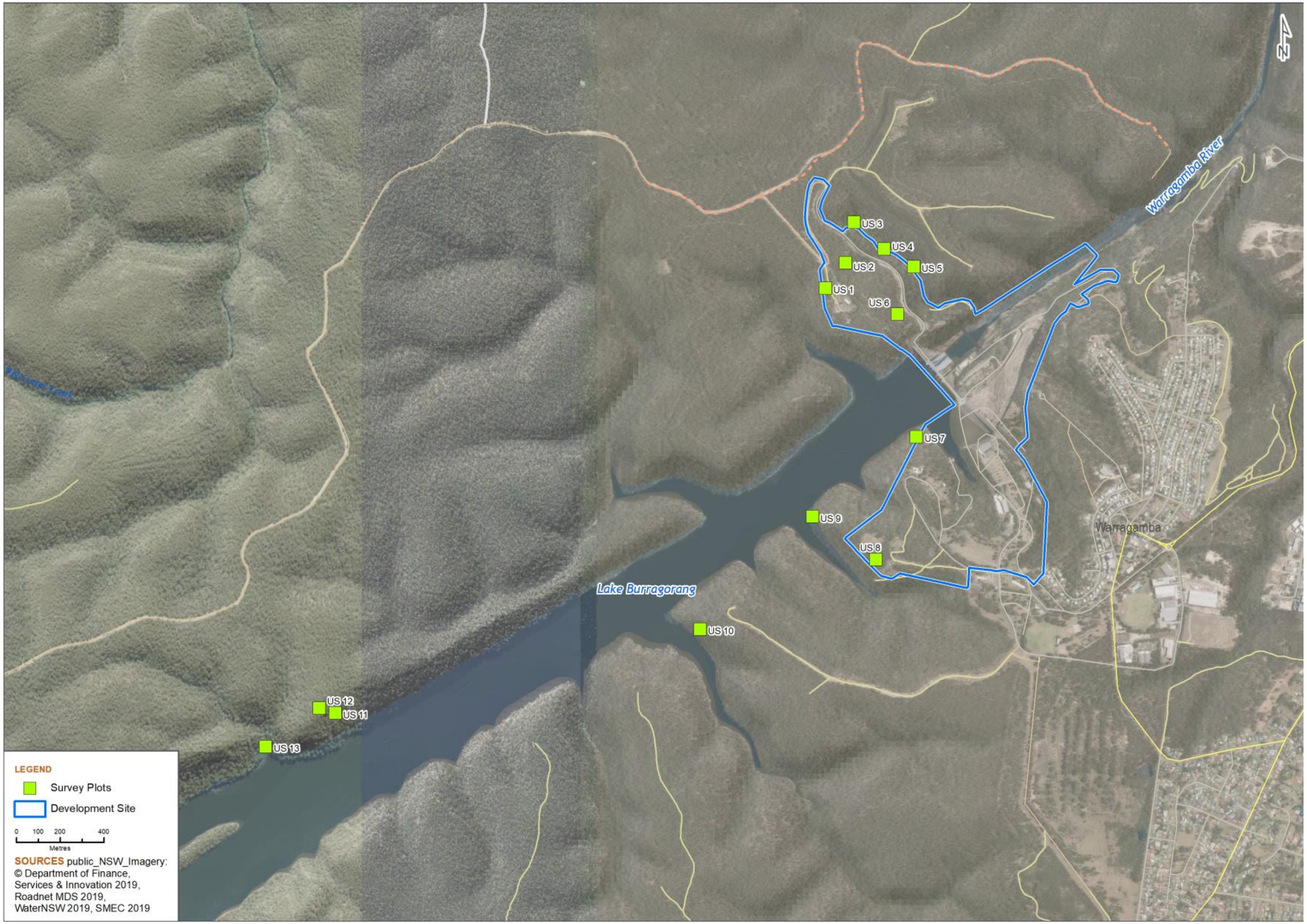
Table 4-1 summarises the plot and transect survey effort undertaken for the Project. With the exception of Vegetation Zone 3 and Vegetation Zone 5, the minimum number of plot and transect surveys required under the FBA have been conducted. Surrogate plots have been used in order for the assessment to meet minimum plot requirements for Vegetation Zone 3 and Vegetation Zone 5 as a result of access limitations. Site attribute values for the surrogate plot used within Vegetation Zone 3 were entered into the BBCC at benchmark, while site attribute values for the surrogate plot used within Vegetation Zone 5 were entered into the BBCC at 50 percent of benchmark because this vegetation zone had been disturbed though dam construction and operation. Data collected from all plot and transect sites was used to determine the site value score for each vegetation zone.

Table 4-1. Plot and transect survey efforts

Vegetation zone	PCT Code/ BVT Code	Condition*	Area within development site (ha)	Min. plot and transects required	No. plot and transects sampled
1	1081/HN564	Moderate/Good	14.11	3	4
2	1083/HN566	Moderate/Good	24.78	4	4
3	1086/HN568	Moderate/Good	8.61	3	2**
4	1281/HN604	Moderate/Good	4.88	3	3
5	1081/HN564	Moderate/Good_poor	2.85	1	0**#

** Condition names reflect options available within the BioBanking Credit Calculator rather than on-ground condition.*
*** One surrogate plot utilised in BioBanking Calculations.*
#Surrogate data entered at 50% of benchmark

Figure 4-1. Plot-based floristic survey points and plot transect survey points at the development site and adjoining land



4.3 Identification of plant community types

Identification of the PCTs occurring within the development site was guided by the review of existing data (see Section 4.1) and surveys of the development site (see Section 4.2). The data collected during surveys of the development site was analysed in conjunction with a review of the PCTs held within the VIS Classification Database, and previous published vegetation mapping of Tozer, et al. (2010). Consideration was given to the following:

- occurrence within the Wollemi, Burragorang, and Cumberland IBRA subregions
- vegetation formation
- landscape position
- soil type and edaphics
- dominant upper, mid and ground strata species.

The analysis determined that the vegetation within the development site aligned with four PCTs defined within the VIS Classification Database. Table 4-2 lists the PCTs that have been identified within the development site and the justification for their selection.

Table 4-2. Justification for selection of PCTs within the development site

PCT Code/ BVT Code	PCT name	Evidence used for identification	Species relied upon for identification
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	IBRA Subregion: Occurs within the Burragorang and Wollemi IBRA subregions Vegetation formation: Dry sclerophyll (Shrubby sub-formation) Landscape position: Occurs on loamy soils on dry ridges below approximately 400 m in the rain shadow zone surrounding the Cumberland Plain	Upper stratum species: *Corymbia gummifera, Eucalyptus punctata, Angophora costata, Syncarpia glomulifera* Mid stratum species: *Phyllanthus hirtellus, Persoonia linearis, Leptospermum trinervium, Acacia ulicifolia* Ground stratum species: *Entolasia stricta, Lomandra obliqua, Pomax umbellata, Themeda australis*
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	IBRA Subregion: Occurs within the Burragorang and Wollemi IBRA subregions Vegetation formation: Dry sclerophyll (Shrubby sub-formation) Landscape position: Occurs on crests, ridges and exposed slopes on coastal sandstone plateaux	Upper stratum species: *Corymbia gummifera, Eucalyptus haemastoma, Eucalyptus racemosa, Eucalyptus oblonga* Mid stratum species: *Acacia suaveolens, Acacia ulicifolia, Angophora hispida, Banksia ericifolia* Ground stratum species: *Actinotus minor, Caustis flexuosa, Cyathochaeta diandra, Dampiera stricta*
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	IBRA Subregion: Occurs within the Burragorang, Kanangra and Wollemi IBRA subregions Vegetation formation: Dry sclerophyll (Shrubby sub-formation) Landscape position: Occurs on sandy loams on elevated sandstone slopes between 250 and 800 m, mainly in the Nattai-Wingecarribee area	Upper stratum species: *Eucalyptus globoidea, Corymbia gummifera, Eucalyptus punctata, Eucalyptus sieberi* Mid stratum species: *Banksia spinulosa, Leptospermum trinervium, Lomatia silaifolia, Persoonia levis* Ground stratum species: *Billardiera scandens, Dampiera purpurea, Dianella caerulea, Entolasia stricta*
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	IBRA Subregion: Occurs within the Burragorang and Wollemi IBRA subregions	Upper stratum species: *Syncarpia glomulifera, Eucalyptus punctata, Eucalyptus pilularis, Eucalyptus paniculata subsp. paniculata*

PCT Code/ BVT Code	PCT name	Evidence used for identification	Species relied upon for identification
		Vegetation formation: Wet sclerophyll (Grassy sub-formation) Landscape position: Occurs in moist sheltered gully heads on shale up to 500 m around the edge of the Cumberland Plain and in the lower Blue Mountains	Mid stratum species: *Pittosporum undulatum, Polyscias sambucifolia, Acacia parramattensis, Breynia oblongifolia* Ground stratum species: *Dianella caerulea, Lomandra longifolia, Microlaena stipoides var. stipoides, Pratia purpurascens*

4.4 Description of plant community types

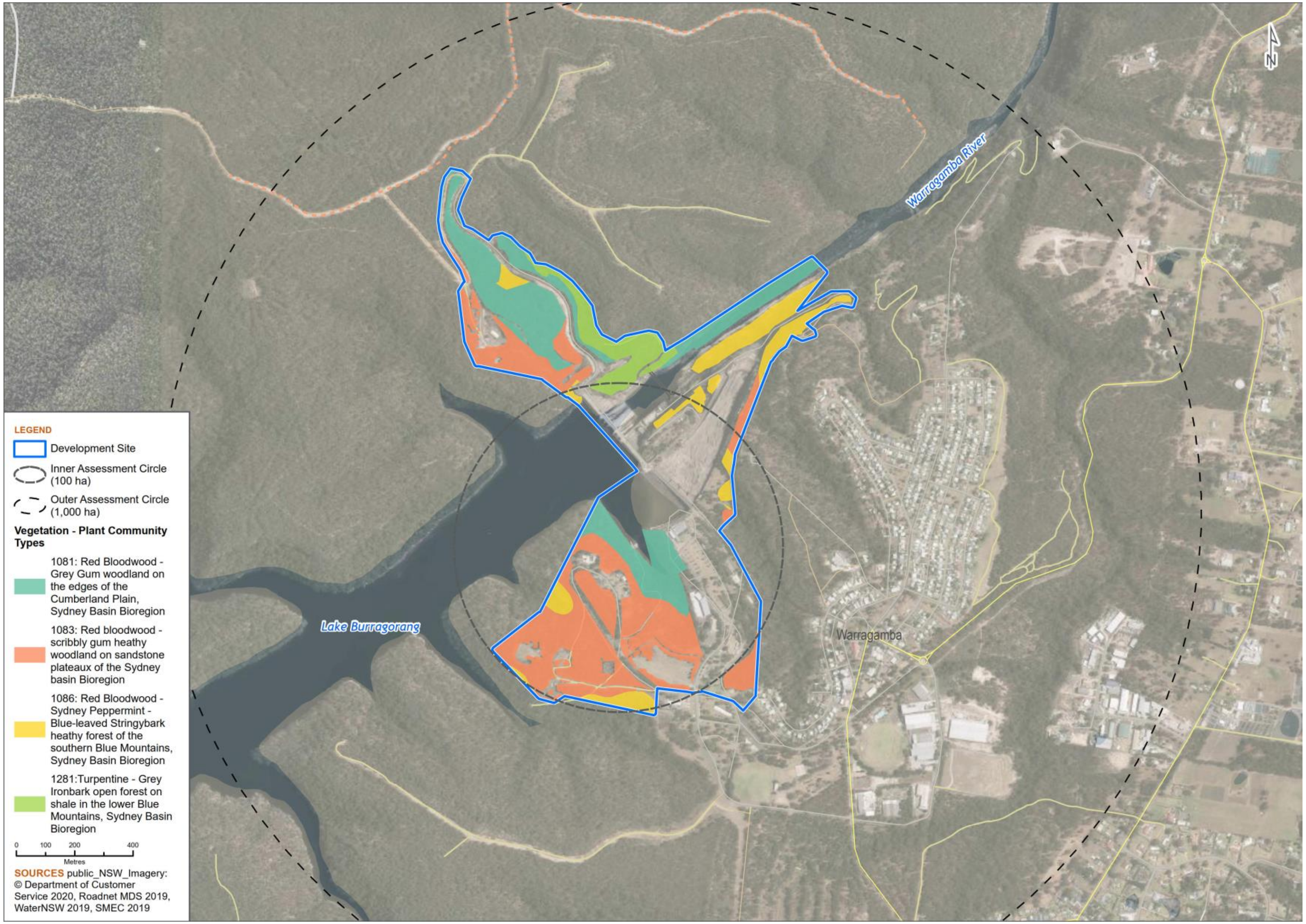
4.4.1 Overview

Table 4-3 provides a summary of the PCTs occurring within the development site, including vegetation formation, percent cleared within the Hawkesbury-Nepean catchment and extent within the development site. The distribution of these PCTs within the development site is shown in Figure 4-2. Data collected within the 20 x 20 metre floristic plots used to inform PCT identification can be found in Appendix D .

Table 4-3. Summary of PCTs occurring within the development site

PCT Code/ BVT Code	PCT Name	Vegetation Formation	Vegetation class	% cleared within Hawkesbury-Nepean catchment	Area within development Site (ha)
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	40	16.96
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	25	24.78
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	20	8.61
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Wet Sclerophyll Forests (Grassy sub-formation)	Northern Hinterland Wet Sclerophyll Forests	90	4.88

Figure 4-2. Plant community types within the development site



4.4.2 Threatened ecological communities

Based on the VIS Classification Database one PCT (HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion) identified within the development site has the potential to be a component of three different Threatened Ecological Communities (TEC) listed under both the BC Act and EPBC Act:

- Shale Sandstone Transition Forest (SSTF) in the Sydney Basin Bioregion listed as Critically Endangered under both the BC Act and EPBC Act (NSW Scientific Committee, 2014).
- Sydney Turpentine-Ironbark Forest (STIF) listed as Endangered under the BC Act and Critically Endangered under the EPBC Act (NSW Threatened Species Scientific Committee, 2019).
- Blue Mountains Shale Cap Forest (BMSCF) in the Sydney Basin Bioregion listed as Endangered under the BC Act and Critically Endangered under the EPBC Act (NSW Scientific Committee, 2011).

The vegetation within the development site was compared against the assemblage of species, area of occupancy, and supplementary descriptors outlined within the NSW Scientific Committee's Scientific Determination under the BC Act for each of the TECs listed above. In addition, the vegetation within the development site was compared against the listing advice and/or conservation advice for each TEC under the EPBC Act, especially in relation to relevant size and condition thresholds pertinent to EPBC Act listings. The comparisons and assessment as to whether the PCT conforms to either the BC or EPBC listings of these three TECs are provided in Table 4-4.

Note that acronyms for each threatened community in this section relate only to the particular legislation for it discussed within the subsection. Figure 4-3 shows the location of BC Act threatened ecological communities within the development site.

Table 4-4. TECs associated within PCTs occurring within the development site

PCT code	PCT name	TEC (BC Act)	TEC (EPBC Act)	TEC status	Assessed as associated TEC
HN604	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	Shale Sandstone Transition Forest in the Sydney Basin Bioregion	BC Act – Critically Endangered EPBC Act – Critically Endangered	Yes

4.4.2.1 Shale sandstone transition forest

Shale sandstone transition forest under the Biodiversity Conservation Act

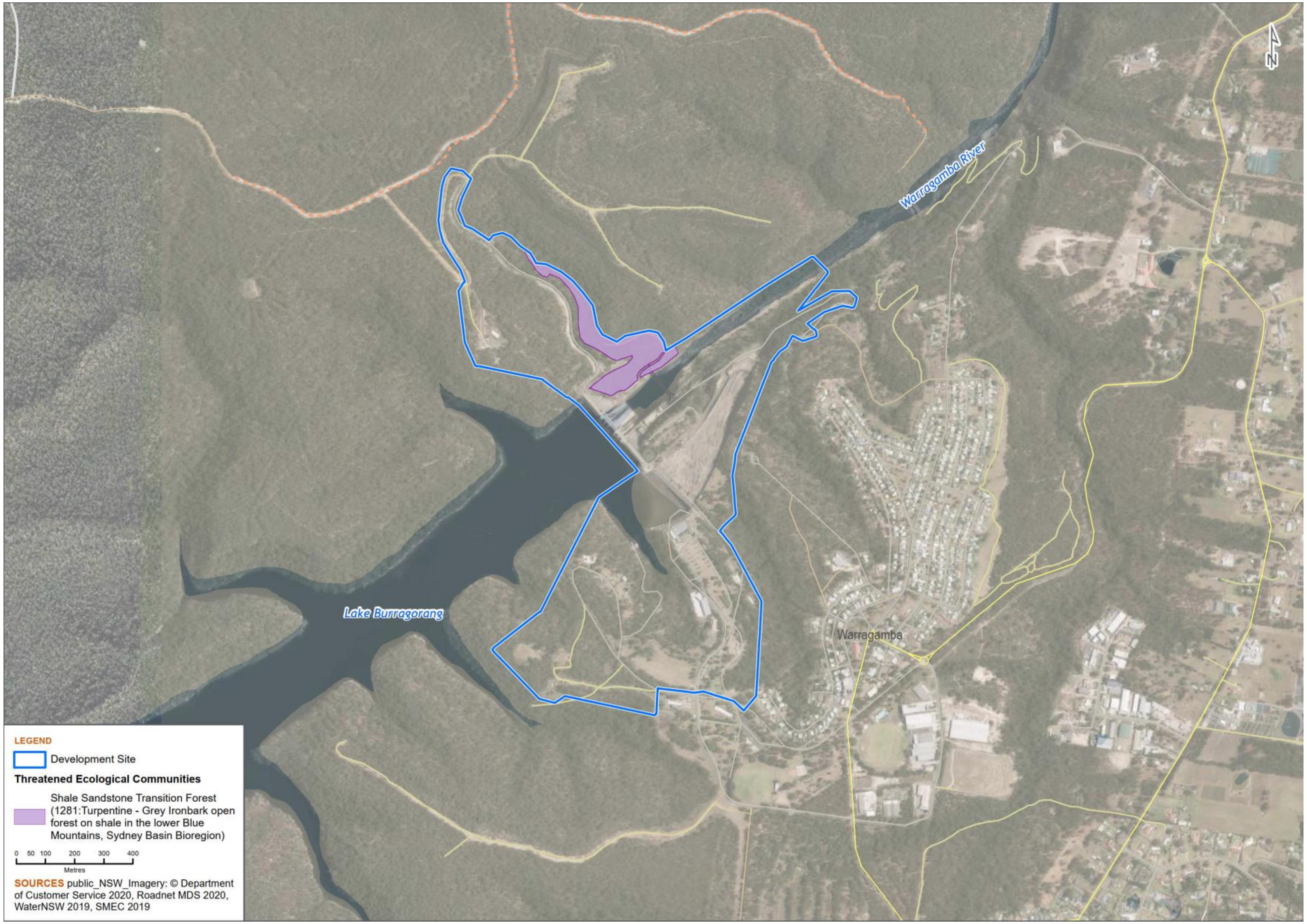
The NSW Scientific Committee Final Determination lists characteristic species of this assemblage. The Final Determination also includes plant species that may be part of the assemblage but are atypical of its broader distribution, particularly on the margins of the community's distribution.

Two 20 metre x 20 metre plots were carried out in HN604 within the development site, with a third plot carried out approximately 10 metres outside the development site in the same contiguous polygon of this PCT. Within these three plots, species listed as characteristic species of Shale Sandstone Transition Forest (SSTF) as per the NSW Scientific Committee's Final Determination include:

- Plot US3 had 15 SSTF characteristic species of a total 35 species identified in that plot (43 percent characteristic species).
- Plot US4 had 15 SSTF characteristic species of a total 44 species identified in that plot (34 percent characteristic species).
- Plot US5 had 13 SSTF characteristic species of a total 51 species identified in that plot (26 percent characteristic species).

Across all three plots carried out within HN604 24 SSTF characteristic species were recorded. This represents 32 percent of the 76 species described as characteristic within the Final Determination for SSTF. Beyond the number of species found in each plot that are described as characteristic species of SSTF, within the total mapped extent of this PCT visited, the dominant species in terms of abundance, cover and/or biomass are representative of the assemblage detailed in the Final Determination. This includes species such as *Corymbia gummifera* and *Eucalyptus*

Figure 4-3. BC Act threatened ecological communities within the development site



pilularis which were co-dominant across the community, and consistent with the description of the CEEC as described within Section 4.5 of the Final Determination (NSW Scientific Committee 2014).

The characteristic species listed within the Final Determination for SSTF comprises only a subset of the complete list of species recorded within known examples of the CEEC. An additional 11 species recorded within the three plots, or observed within HN604, were also listed within the superseded endangered ecological community listing of SSTF (NSW Scientific Committee 1998b). These may be considered additional to the listed characteristic species in accordance with Section 1.2 of the Final Determination (NSW Scientific Committee 2014).

Structurally, the extent of HN604 is generally as intact forest, with all vegetation layers generally present. An unsealed road of approximately five metres width occupies the central part of this PCT and represents the principal disturbance. For the purposes of this report, the narrow width of the disturbance, the overhanging canopy extent, the nature of intermittent recruitment of plants, presumed diaspore rain onto and over the road, the absence of imported material into the road, and the use of the road as habitat by broader floral and faunal assemblage component species, have all been considered in determining that the area of unsealed road disturbance within this patch of HN604 is part of the area occupied by the assemblage and as such is also mapped as SSTF.

The Final Determination notes that SSTF occurs within the Sydney Basin Bioregion, which is the 'particular area' as per section 1.6 of the BC Act. The entire development site and study area are within the Sydney Basin Bioregion.

The nearest extent of SSTF is mapped approximately one kilometre to the south east (OEH 2019d). This mapping is broad scale and is not ground-truthed.

eSPADE v2.0 (OEH 2019d), maps the areas of HN604 within the development site as Hawkesbury and Faulconbridge soil landscapes.

The Hawkesbury soil landscape is a colluvial landscape which is derived from Hawkesbury Sandstone of medium to coarse-grained quartz sandstone with minor shale and laminite lenses. According to the eSPADE soil landscape report, Hawkesbury soil landscape can support soil materials of sand, sandy loam, fine sandy clay loam, sandy clay loam, clayey sand and medium clay

The Faulconbridge soil landscape is a residual soil landscape which is derived from Hawkesbury Sandstone of medium to coarse-grained quartz sandstone with minor shale and laminite lenses. According to the eSPADE soil landscape report, Faulconbridge soil landscape can support materials of loose sand, fine sandy loam, clayey sand and sandy clay loam.

The Final Determination notes that SSTF's distribution is strongly correlated with soils derived from Wianamatta Shale, and in general, examples of SSTF on soils derived from Hawkesbury Sandstone are rare. Field surveys identified soils within the three plots as having both sand and clay. As the clay component of the soils observed on site in HN604 that are within the area mapped as either Hawkesbury Soil landscape (a colluvial landscape), or Faulconbridge (a residual landscape), it is presumed that the clay component is most likely to be autochthonous to the parent geology here, including the matrix of the sandstone and any shale lenses within the Hawkesbury sandstone, and unlikely derived from Wianamatta Shale. While there are extents of the Blacktown soil landscape in the locality, they are separated from HN604 in the development site by the Warragamba River to the south-east and the Nepean River to the north-east.

As per the definition of an ecological community in section 1.6 of the BC Act, this report finds the extent of HN604 mapped in the development site conforms floristically to the assemblage of species outlined in the Final Determination for SSTF, and that extent is within the Sydney Basin Bioregion. Further to that, while supplementary descriptions in the Final Determination indicate that SSTF is strongly associated with soils, at least in part, derived from Wianamatta shale, and the occurrence of SSTF in the soil landscapes not associated with this geology is rare, the Final Determination notes that this soil and landform association is known to occur with SSTF, particularly on the margins of SSTF extent.

Shale/Sandstone Transition Forest under the EPBC Act

Attachment A to the SEARs advises that SSTF as listed under the EPBC Act is particularly likely to be significantly impacted by the project.

The Approved Conservation Advice (including listing advice) for Shale/Sandstone Transition Forest of the Sydney Basin Bioregion listed under the EPBC Act identifies key diagnostic characteristics, and how these relate to HN604 on site are detailed in Table 4-5.

Table 4-5. Key diagnostic characteristics of Shale/Sandstone Transition Forest (EPBC Act)

Key diagnostic characteristics for shale/sandstone transition forest of the Sydney Basin Bioregion (EPBC Act) as per 1.5.1 of Approved conservation advice (including listing advice)	Discussion of key diagnostic characteristics present in HN604 of development site
Limited to the Sydney Basin Bioregion (IBRA v7).	The mapped extent of HN604 in the development site is within the Sydney Basin.
Occurs at the transition between shales and sandstones of the Wianamatta and Hawkesbury Groups, including the transitional Mittagong Formation.	Occurs near the transition between shales and sandstones of the Wianamatta and Hawkesbury Groups. The soil landscapes mapped by eSPADE identify the residual and colluvial parent geology as Hawkesbury, with a presumed low likelihood of Wianamatta shale influence, with observed clay component of soils presumed to be derived from inherent clay laminates within the parent geology. As per 1.2 of the Approved Conservation Advice, while SSTF is found primarily on shale derived soils (most commonly where the Wianamatta Group shale grades into sandstone), the ecological community less commonly occurs on Hawkesbury shale lenses within the otherwise sandstone-dominated Hawkesbury Group, as is mapped on site by eSPADE.
Occurs as forest or woodland, and may have a primarily shrubby or primarily grassy understorey, or be a mixture	Occurs as a forest to woodland.
Canopy is a mix of species typically including two or more of the following: *Eucalyptus punctata* (grey gum), *E. crebra* (narrow-leaved ironbark), *E. fibrosa* subsp. *fibrosa* (broad-leaved ironbark), *E. tereticornis* subsp. *tereticornis* (forest red gum), *E. resinifera* subsp. *resinifera* (red mahogany), *E. eugenioides* (or *E. globoidea* depending on local species present and degree of sandstone influence) and *Angophora bakeri* (narrow-leaved apple).	*Eucalyptus punctata* and at least one ironbark species was observed within and adjacent to the PCT mapped within the development site. Both ironbark species listed in point 4 above are the only ironbark species noted during upstream surveys within 10km of the development site. *Eucalyptus resinifera* was also noted, including in one plot. Further to the canopy species listed in the key diagnostic characteristics that are typically present, characteristic plant species listed in Table A1 of the Conservation Advice also give more clarification as to the presence of SSTF on site, with the advice that if the total species recorded in a 0.04 hectare survey plot (20 metre x 20 metre) contains a high representation of these distinctive species, there is a strong indication that Shale Sandstone Transition Forest is present. Of all the seven canopy species recorded in all plots, with all plots having five or six canopy species, only one plot had a canopy species not listed as a characteristic plant species in Table A1.
Where present the mid layer of the understorey varies in structure and floristics. Where present, the small tree layer is likely to be dominated by Eucalypt species and *Allocasuarina littoralis* (black she-oak). Where shrubs are present, the mid layer is likely to be dominated by Bursaria spinosa (blackthorn) in areas with low sandstone influence, with other common species including *Leucopogon juniperinus*, *Kunzea ambigua* (tick bush), *Persoonia linearis* (narrow-leaved geebung), *Ozothamnus diosmifolius* (rice flower, sago bush, white dogwood) and Hibbertia aspera (rough guinea flower).	Within two of the three the plots, the small tree layer is dominated by *Allocasuarina torulosa* (a species listed in Table 1A of the Conservation Advice). The shrubs *Persoonia linearis* is present in all three plots. Five other shrub species listed in Table 1A of the Listing Advice also occur in the three plots.
Where present, the ground layer of the understorey is typically diverse and dominated by grasses and herbs including: *Aristida vagans* (three-awned spear grass), *Austrostipa pubescens* (spear grass), *Cheilanthes sieberi* subsp. *sieberi* (poison rock fern), *Dichondra repens* (kidney weed), *Echinopogon ovatus* (forest hedgehog grass), *Entolasia marginata* (bordered panic), *Entolasia stricta* (wiry panic), *Lepidosperma laterale* (saw sedge),	Nine species of groundcover were recorded from the three plots that are listed as characteristic species in Table 1A of the Conservation Advice.

Key diagnostic characteristics for shale/sandstone transition forest of the Sydney Basin Bioregion (EPBC Act) as per 1.5.1 of Approved conservation advice (including listing advice)	Discussion of key diagnostic characteristics present in HN604 of development site
Lomandra multiflora, *Microlaena stipoides* var. *stipoides* (weeping grass), *Oxalis perennans* (wood-sorrel), *Pimelea linifolia* subsp. *linifolia*, *Pomax umbellata*, *Phyllanthus hirtellus*, *Pratia purpurascens* (white root), *Solanum prinophyllum* (forest nightshade) and *Themeda triandra* syn. *T. australis* (kangaroo grass). The ground layer may also contain small shrubs, including Hibbertia aspera (rough guinea flower).	
May contain fauna species presented in Appendix A, Table A2 if the Listing Advice.	Noted but not considered in detail here.

Two 20-metre x 20-metre plots were carried out in HN604 within the development site, with a third plot carried out just outside the development site in the same contiguous polygon of this PCT. Within these three plots, species listed as characteristic species of SSTF (EPBC Act) as per the Conservation Advice include:

- Plot US3 had 18 SSTF characteristic species of a total 35 species identified in that plot (51 percent characteristic species).
- Plot US4 had 18 SSTF characteristic species of a total 44 species identified in that plot (41 percent characteristic species).
- Plot US5 had 15 SSTF characteristic species of a total 51 species identified in that plot (29 percent characteristic species).

In addition to the key diagnostic characteristics discussed above, condition thresholds have been considered in order to identifying the mapped extent of HN604 as SSTF (EPBC Act). The entire extent of HN604 mapped within the development site is itself 4.88 hectares and is part of a single patch that extends outside the development site. This patch is made up of more than 70 percent native species in the perennial understorey layer and is contiguous with a native vegetation remnant greater than one hectare in area. All of these factors mean the HN604 in the development site and study area meet the 'high' condition class as described in Section 1.5.2 of the Conservation Advice.

The extent of HN604 mapped by the current study has been found to conform to SSTF (as listed on the EPBC Act) due to species abundance, cover and richness of characteristic species listed in the Conservation Advice for SSTF, and the condition thresholds being met.

4.4.2.2 Sydney Turpentine-Ironbark Forest

Sydney Turpentine-Ironbark Forest under the BC Act

The Final Determination notes that Sydney Turpentine-Ironbark Forest (STIF) occurs within the Sydney Basin Bioregion, which is the 'particular area' as per section 1.6 of the BC Act. The development site is in the Sydney Basin Bioregion. The Final Determination for STIF states that it *'occurs within the local government areas of Ashfield, Auburn, Canterbury, Concord, Drummoyne, Leichhardt, Marrickville, Bankstown, Ryde, Hunters Hill, Baulkham Hills, Ku-ring-gai, Hornsby, Parramatta, Bankstown, Rockdale, Kogarah, Hurstville and Sutherland. The area is within the County of Cumberland and entirely within the Sydney Basin Bioregion'*. While the definition of STIF seems relatively well defined in terms of its particular area, the *Guidelines for interpreting listing criteria for species, populations, and ecological communities under the NSW Biodiversity Conservation Act 2016* (NSW Threatened Species Scientific Committee 2018) states that 'particular area' is defined by one of more bioregions, and that information referring to LGAs was not intended to be exhaustive for the purposes of defining a threatened ecological community. Consequently, the occurrence of HN604 within the Wollondilly LGA does not preclude the community to conforming to the Final Determination of STIF.

Three plots were carried within HN604 for the purposes of this assessment. Within these three plots, species listed as characteristic species of STIF as per the NSW Scientific Committee's Final Determination include:

- Plot US3 had 14 STIF characteristic species of a total 35 species identified in that plot (40 percent characteristic species).

- Plot US4 had 17 SSTF characteristic species of a total 44 species identified in that plot (39 percent characteristic species).
- Plot US5 had 14 SSTF characteristic species of a total 51 species identified in that plot (29 percent characteristic species).

Across all three plots carried out within HN604 24 STIF characteristic species were recorded. This represents 32 percent of the 76 species described as characteristic within the Final Determination for STIF. However, the dominant species in terms of abundance, cover and/or biomass, both within the plots and across the wider occurrence of the PCT, are not representative of the assemblage detailed in the Final Determination. Specifically, the Final Determination lists six characteristic tree species in STIF (*Syncarpia glomulifera*, *Eucalyptus globoidea*, *Eucalyptus resinifera*, *Eucalyptus paniculata*, *Angophora costata*, and *Angophora floribunda*) of which three occur within the patch of HN604. With the exception of *Angophora costata* which is co-dominant with *Eucalypts pilularis* across the PCT, *Syncarpia glomulifera* generally occurs as small trees below the canopy, with an average cover of nine percent across the three plots. This pattern of occurrence was representative of the rest of HN604 within the development site. *Eucalyptus resinifera* occurs uncommonly. Tozer (2003) describes Turpentine Ironbark Forest and Turpentine Ironbark Margin Forest (two component communities of STIF) as being dominated by *Syncarpia glomulifera*, with *Eucalyptus paniculata*, *Eucalyptus eugenioides*, and *Eucalyptus punctata* occurring less frequently. The absence of *Syncarpia glomulifera* within the canopy of HN604 indicates that the patch within the development site does necessarily meet the structural and floristic definitions of STIF.

The nearest extent of STIF is mapped by OEH (2015) as approximately five kilometres to the north east and south west.

The Final Determination for STIF states that the EEC typically occurs within areas of clay soil derived from Wianamatta shale or shale layers within Hawksbury Sandstone. As discussed in Section 4.4.2.1, it is presumed that the clay component is most likely to be autochthonous to the parent geology within HN604, including the matrix of the sandstone and any shale lenses within the Hawkesbury sandstone, and unlikely derived from Wianamatta Shale.

In considering the definition of STIF in line with the Final Determination, the assessment has found that the extent of HN604 within the development site does not meet the required structural and floristic definitions of STIF. Specifically,

- *Syncarpia glomulifera* is not present within the canopy and comprises a small proportion of the cover within the PCT.
- Ironbark species occur at low abundance within the extent of HN604.

Turpentine-Ironbark Forest under the EPBC Act

The approved conservation advice (including listing advice) for Turpentine-Ironbark Forest in the Sydney Basin Bioregion listed under the EPBC Act identifies key diagnostic characteristics, and how these relate to HN604 on site are detailed in Table 4-6. The EPBC listing includes two communities listed under the BC Act:

- STIF.
- Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion.

Table 4-6. Key diagnostic characteristics of Turpentine-Ironbark Forest (EPBC Act)

Key diagnostic characteristics for Turpentine-Ironbark Forest of the Sydney Basin Bioregion (EPBC Act) as per approved conservation advice (including listing advice)	Discussion of key diagnostic characteristics present in HN604 of development site
Limited to the Sydney Basin Bioregion (IBRA v7).	The mapped extent of HN604 in the development site is within the Sydney Basin.
Occurs primarily on clay soils derived from Wianamatta shale, including clay lenses of Wianamatta shale within Hawkesbury sandstone. The ecological community less commonly occurs on transitional areas between soils derived from the Wianamatta shale and Hawkesbury sandstone, or on soils derived from Holocene alluvium, or the Mittagong formation.	Occurs near the transition between shales and sandstones of the Wianamatta and Hawkesbury Groups. The soil landscapes mapped by eSPADE identify the residual and colluvial parent geology as Hawkesbury, with a presumed low likelihood of Wianamatta shale influence, with observed clay component of soils presumed to be derived from inherent clay laminates within the parent geology.
Occurs as forest or woodland, and may have a primarily shrubby or primarily grassy understorey	Occurs as a forest to woodland.

Key diagnostic characteristics for Turpentine-Ironbark Forest of the Sydney Basin Bioregion (EPBC Act) as per approved conservation advice (including listing advice)	Discussion of key diagnostic characteristics present in HN604 of development site
Tree canopy: Turpentine (*Syncarpia glomulifera*) and Ironbarks (*Eucalyptus* spp) are dominant. Turpentine occurs throughout the ecological community, but the associated tree species varies with local abiotic conditions.	*Syncarpia glomulifera* and at least one ironbark species was observed within and adjacent to the PCT mapped within the development site, however both were sub-dominant within the PCT.
Midstorey: A stratum of small trees may occur, including *Pittosporum undulatum*, *Trema aspera*, and *Acacia parramattensis*. Where present, a shrub layer may include *Polyscias sambucifolia*, *Notelaea longifolia*, *Leucopogon juniperinus*, *Pittosporum revolutum*, *Breynia oblongifolia*, *Maytenus silvestris* and *Ozothamnus diosmifolius*.	*Pittosporum revolutum* was recorded within two of the three the plots. *Breynia oblongifolia* and *Notelaea longifolia* were recorded within one plot. The other species listed within the listing description were not recorded.
Ground layer: Where present in its natural state, the ground layer may include *Oplismenus aemulus*, *Pseuderanthemum variabile*, *Echinopogon ovatus Microlaena stipoides* and *Themeda triandra*.	One only species on the key diagnostics list, *Oplismenus aemulus,* was recorded within the PCT.

Two 20-metre x 20-metre plots were carried out in HN604 within the development site, with a third plot carried out just outside the development site in the same contiguous polygon of this PCT. Within these three plots, species listed as characteristic species of turpentine-ironbark forest as per the Listing Advice include:

- Plot US3 had 3 turpentine-ironbark forest characteristic species of a total 35 species identified in that plot (8 percent characteristic species)
- Plot US4 had 2 turpentine-ironbark forest characteristic species of a total 44 species identified in that plot (5 percent characteristic species)
- Plot US5 had 2 SSTF characteristic species of a total 51 species identified in that plot (5 percent characteristic species).

The extent of HN604 occurring within the development site does not to turpentine-ironbark forest due to the sub-dominance of *Syncarpia glomulifera* within the PCT, and the absence of other characteristic species listed in the Listing Advice for Turpentine-Ironbark Forest.

4.4.2.3 Blue Mountains Shale Cap Forest

Blue Mountains Shale Cap Forest under the Biodiversity Conservation Act

Two 20-metre x 20-metre plots were carried out in HN604 within the development site, with a third plot carried out approximately 10 metres outside the development site in the same contiguous polygon of this PCT. Within these three plots, species listed as characteristic species of Blue Mountains Shale Cap Forest as per the NSW Scientific Committee's Final Determination include:

- Plot US3 had 17 Blue Mountains Shale Cap Forest characteristic species of a total 35 species identified in that plot (48 percent characteristic species)
- Plot US4 had 23 Blue Mountains Shale Cap Forest characteristic species of a total 44 species identified in that plot (52 percent characteristic species)
- Plot US5 had 18 Blue Mountains Shale Cap Forest characteristic species of a total 51 species identified in that plot (32 percent characteristic species).

Across all three plots carried out within HN604, 31 Blue Mountains Shale Cap Forest characteristic species were recorded. This represents 40 percent of the 76 species described as characteristic within the Final Determination for Blue Mountains Shale Cap Forest.

The Final Determination lists three characteristic species for Blue Mountains Shale Cap Forest (*Eucalyptus deanei*, *Eucalyptus cypellocarpa*, *Syncarpia glomulifera*). Of these, *Syncarpia glomulifera* generally occurs as small trees below the canopy, with an average cover of nine percent across the three plots. This pattern of occurrence was representative of the rest of HN604 within the development site. *Eucalyptus deanei* was present within the occurrence of the PCT, at lower and more sheltered locations. The Final Determination also lists other tree species associated with the TEC (*Angophora costata*, *Angophora floribunda*, *Eucalyptus notabilis*, *Eucalyptus piperita*, and *Eucalyptus punctata*). Of these, both *Angophora costata* and *Eucalyptus punctata* occurred within the PCT.

Structurally, the extent of HN604 is generally as intact forest, with all vegetation layers generally present. This is consistent with the description within the Final Determination, although the determination also notes that Blue Mountains shale cap forest can also exist as woodland or groups of remnant trees as a result of past disturbance.

The Final Determination notes that Blue Mountains Shale Cap Forest occurs within the Sydney Basin Bioregion, which is the 'particular area' as per section 1.6 of the BC Act. The development site is within the Sydney Basin Bioregion.

eSPADE v2.0 (OEH, 2019d), maps the areas of HN604 within the development site as Hawkesbury and Faulconbridge soil landscapes. A description of the soil landscapes can be found in in Section 4.4.2.1.

The Final Determination for Blue Mountains Shale Cap Forest notes that the EEC is found on deep fertile Wianamatta shale soils. The soils present within the development site were identified as having both sand and clay components. The topography of the development site, including presence of sandstone rock outcropping within HN604 are not consistent with deep Wianamatta shale soils. While there are extents of the Blacktown soil landscape in the locality, they are separated from PCT 1281/HN604 in the development site by the Warragamba River to the south-east and the Nepean River to the north-east.

In considering the definition of Blue Mountains Shale Cap Forest in line with the Final Determination, the assessment has found that the extent of HN604 within the development site does not meet the required structural and floristic definitions of Blue Mountains Shale Cap Forest. Specifically:

- The characteristic tree species occurred only occasionally within the PCT, with *Syncarpia glomulifera* and *Eucalyptus deanei* comprising a small proportion of the cover within the PCT
- The soils identified within the PCT were not consistent with the presence of deep fertile Wianamatta Shale soils as described within the Scientific Determination.

4.4.3 Description of plant community types within the development site

HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion

Photograph 4-1. Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion Plot US37

Photograph 4-2. Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion Plot US11

HN564 was recorded occurring on both sides of the Warragamba Gorge where it was found on moderately exposed, sloping sandstone terrain. This community was confirmed within the development site as occurring on sandy-clay soils. This PCT is equivalent to 'MU27 Burragorang Sandstone Dry Shrub Forest' within NPWS (2003) and 'DSF p146: Sydney Hinterland Transition Woodland' in Tozer *et al*. (2010).

This community is a dry sclerophyll woodland with a shrubby, open understorey. The canopy has been described in NPWS (2003) as consisting of *Eucalyptus punctata, Angophora costata, Syncarpia glomulifera* subsp. *glomulifera* and *Corymbia gummifera*, growing to a mean height of 20 metres. SMEC surveys found these species as occurring within the development site, as well as *Corymbia eximia* and *Eucalyptus pilularis*. The recorded shrub layer was comprised of *Persoonia linearis, Grevillea mucronulata, Acacia linifolia, Dodonaea triquetra, Leptospermum trinervium* and *Banksia spinulosa* var. *spinulosa*. A diverse ground cover occurs throughout the surveyed areas of this community including *Pomax umbellata, Entolasia stricta, Lepidosperma laterale, Xanthorrhoea media, Lomandra longifolia* and *Cyathochaeta diandra*.

This PCT is almost entirely weed free and occurs within the development site as one condition class (Moderate/Good).

HN566: Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion

Photograph 4-3. Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion Plot US10	*Photograph 4-4. Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion Plot US10*
	

HN566 occurs on ridgetops and upper valley slopes. The community consists of a low eucalypt forest characterised by a sclerophyll shrub layer and a sparse groundcover of sedges. The composition of the PCT throughout its range may vary between sites depending on the level of exposure, elevation, and parent geology. This PCT is broadly equivalent to 'MU41 Exposed Burragorang Sandstone Shrub Woodland' and 'MU42 Rocky Sandstone Heath Woodland' within NPWS (2003) and 'DSF p131 Coastal Sandstone Ridgetop Woodland' in Tozer *et al* (2010).

The extent of this community across the development site includes ridgetops on skeletal soils, primarily within the north and south west of the development site. The canopy within the development site is made up of *Corymbia gummifera, Eucalyptus piperita, Corymbia eximia, Angophora costata,* and *Eucalyptus eugenioides*. The midstorey consisted of a diverse range of species including *Allocasuarina littoralis*, *Leptospermum trinervium*, *Banksia serrata*, *Banksia spinulosa*, and *Xylomelum pyriforme*. The groundcover extent and diversity within the development site is variable across the area, dependent upon seral stage and fire frequency. The stratum is comprised of a mixture of sclerophyllous shrubs, grasses, forbs, and graminoids including *Xanthorrhoea arborea*, *Xanthosia pilosa*, *Dillwynia retorta*, *Caustis flexuosa*, *Dianella caerulea*, *Entolasia stricta*, and various *Lomandra* species.

Much of this PCT was burnt during a prescribed burn in early 2018. In these areas, the PCT was identified based on broadscale vegetation mapping and identification of remaining canopy trees.

This PCT is almost entirely weed free and occurs within the development site as one condition class (Moderate/Good).

HN568: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion

Photograph 4-5. Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion Plot US9

HN568 has been mapped by SMEC in a number of isolated pockets within the development site. HN568 occurs as an open forest on sandy loams that have accumulated adjacent to sandstone ridges and outcrops. This PCT is broadly equivalent to 'MU25 Blue Mountains Sandstone Dry Shrub Forest' and 'MU26 Nattai Sandstone Dry Shrub Forest' within NPWS (2003). Within Tozer *et al*. (2010) it is equivalent to 'DSF p144: Wingecarribee-Burragorang Sandstone Forest'.

Within the development site, the canopy of this community is open and between 15 and 25 metres tall, consisting of species such as *Corymbia gummifera*, *Corymbia eximia*, *Angophora costata* and *Syncarpia glomulifera* subsp. *glomulifera* and stringybark species such as *Eucalyptus eugenioides*. The shrub layer contained species such as *Persoonia linearis*, *Banksia spinulosa*, *Boronia ledifolia*, *Lomatia silaifolia* and *Lambertia formosa*. A patchy yet diverse ground cover occurs throughout the community comprising of species such as *Lomandra obliqua*, *Lomandra multiflora*, *Xanthorrhoea media*, *Cyathochaeta diandra* and *Patersonia glabrata*.

This PCT is almost entirely weed free and occurs within the development site as one condition class (Moderate/Good).

HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion

Photograph 4-6. Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion US3	*Photograph 4-7. Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion US4*
	

HN604 occurs in the north of the development site, immediately north-east of the dam wall. The community occurs on sandy-clay soil, thus the floristic composition of the PCT is transitional with a mix of species typical of both sandstone and clay soils. This PCT is equivalent to MU22 Oakdale Blackbutt Gully Forest in NPWS (2003).

Within the development site, the canopy of this PCT is dominated by *Eucalyptus pilularis* and *Eucalyptus punctata*, with *Syncarpia glomulifera* subsp. *glomulifera*, *Angophora costata*, *Corymbia eximia* common throughout the area. *Eucalyptus deanei*, *Eucalyptus sieberi*, and *Eucalyptus fibrosa* occur occasionally. The midstorey is comprised of *Allocasuarina torulosa*, *Syncarpia glomulifera* subsp. *glomulifera*, *Xylomelum pyriforme*, *Persoonia linearis*, and *Acacia prominens*. The understorey contains a mixture of shrubs, grasses, and graminoids including *Grevillea mucronulata*, *Breynia oblongifolia, Lomatia silaifolia*, *Banksia spinulosa*, *Lepidosperma laterale*, *Dianella longifolia*, *Cyathochaeta diandra*, *Entolasia stricta*, *Microlaena stipoides* var. *stipoides*, and *Pteridium esculentum*.

This PCT is almost entirely weed free and occurs within the development site as one condition class (Moderate/Good).

4.5 Vegetation zones

All of the PCTs identified within the development site were assessed as being in Moderate/Good condition in line with the broad condition definitions outlined in the FBA. Three of the four PCTs were assessed as being within one broad condition state and consisted of largely homogenous tracts of vegetation. Thus, they have been included within their own distinct vegetation zone (one vegetation zone per PCT). The other PCT consisted of two varying condition classes and was thus split into two vegetation zones. Hence, a total of five vegetation zones were identified within the development site. A summary of the vegetation zones within the development site is provided in Table 4-7 and their distribution is shown in Figure 4-4.

Each vegetation zone was assessed using plot and transect surveys to determine the site value score. Plot and transect data collected from the vegetation zones are provided in Appendix C . The calculated site value score for each of the vegetation zones identified within the development site is shown in Table 4-7. All vegetation zones within the development site have a calculated site value score greater than 17 and therefore required further assessment.

Table 4-7. Vegetation zones within development site

Vegetation zone	PCT name	Condition	Area in development site (ha)	Area in development footprint (ha)	Site value score	Patch size (ha)
1	HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate/ Good	14.11	0.31	60.63	>1,000
2	HN566: Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Moderate/ Good	24.78	12.25	77.08	>1000
3	HN568: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Moderate/ Good	8.61	5.77	91.06	>1,000
4	HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Moderate/ Good	4.88	1.64	60.14	>1,000
5	HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate/ Good_poor	2.85	2.45	30.68	>1,000

Figure 4-4. Vegetation zones within the development site

4.6 Groundwater dependent ecosystems

Groundwater dependent ecosystems (GDEs) were initially identified by reviewing the Groundwater Dependent Ecosystem Atlas (BOM, 2019) for the development site. Each GDE is classified as having a high, moderate or low potential of interaction with groundwater. Five GDEs were identified within the development site, all within the Greater Metropolitan Region Groundwater Sources – Sydney Basin area, as described in Table 4-8 and shown in Figure 4-5.

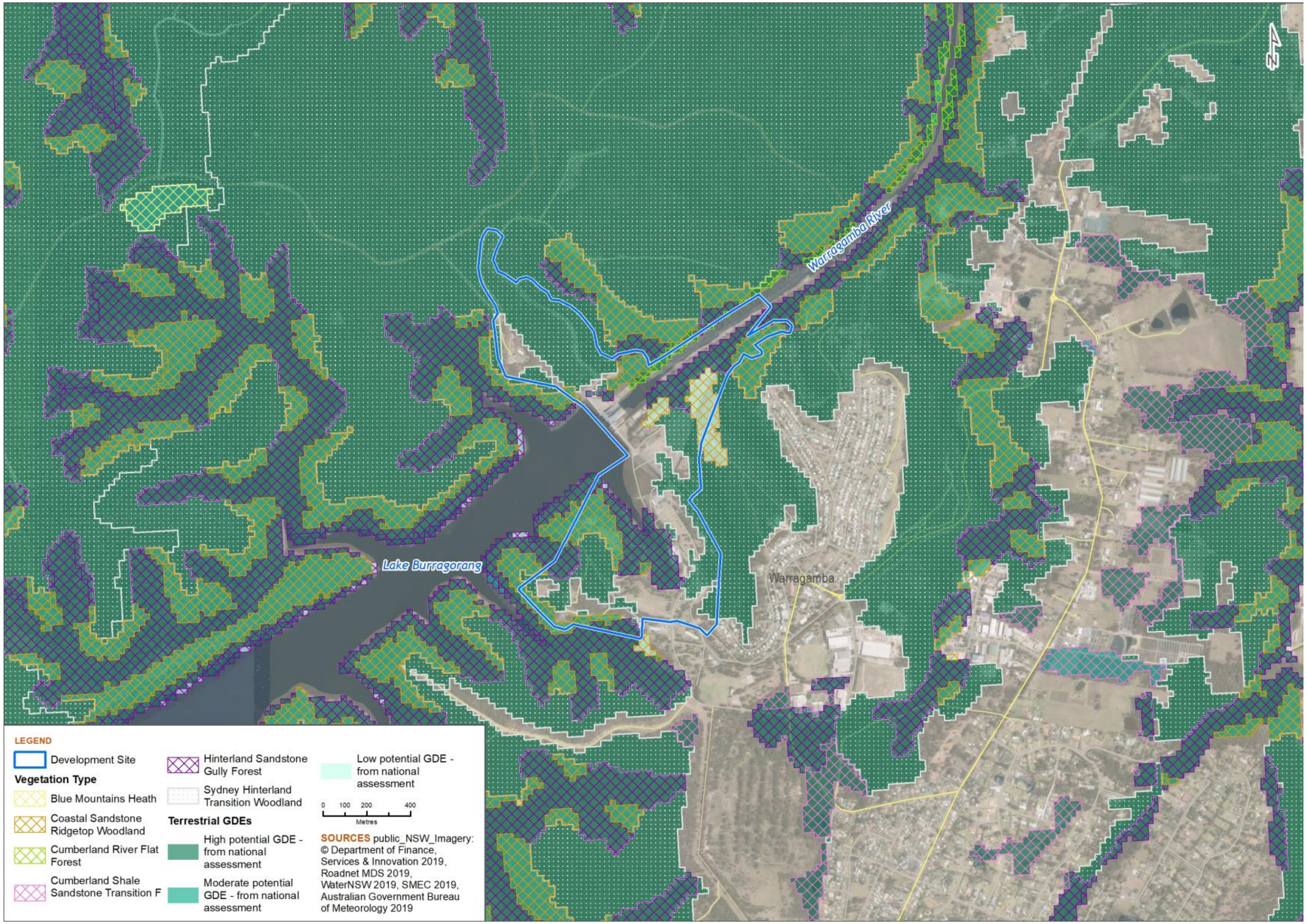
.Table 4-8. Groundwater dependent ecosystems

Vegetation type	Landscape	Bioregion	Land use	Groundwater management area	IDE Likelihood	GDE Classification
Coastal Sandstone Ridgetop Woodland	Low Lying	Wollemi	Forestry	Blue Mountains Sandstone	9	Moderate potential GDE
			Minimal use	Nepean Sandstone	9	Moderate potential GDE
			Other protected areas including Indigenous uses	Nepean Sandstone	9	Moderate potential GDE
			Forestry	Blue Mountains Sandstone	10	Moderate potential GDE
	Plateau	Burragorang	Forestry	Nepean Sandstone	10	Moderate potential GDE
			Minimal use	Nepean Sandstone	9	Moderate potential GDE
	Slope	Wollemi	Other protected areas including Indigenous uses	Nepean Sandstone	7	Low potential GDE
			Forestry	Nepean Sandstone	10	Low potential GDE
			Forestry	Nepean Sandstone	9	Moderate potential GDE
Cumberland River Flat Forest	Low Lying	Wollemi	Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Blue Mountains Sandstone	8	High potential GDE
			Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Blue Mountains Sandstone	9	High potential GDE
Hinterland Sandstone Gully Forest	Low Lying	Wollemi	Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Nepean Sandstone	9	High potential GDE

Vegetation type	Landscape	Bioregion	Land use	Groundwater management area	IDE Likelihood	GDE Classification
			Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Blue Mountains Sandstone	9	High potential GDE
Hinterland Sandstone Gully Forest			Forestry	Blue Mountains Sandstone	9	High potential GDE
	Slope	Wollemi	Forestry	Nepean Sandstone	9	High potential GDE
			Forestry	Nepean Sandstone	2	Low potential GDE
	Plateau	Wollemi	Forestry	Nepean Sandstone	10	High potential GDE
			Forestry	Nepean Sandstone	10	High potential GDE
		Burragorang	Minimal use	Nepean Sandstone	9	High potential GDE
Sydney Hinterland Transition Woodland	Low Lying	Wollemi	Forestry	Blue Mountains Sandstone	9	High potential GDE
			Forestry	Nepean Sandstone	10	High potential GDE
			Forestry	Blue Mountains Sandstone	10	High potential GDE
			Forestry	Blue Mountains Sandstone	9	High potential GDE
	Plateau	Burragorang	Minimal use	Nepean Sandstone	9	Low potential GDE
			Minimal use	Nepean Sandstone	9	High potential GDE
			Minimal use	Nepean Sandstone	9	High potential GDE
			Minimal use	Nepean Sandstone	9	High potential GDE
		Wollemi	Minimal use	Nepean Sandstone	9	High potential GDE
			Forestry	Nepean Sandstone	9	High potential GDE
			Forestry	Nepean Sandstone	9	High potential GDE
	Slope	Wollemi	Forestry	Blue Mountains Sandstone	10	High potential GDE
			Other protected areas including Indigenous uses	Nepean Sandstone	8	High potential GDE

The location of the GDEs identified within the development site is shown in Figure 4.6. The impacts to the PCTs that are identified as GDEs within the development site is assessed in Chapter 7 of this report.

Figure 4-5. Groundwater dependent ecosystems within the development site



5 Threatened species and populations

This section discusses the type and occurrence of threatened species and populations that would be potentially impacted by the construction of the Project.

5.1 Review of existing data

The following primary sources of information were consulted to develop a list of species and populations potentially occurring within the development site:

- BioBanking Credit Calculator (OEH n.d.a)
- Atlas of NSW Wildlife Database (OEH 2017b)
- NSW Threatened Species Profile Database (TSPD) (OEH 2017d)
- Protected Matters Search Tool (DoEE 2015)
- Species Profiles and Threats database (SPRAT) (DoEE n.d.b)
- Warragamba Dam Raising Preliminary Ecological Assessment (BMT WBM Pty Ltd 2016).

Information obtained during the review of existing data was utilised in determining candidate ecosystem credit species and species credit species.

5.2 Ecosystem credit species

5.2.1 Predicted ecosystem credit species

The BBCC generates a list of predicted ecosystem credit species from numerous inputs such as landscape features and the native vegetation communities present. Table 5-1 shows the ecosystem credit species that have the highest Threatened Species Offset Multiplier (TS multiplier) in each vegetation zone. The TS multiplier is applied to Equation 5 of Appendix 1 in the FBA to calculate the number of ecosystem credits required to offset the impact on vegetation that contains threatened species habitat. The TS multiplier equals the multiplicative inverse of the Tg value. The Tg value is defined within the FBA as the ability of a species to respond to improvement in site value or other habitat improvements at a BioBanking site with management actions. The Tg value is based on an assessment of effectiveness of management actions, life history characteristics, naturally rare species, and poorly known species.

Table 5-1. Ecosystem credit species with the highest TS offset multiplier in each vegetation zone

Vegetation zone	Scientific name	Common name	TS offset multiplier
1 (HN564)	*Ninox connivens, Ninox strenua* and *Tyto novaehollandiae*	Barking Owl, Powerful Owl and Masked Owl	3.0
2 (HN566)	*Ninox connivens, Ninox strenua* and *Tyto novaehollandiae*	Barking Owl, Powerful Owl and Masked Owl	3.0
3 (HN568)	*Ninox connivens, Ninox strenua, Tyto novaehollandiae* and *Tyto tenebricosa*	Barking Owl, Powerful Owl, Masked Owl and Sooty Owl	3.0
4 (HN604)	*Ninox connivens, Ninox strenua, Tyto novaehollandiae* and *Tyto tenebricosa*	Barking Owl, Powerful Owl, Masked Owl and Sooty Owl	3.0
5 (HN564)	*Ninox connivens, Ninox strenua* and *Tyto novaehollandiae*	Barking Owl, Powerful Owl and Masked Owl	3.0

The ecosystem credit species applicable to this Project (Table 5-2) have been predicted using the BBCC based on the following criteria:

- IBRA subregions: Wollemi
- Associated PCTs: HN564, HN566, HN568 and HN604
- Percentage native vegetation in outer assessment circle: 75 percent
- Condition of vegetation: moderate to good (all vegetation zones)
- Patch size: 1001+
- Credit type: Ecosystem.

No additional assessment of habitat components for the predicted ecosystem credit species has been undertaken for this assessment.

Table 5-2. Predicted ecosystem credit species

Scientific name	Common name	Tg value	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Ninox connivens	Barking Owl	3.0	✓	✓	✓	✓	✓
Melithreptus gularis subsp. *gularis*	Black-chinned Honeyeater (eastern subspecies)	1.3	✓	✓	-	✓	✓
Climacteris picumnus subsp. *victoriae*	Brown Treecreeper	2.0	✓	✓	✓	-	✓
Stagonopleura guttata	Diamond Firetail	1.3	✓	-	✓	-	✓
Falsistrellus tasmaniensis	Eastern False Pipistrelle	2.2	✓	✓	✓	✓	✓
Micronomus norfolkensis	Eastern Coastal Free-tailed Bat	2.2	✓	✓	✓	✓	✓
Callocephalon fimbriatum	Gang-gang Cockatoo	2.0	✓	✓	✓	✓	✓
Calyptorhynchus lathami	Glossy Black-Cockatoo	1.8	✓	✓	✓	✓	✓
Scoteanax rueppellii	Greater Broad-nosed Bat	2.2	✓	✓	✓	✓	✓
Melanodryas cucullata subsp. *cucullata*	Hooded Robin (south-eastern form)	1.7	✓	✓	✓	✓	✓
Hieraaetus morphnoides	Little Eagle	1.4	✓	✓	✓	✓	✓
Glossopsitta pusilla	Little Lorikeet	1.8	✓	✓	✓	✓	✓
Tyto novaehollandiae	Masked Owl	3.0	✓	✓	✓	✓	✓
Pseudomys novaehollandiae	New Holland Mouse	2.6	✓	✓	✓	✓	✓
Ninox strenua	Powerful Owl	3.0	✓	✓	✓	✓	✓
Petroica boodang	Scarlet Robin	1.3	✓	✓	✓	✓	✓
Tyto tenebricosa	Sooty Owl	3.0	-	-	✓	✓	-
Chthonicola sagittata	Speckled Warbler	2.6	-	-	-	✓	-
Dasyurus maculatus	Spotted-tailed Quoll	2.6	✓	✓	✓	✓	✓
Lophoictinia isura	Square-tailed Kite	1.4	✓	✓	✓	✓	✓
Lathamus discolour	Swift Parrot	1.3	✓	✓	✓	✓	✓
Neophema pulchella	Turquoise Parrot	1.8	✓	✓	✓	✓	✓
Daphoenositta chrysoptera	Varied Sittella	1.3	✓	✓	✓	✓	✓
Petaurus australis	Yellow-bellied Glider	2.3	-	✓	✓	-	-
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	2.2	✓	✓	✓	✓	✓

5.3 Species credit species

5.3.1 Candidate species credit species

Candidate species were identified in accordance with Section 6.5.1.2 of the FBA. The BBCC generates a list of candidate species based on the distribution of the species occurring within the same IBRA subregion as the development site and the presence of habitat features and components associated with these species.

The habitat features and components that have been used to assess presence/absence within the development site are as follows:

- land within 250 metres of termite mounds or rock outcrops
- heath or eucalypt forest on sandstone with a build-up of litter or other debris and containing, or within 40 metres of, ephemeral or intermittent drainage lines
- land containing escarpments, cliffs, caves, deep crevices, old mine shafts or tunnels
- land within 40 metres of heath, woodland or forest
- land within 500 metres of sandstone escarpments with hollow-bearing trees, rock crevices or flat sandstone rocks on exposed cliff edges and sandstone outcropping
- Moist wet forest and rainforest gullies
- land within one kilometre of rock outcrops or cliff lines
- land containing bark or leaf litter accumulation.

Species credit species identified as candidate species through the BBCC are listed in Table 5-3. In addition to these, species credit species have also been included within the list of candidate species if they:

- have been recorded within a 10-kilometre radius of the development site on the Atlas of NSW Wildlife Database.
- ere known or predicted to occur within the IBRA subregions within which the development site is located.
- have been confirmed as occurring within the development site as a result of previous surveys.

The list of candidate species was assessed against the criteria outlined in Section 6.5.1.3 of the FBA in order to determine if the species required further assessment. Species were not considered to require further assessment where:

- a habitat assessment has determined that habitat components required by the species as determined by the TSPD or OEH Threatened Species Profile do not occur, or have been substantially degraded such that the species is unlikely to occur, on the development site
- an expert report has stated that the species is unlikely to occur
- the species is a vagrant species and unlikely to occur within the development site.

Table 5-3. Assessment of potential presence of species credit species

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
FLORA						
Acacia baueri subsp. *aspera*	*Acacia baueri* subsp. *aspera*	BBCC	HN566	N/A	This species occurs in low heathlands, often on exposed rocky outcrops over a wide range of climatic and topographical conditions. Appears to prefer open conditions; rarely observed where there is any shrub or tree canopy development; and many of the observations of this species have been made following fire, suggesting the species prefers early successional habitats. Site contains some suitable habitat present as floristic and structural associations, edaphic and landscape features.	Yes
Acacia bynoeana	Bynoe's Wattle	BBCC SEARs PMST	HN564 HN566 HN568 HN604	N/A	Suitable dry sclerophyll habitat, including floristic and structural associations, occurring on sandy soils is present within the development site. Known from only 30 populations the closest of which is in the Blue Mountains near Hazelbrook. This species could occur in the development site.	Yes
Acacia flocktoniae	Flockton's Wattle	BBCC	HN564 HN568	N/A	Habitat includes dry sclerophyll forest on sandstone which does occur in the development site. The nearest records of this species are west of Lake Burragorang near Yerranderie. The development site contains some suitable habitat present as floristic and structural associations, edaphic and landscape features. This species has the potential to occur in the development site.	Yes
Acacia gordonii	*Acacia gordonii*	BBCC SEARs	HN566	N/A	Rock platforms habitat within dry sclerophyll forest occurs in the development site. The closest recorded individual is near Springwood. Site contains some suitable habitat present as floristic and structural associations, edaphic and landscape features.	Yes
Acacia pubescens	Downy Wattle	BBCC SEARs	HN566 HN568 HN604	N/A	Suitable habitat includes shales, alluviums and the intergrades between shales and sandstone. The closest recorded populations are near Kemps Creek on the Cumberland Plain and near Oakdale. The development site contains some suitable habitat present as floristic and structural associations, edaphic and landscape features.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Acrophyllum australe	*Acrophyllum australe*	SEARs	HN566	Land containing sheltered gullies beneath waterfalls or drip zones of rock overhangs/cliff faces	Suitable habitat for this species includes sheltered gullies beneath waterfalls and drip zones of rock overhangs and cliff faces, typically where there is a constant source of water. It is generally associated with *Callicoma serratifolia*, *Dracophyllum secundum*, *Todea barbata*, *Alania endlicheri* and *Blechnum ambiguum*. The development site does not contain suitable edaphic or landscape features, or floristic associations for this species.	No
Allocasuarina glareicola	*Allocasuarina glareicola*	PMST SEARs	HN564	N/A	The species is found in open woodland, typically growing with *Eucalyptus parramattensis*, *Eucalyptus fibrosa*, *Angophora bakeri*, *Eucalyptus sclerophylla* and *Melaleuca decora* on lateritic soils. The development site does not contain suitable edaphic or landscape features, or floristic associations for this species.	No
Ancistrachne maidenii	*Ancistrachne maidenii*	BBCC NSW Atlas SEARs	HN564 HN566	N/A	Species known from St Albans - Mt White - Maroota - Berowra areas on transitional soils, and from a recent record along Erskine Creek near the development site. The development site contains associated PCTs and transitional soils, consistent with suitable habitat for the species.	Yes
Asterolasia elegans	*Asterolasia elegans*	PMST SEARs	HN564 HN566	N/A	Species occurs on Hawkesbury Sandstone in sheltered forests on mid- to lower slopes and valleys, e.g. in or adjacent to gullies which support sheltered forest. The canopy at known sites includes *Syncarpia glomulifera* subsp. *glomulifera*), *Angophora costata*, *Eucalyptus piperita*, *Allocasuarina torulosa* and *Ceratopetalum gummiferum*. Ecological knowledge about this species is very limited. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Astrotricha crassifolia	Thick-leaf Star-hair	BBCC	HN566	N/A	Suitable habitat in the form of dry sclerophyll forest on sandstone occurs in the development site. The nearest record is from the Royal National Park however other records have been made from parts of the Sydney Basin that have not been cleared. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Bossiaea oligosperma	Few-seeded Bossiaea	SEARs	N/A	N/A	Limited information on this plant's ecology. Occurs on sandstone slopes or ridges in the Yerranderie area. Occurs in low woodland on loamy soil in the Windellama area. The development site does not contain any of the PCTs, or soil types associated with this species.	No
Caesia parviflora subsp. *parviflora*	Small Pale Grass-lily	BBCC	HN564 HN566	N/A	Suitable habitat in the form of damp places occurring on sandstone that supports open forest (habitat) occur in the development site. This species could potentially occur in the development site.	Yes
Callistemon megalongensis	Megalong Valley Bottlebrush	SEARs	N/A	N/A	Species occurs in shrubby swamp habitat and swamp woodland. Associated species include *Callistemon citrinus*, *Leptospermum morrisonii*, *Leptospermum juniperinum, Leptospermum polygalifolium*, *Leptospermum obovatum*, *Empodisma minus* and *Grevillea aspleniifolia*. The development site does not contain suitable edaphic or landscape features, or floristic associations for this species.	No
Cryptostylis hunteriana	Leafless Tongue-orchid	PMST	HN566	N/A	The species has an extensive distribution and poorly defined habitat preferences. Larger populations typically occur in woodland dominated by *Eucalyptus sclerophylla*, *Corymbia gummifera*, *Eucalyptus sieberi*, and *Allocasuarina littoralis*. These vegetation associations occur within the development site.	Yes
Cynanchum elegans	White-flowered wax plant	SEARs PMST	N/A	N/A	The White-flowered Wax Plant usually occurs on the edge of dry rainforest vegetation. Other associated vegetation types include littoral rainforest; *Leptospermum laevigatum – Banksia integrifolia* subsp. *integrifolia* coastal scrub; *Eucalyptus tereticornis* aligned open forest and woodland; *Corymbia maculata* aligned open forest and woodland; and *Melaleuca armillaris* scrub to open scrub. None of these vegetation associations occur on the development site.	No
Darwinia biflora	*Darwinia biflora*	SEARS	HN564 HN566	N/A	The species occurs on the edges of weathered shale-capped ridges over Hawkesbury sandstone, and is associated with *Eucalyptus haemastoma*, *Corymbia gummifera*, and *Eucalyptus squamosa*. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species. Recent records have been made in the lower Blue Mountains.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Darwinia peduncularis	*Darwinia peduncularis*	BBCC	HN566	N/A	Habitat is comprised of rocky outcrops supporting patches of well-drained sandy soil over sandstone. The nearest record in AVH is approximately 19km to the west near McMahons Point. The development site contains some suitable habitat present as floristic and structural associations, edaphic and landscape features.	Yes
Dillwynia tenuifolia	*Dillwynia tenuifolia*	BBCC NSW Atlas SEARs	HN564 HN566	N/A	Known to be locally abundant within Shale Gravel Transition Forest on laterised clays. The nearest records are from near Glenbrook and Luddenham on the Cumberland Plain. Soil associations include Faulconbridge, Gymea and Hawkesbury soil landscapes. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Epacris purpurascens var. purpurascens	*Epacris purpurascens var. purpurascens*	NSW Atlas SEARs	HN564 HN566	N/A	Found in a range of habitat types, most of which have a strong shale soil influence. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Epacris sparsa	Sparse heath	SEARs	N/A	N/A	Grows in riparian sandstone scrub, where it can be found on the base of cliffs or rock faces, on rock ledges or among rocks in the riparian flood zone. Grows in pockets of damp clay soil, chiefly on south-west facing slopes. The development site does not contain suitable habitat for this species.	No
Eucalyptus aggregata	Black Gum	PMST	N/A	N/A	Grows on alluvial soils, on cold, poorly drained flats and hollows adjacent to creeks and small rivers. Often grows in association with other cold-adapted eucalypts such as *Eucalyptus pauciflora*, *Eucalyptus viminalis*, *Eucalyptus rubida*, *Eucalyptus stellulata* and *Eucalyptus ovata*. The development site does not contain any of the PCTs, or soil types associated with this species.	No
Eucalyptus benthamii	Camden White Gum	NSW Atlas SEARs PMST	N/A	N/A	Occurs on the alluvial flats of the Kedumba and Nepean Rivers and their tributaries. Requires a combination of deep alluvial sands and a flooding regime that permits seedling establishment. The development site does not contain any of the PCTs, or soil types associated with this species.	No

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Genoplesium baueri	Bauer's Midge Orchid	SEARs PMST	HN566	N/A	Occurs in coastal areas. Habitats include heathland, open forest, shrubby forest, heathy forest and woodland with sandy/sandy loam and well-draining soils. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Gentiana wingecarribiensis	Wingecarribee Gentian	SEARs	N/A	N/A	Wingecarribee Gentian grows in bogs, in Sphagnum Moss humps and in sedge communities. Suitable habitat does not occur on the development site.	No
Grammitis stenophylla	Narrow-leaf Finger Fern	N/A	N/A	N/A	High moisture habitat in which this species occurs, such as streams and rainforest gullies, occurs in the development site. This species has been recorded in the Warragamba Gorge immediately outside the development site during the recent surveys.	Yes
Grevillea evansiana	Evan's Grevillea	BBCC	HN566	N/A	This species occurs in dry sclerophyll forest or woodland over Hawkesbury sandstone. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Grevillea juniperina subsp. juniperina	Juniper-Leaved Grevillea	NSW Atlas	N/A	N/A	Grows on reddish clay to sandy soils derived from Wianamatta Shale and Tertiary alluvium (often with shale influence), typically containing lateritic gravels. Vegetation and soil types associated with this species are not present within the development site.	No
Grevillea parviflora subsp. *parviflora*	Small flowered Grevillea	BBCC	HN564 HN566 HN604	N/A	This taxon was recorded in the development site.	Yes
Gyrostemon thesioides	*Gyrostemon thesioides*	SEARs	HN564 HN604	N/A	Grows on hillsides and riverbanks and may be restricted by fine sandy soils. A fire-opportunist, with recruitment occurring from a soil stored seed bank following fire. Associated PCTs occur within the development site.	Yes
Hakea dohertyi	Kowmung hakea	SEARs	N/A	N/A	Confined to a small area in the Kowmung Valley of the Kanangra Boyd National Park along with smaller populations at Lake Burragorang, Tonalli Cove and the Bindook area. Grows in dry sclerophyll forest, usually dominated by grey gum or silvertop ash, with a sparse groundcover and midstorey. No associated PCTs occur within the development site.	No

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Haloragis exalata subsp. exalata	*Square Raspwort*	SEARs PMST	N/A	N/A	Square Raspwort occurs in four widely scattered localities in eastern NSW. It is disjunctly distributed in the Central Coast, South Coast and North Western Slopes botanical subdivisions of NSW. Appears to require protected and shaded damp situations in riparian habitats. Vegetation and soil types associated with this species are not present within the development site.	No
Haloragodendron lucasii	*Haloragodendron lucasii*	BBCC SEARs	HN566	N/A	Suitable habitat (gentle slopes below cliff lines in dry sclerophyll forest) do occur within the development site.	Yes
Hibbertia puberula	*Hibbertia puberula*	BBCC SEARs	HN564 HN566 HN568 HN604	N/A	Suitable dry sclerophyll habitat occurs in the development site. The nearest recorded sightings are from the Penrith/Lapstone area, an area with similar geology and in places topography. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Hygrocybe anomala subsp. *ianthinomarginata*	*Hygrocybe anomala* subsp. *ianthinomarginata*	BBCC	HN566 HN604	N/A	The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Kunzea cambagei	*Cambage kunzea*	SEARs	N/A	N/A	*Kunzea cambagei* mainly occurs in the western and southern parts of the Blue Mountains, NSW, mainly the Yerranderie/Mt Werong area, with four main populations with 20 to 150 individuals. Populations are also located west of Berrima, along the Wingecarribee River; Loombah Plateau east of Mount Werong; the Oberon-Colong Stock Route within Kanangra-Boyd National Park (NP); and Wanganderry Plateau within the Nattai NP. Vegetation and soil types associated with this species are not present within the development site.	No
Kunzea rupestris	*Kunzea rupestris*	SEARs	HN564 HN566	Sandstone rock outcrops	Occurs in shallow, sandy, low nutrient soil in depressions on sandstone rock platforms. It is typically found in short to tall shrubland or heathland at altitudes of 50–300 metres. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Lastreopsis hispida	Bristly Shield Fern	BBCC	N/A	Moist wet forest and rainforest gullies.	Suitable wet forest and rainforest gully habitat occurs in the development site. A record of this species has been made beneath the Kedumba Walls in the north of the Warragamba Special Area.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Leucopogon exolasius	Woronora Beard-heath	BBCC	HN564 HN566 HN568	N/A	Suitable habitat for the species, woodland on sandstone habitat occurs in the development site. The closest occurrence is within 25 kilometres of the development site, along the northern extent of the Nattai River. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Leucopogon fletcheri subsp. *fletcheri*	*Leucopogon fletcheri* subsp. *fletcheri*	BBCC	HN564 HN566	N/A	This species occurs in dry eucalypt woodland on clayey lateritic soils on gently sloping terrain along ridges. The closest reliable record of this taxon comes from 20 km to the north at Springwood. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Marsdenia viridiflora subsp. *viridiflora*	*Marsdenia viridiflora R. Br. subsp. viridiflora* population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith Local Government Areas	NSW Atlas SEARs	N/A	N/A	The development site does not occur in the population's associated LGAs.	No
Melaleuca deanei	Deane's Paperbark	BBCC SEARs PMST	HN564 HN566	N/A	Ridgetop woodland occurs in the development site; however this species is predominantly known from the Ku-ring-gai/Berowra and Holsworthy/Wedderburn areas. Isolated observations have been recorded from the Springwood area. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Melaleuca groveana	Grove's Paperbark	BBCC	HN566	N/A	The species grows in heath and shrubland on a variety of substrates including sandstone on rocky outcrops and cliffs. The known southern extent of this species distribution is around the southern edge of the Hunter Valley. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Micromyrtus blakelyi	*Micromyrtus blakelyi*	SEARs	HN564 HN566	N/A	The species is typically associated with heathlands on shallow sandy soils in cracks and depressions of sandstone rock platforms. Its current known extent is restricted to areas north of Sydney, near the Hawkesbury River. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Micromyrtus minutiflora	*Micromyrtus minutiflora*	NSW Atlas SEARs	N/A	N/A	The species habitat includes Castlereagh Scribbly Gum Woodland, Ironbark Forest and Shale/Gravel Transition Forest on tertiary alluvium and consolidated river sediments. Vegetation and soil types associated with this species are not present within the development site.	No
Olearia cordata	*Olearia cordata*	BBCC SEARs	HN564 HN566	N/A	The species grows on dry open sclerophyll forest habitat on sandstone ridges. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Pelargonium sp. Striatellum	*Omeo Storksbill*	SEARs PMST	N/A	N/A	The species has a narrow habitat that is usually just above the high-water level of irregularly inundated or ephemeral lakes, in the transition zone between surrounding grasslands or pasture and the wetland or aquatic communities. Vegetation and soil types associated with this species are not present within the development site.	No
Persicaria elatior	Tall Knotweed	PMST	N/A	N/A	This species occurs in damp places, especially besides streams and lakes, forested wetlands, and can be associated with disturbance. The species is known from the South Coast through to Grafton area.	No
Persoonia acerosa	Needle Geebung	BBCC SEARs PMST	HN566 HN568	N/A	Dry open forest occurring on low nutrient soil occurs in the development site. The only records within 30 km of the development site are from atop the Blue Mountains escarpment. The escarpment habitat supporting the nearest population does not occur in the development site.	Yes
Persoonia hirsuta	Hairy Geebung	BBCC SEARs PMST	HN564 HN566 HN568 HN604	N/A	This species has a large distribution (though scattered) occurring in dry sclerophyll forests on sandstone. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Persoonia nutans	Nodding Geebung	SEARS	N/A	N/A	This species is associated with a variety of vegetation communities occurring on aeolian and alluvial sediments on the Cumberland Plain, and is known to extend onto shale sandstone communities. The development site does not contain the known associated PCTs or soil type.	No
Pimelea curviflora var. curviflora	*Pimelea curviflora var. curviflora*	PMST SEARS	HN564 HN566 HN604	N/A	The species occurs on shale/sandstone soils on ridgetops and upper slopes within woodland. It has a cryptic habitat and can persist as a tuberous root without foliage for an extended period of time after fire. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Pimelea spicata	Spiked Rice-Flower	NSW Atlas SEARs	N/A	N/A	Within both known populations, the species is associated with well-structured clay soils. On Cumberland Plain, the species is associated with Grey Box communities. The development site does not contain the known associated PCTs or soil type.	No
Pomaderris brunnea	Brown Pomaderris	BBCC SEARs PMST	HN564	N/A	This species was recorded around the edge of Lake Burragorang with the exception of the Warragamba Gorge. The species is associated with moist woodland or forest or clay, and on alluvial soils on floodplains and creek lines. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Pterostylis saxicola	Sydney Plains Greenhood	SEARs PMST	HN564 HN566	Typically in shallow/skeletal soils on rock shelves and platforms	The species is described as occurring within sclerophyll forest or woodland on a variety of soil types. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species. An expert report for this species has been provided in Appendix M of this report.	Yes
Pultenaea elusa	*Pultenaea elusa*	SEARS	N/A	N/A	This species has been recorded twice in 1938 as occurring in swamp. The development site does not contain the known associated PCTs or soil type.	No
Pultenaea villifera population in the Blue Mountains Local Government Area	*Pultenaea villifera* population in the Blue Mountains Local Government Area	BBCC	HN564 HN566	N/A	This population is located specifically in the Blue Mountains and Hawkesbury LGAs. The development site is in the Wollondilly LGA.	No

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Pultenaea glabra	Smooth Bush-Pea	BBCC SEARs PMST	HN566 HN568	N/A	Suitable riparian sandstone habitat occurs in the development site. The nearest records have been made in the higher Blue Mountains in the Katoomba-Hazelbrook areas. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Pultenaea parviflora	*Pultenaea parviflora*	NSW Atlas SEARs PMST	HN566	N/A	Species occurs in Castlereagh Ironbark Forest and Shale Gravel Transition Forest on tertiary alluvium or laterised clays. Associated species include, *Eucalyptus fibrosa*, *Eucalyptus globoidea*, *Eucalyptus longifolia*, *Eucalyptus parramattensis, Eucalyptus sclerophylla*. *Eucalyptus sideroxylon* may also be present or co-dominant, with *Melaleuca decora* frequently forming a secondary canopy layer. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Pultenaea sp. Olinda	*Pultenaea sp.* Olinda	BBCC	HN566	N/A	Has only been recorded in a limited area of pagoda rock formation east of Rylstone. These records were taken over 50 km from the development site. The development site contains PCTs associated with the species.	Yes
Rhizanthella slateri	Eastern Australian Underground Orchid	SEARs	N/A	N/A	The habitat requirements of this species area poorly understood making the occurrence of this species in the development site possible.	No
Rhodamnia rubescens	Scrub Turpentine	NSW Atlas	HN604	N/A	Shrub or small tree that occurs within littoral, warm temperate, and subtropical rainforest, and wet sclerophyll forest. The development site contains PCTs associated with the species.	Yes
Syzygium paniculatum	Magenta Lilly Pilly	PMST	HN604	N/A	Generally recorded rainforest close to the coast, however the distribution and ecology of the species is not well understood. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Tetratheca glandulosa	*Tetratheca glandulosa*	BBCC SEARs	HN564 HN566 HN568 HN604	N/A	Shale-sandstone transition habitat occurs in the development site as do associated species such as *Corymbia gummifera, C. eximia* and *Eucalyptus punctata*. This species has the potential to occur in the development site.	Yes
Tetratheca juncea	Black-eyed Susan	SEARS	N/A	N/A	The species occurs in low open forest or woodland on the Awaba soil landscape. The development site does not contain the known associated PCTs or soil type.	No

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Thelymitra kangaloonica	Kangaloon Sun Orchid	PMST	N/A	N/A	The species if found in swamps and sedge lands over grey silty grey loams. The development site does not contain the known associated PCTs or soil type.	No
Thesium australe	Austral toadflax	PMST SEARS	N/A	N/A	Grows in grasslands on coastal headlands, or on grassland and grassy woodland away from the coast. It often grows with *Themeda triandra.* The development site does not contain the known associated PCTs.	No
Velleia perfoliata	*Velleia perfoliata*	BBCC	HN564 HN566	N/A	Occurs in heath and forest on Hawkesbury sandstone shelves, on rocky hill sides, under cliffs or on rocky/sandy soils along tracks and trails. The species is associated with *Angophora bakeri*, *Corymbia eximia*, *Backhousia myrtifolia*, *Eucalyptus sparsifolia*, *Eucalyptus crebra*, *Eucalyptus notabilis*, *Allocasuarina torulosa* and *Leptospermum trinervium*. The development site contains PCTs, specific species associations, and soil type/edaphics associated with this species.	Yes
Zieria involucrata	*Zieria involucrata*	SEARs	N/A	N/A	Occurs within sheltered forests on mid-lower slopes and valleys on Hawkesbury sandstone. It is typically associated with *Syncarpia glomulifera*, *Angophora costata*, *Eucalyptus agglomerata*, and *Allocasuarina torulosa,* however current ecological knowledge is limited. The development site specific species associations, and soil type/edaphics associated with this species.	Yes
Zieria murphyi	Velvet Zieria	BBCC	HN566	N/A	Suitable sheltered gully habitat supporting eucalypt forest occurs in the development site. The development site contains PCTs and soil type/edaphics associated with this species.	Yes
FAUNA						
Anthochaera phrygia	Regent Honeyeater	BBCC NSW Atlas SEARs PMST	HN564 HN566 HN568 HN604	N/A	Dry and open forest habitat with a large number of mature trees occurs in the development site. Additionally, this species was recently recorded on the western side of Lake Burragorang near Tonalli Point.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Aprasia parapulchella	Pink-tailed worm-lizard	SEARS	N/A	Land containing surface rocks (embedded or loose)	The species inhabits sloping, open woodland areas with predominantly native grassy ground layers, particularly those dominated by *Themeda triandra*. It is typically found beneath small, partially embedded rocks and appear to spend considerable time in burrows below these rocks. These habitat features are not found on the development site.	No
Cercartetus nanus	Eastern Pygmy-possum	BBCC	HN564 HN566 HN568 HN604	N/A	This species has been found in a variety of habits from rainforest through to dry sclerophyll forest. Suitable habitat occurs in the development site. It is possible that this species occurs in the development site.	Yes
Chalinolobus dwyeri	Large-eared Pied Bat	BBCC NSW Atlas SEARs PMST	HN564 HN566 HN568 HN604	Land containing escarpments, cliffs, caves, deep crevices, old mine shafts or tunnels.	This taxon was recorded in the development site.	Yes
Heleioporus australiacus	Giant Burrowing Frog	BBCC NSW Atlas SEARs PMST	HN564 HN566 HN568 HN604	Land within 40 m of heath, woodland or forest.	Woodland and dry sclerophyll forest supported by a sandstone geology occurs in the development site. An expert report for this species has been provided in Appendix H of this report.	Yes
Hoplocephalus bungaroides	Broad-headed Snake	BBCC SEARs PMST	HN564 HN566 HN568 HN604	N/A	Sandstone terrain essential for this species occurs in the development site.	Yes
Isoodon obesulus subsp. *obesulus*	Southern Brown Bandicoot (eastern)	BBCC SEARs	HN566	N/A	Marginal habitat occurs in the development site. Open woodland occurs, but its understory is not dominated by heath species.	Yes
Litoria booroolongensis	Booroolong Frog	BBCC	HN564 HN566 HN568	Land within 100 m of stream or creek banks.	The species lives along permanent streams with some fringing vegetation. What would have been considered suitable habitat in the form of the Warragamba River downstream of the Dam Wall has been significantly disturbed. This species is currently only known from western flowing creeks and rivers and so the development site is not considered to be suitable habitat as it is east flowing.	No

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Litoria littlejohni	Littlejohn's Tree frog	SEARs PMST	HN566 HN604	Land within 100 m of permanent rocky streams with thick fringing vegetation.	Non-breeding habitat in the form of woodland with low vegetation and leaf litter occurs in the development site. Suitable rocky breeding stream is not present. An expert report for this species has been provided in Appendix J of this report.	No
Meridolum corneovirens	Cumberland Plain Land Snail	BBCC NSW Atlas	HN604	Land containing bark or leaf litter accumulation.	Is known to occur in Shale Gravel Transition Forest where it will live under bark, leaves, logs and within soil and grassy clump. Such habitat occurs within the development site.	Yes
Mixophyes balbus	Stuttering Frog	BBCC SEARs PMST	HN564 HN568	Rainforest or tall open wet forest with understory and/or leaf litter and within 100 m of streams.	Permanent flowing streams with wet gullies absent from construction area. An expert report for this species has been provided in Appendix K of this report.	No
Mixophyes iteratus	Giant Barred Frog	BBCC	N/A	Land below 1000 m in altitude and within 40 m of rainforest or eucalypt forest with deep leaf litter.	Suitable freshwater streams and deep leaf litter absent from the development site. The species southern extent is listed as Warrimoo, but the species is considered extinct in the Blue Mountains and no records have been obtained there since the 1970s. It has been determined not to be present. An expert report for this species has been provided in Appendix L of this report.	No
Petaurus norfolcensis	Squirrel Glider	BBCC	HN566 HN568 HN604	N/A	Suitable Bloodwood-Blackbutt forest with feed trees and hollows occurs in close proximity to the development site.	Yes
Petrogale penicillata	Brush-tailed Rock-wallaby	BBCC NSW Atlas SEARs PMST	HN566 HN568	Land within 1 km of rock outcrops or cliff lines.	Suitable rocky outcrop and cliff habitat occurs in the development site.	Yes
Phascogale tapoatafa	Brush-tailed Phascogale	BBCC	HN564 HN566 HN604	N/A	Dry sclerophyll forest habitat suitable for this species occurs in the development site. The habitat looks to be marginal, but the species is potentially present.	Yes

Scientific name	Common name	Source	Associated PCTs within site	Required habitat component	Assessment of habitat within the site	Requires further assessment
Phascolarctos cinereus	Koala	BBCC NSW Atlas SEARs PMST	HN564 HN566 HN568 HN604	N/A	Records have been made downstream of the development site near the confluence of the Warragamba and Nepean Rivers. This species has the potential to occur in the development site.	Yes
Planigale maculata	Common Planigale	N/A	N/A	N/A	Recorded as part of the previous EIS assessment.	Yes
Pseudophryne australis	Red-crowned Toadlet	BBCC NSW Atlas	HN564 HN566 HN568	Heath or eucalypt forest on sandstone with a build-up of litter or other debris and containing, or within 40 m of, ephemeral or intermittent drainage lines.	This species was recorded in the development site and extensive areas of suitable sandstone drainage line is present.	Yes
Varanus rosenbergi	Rosenberg's Goanna	BBCC	HN564 HN566 HN568 HN604	Land within 250 m of termite mounds or rock outcrops.	Open forest on sandstone and with termite mounds occurs in the development site, providing suitable breeding and shelter habitat.	Yes

5.4 Impacts on biodiversity requiring further consideration

5.4.1 Impacts on threatened species

The threatened species listed in Table 5-4 was additionally listed as requiring further consideration based on Attachment C to the reissued SEARs.

Table 5-4. Threatened species requiring further consideration

Scientific name	Common name	Associated IBRA subregion	Assessment of habitat within the development site	Requires further assessment
FAUNA				
Epthianura albifrons	White-fronted Chat	Wollemi, Burragorang, Cumberland	Suitable damp, moist, swampy or marshy habitat was not identified within the development site. There are also no records in the locality according to BioNet Atlas of NSW Wildlife Database. Hence it has been determined that the species is unlikely to be occur in the development site.	No

5.4.2 Impacts on endangered populations

The endangered population listed in Table 5-5 was identified in Attachment C to the reissued SEARs as requiring further consideration beyond the FBA assessment.

Table 5-5. Endangered populations requiring further consideration

Scientific name	Common name	Associated IBRA subregion	Assessment of habitat within the development site	Requires further assessment
ENDANGERED POPULATIONS				
Marsdenia viridiflora R. Br. subsp. *viridiflora* population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith LGAs	*Marsdenia viridiflora* R. Br. subsp. *viridiflora* population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith LGAs	Wollemi	The development site is within the Wollondilly LGA which is outside the local government areas of Bankstown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool and Penrith that this population occurs. Therefore, it is not considered to be present in the development site.	No

5.4.3 Impacts on threatened ecological communities

No TECs were listed in Attachment C to the SEARs and therefore no additional TECs require further consideration beyond those determined through the FBA assessment process.

5.4.4 Matters excluded from further consideration

The species, communities and populations listed in Table 5-6 were specifically excluded from further consideration in the SEARs. In accordance with Table 4 of the FBA, these entities have been specifically excluded from further consideration and do not require an offset to be calculated.

Table 5-6. Matters which have been specifically excluded further consideration

Scientific name	Associated IBRA subregion within SEARs	Assessment of habitat within the development site	Requires further assessment
THREATENED ECOLOGICAL COMMUNITY			
Sun Valley Cabbage Gum Forest in the Sydney Basin Bioregion CEEC	Wollemi	This CEEC is dominated by *Eucalyptus amplifolia* with *Eucalyptus eugenioides* as an associated tree. Native understorey species include *Acacia parramattensis*, *Imperata cylindrica*, *Lomandra longifolia* and *Pteridium esculentum*. Approximately 15 ha of CEEC remains within Blue Mountains LGA. Floristic associations in the development site do not generally conform to this community.	No
Cumberland Plain Woodland in the Sydney Basin Bioregion CEEC	Burragorang, Cumberland	A woodland community dominated by *Eucalyptus moluccana* and *Eucalyptus tereticornis*, with *Eucalyptus. crebra*, *Corymbia maculata* and *Eucalyptus eugenioides* occurring less frequently. The shrub layer is dominated by Blackthorn *Bursaria spinosa*, with *Themeda australis Microlaena stipoides* var. *stipoides* abundant in the understorey. Floristic associations and soil types in the development site do not generally conform to this community.	No
Robertson Basalt Tall Open-forest in the Sydney Basin and South Eastern Highlands Bioregions CEEC	Burragorang	A tall forest or woodland with a sparse to moderately dense understorey, and dense herbaceous ground layer. The community is dominated by *Eucalyptus fastigata*, *Eucalyptus viminalis*, *Eucalyptus radiata* and *Eucalyptus cypellocarpa*. *Acacia melanoxylon* is a common small tree species in this community. Common shrubs include *Coprosma quadrifida* and *Senecio linearifolius*. Floristic associations and soil types in the development site do not generally conform to this community.	No
Blue Gum High Forest in the Sydney Basin Bioregion CEEC	Cumberland	A tall and moist open forest dominated by *Eucalyptus saligna* and *Eucalyptus pilularis. Allocasuarina torulosa* and *Angophora costata* also occur. Species adapted to moist habitat such as *Acmena smithii*, *Ficus coronata*, *Calochleana dubia* and *Adiantum aethiopicum* may also occur. Floristic associations and soil types in the development site do not generally conform to this community.	No
Elderslie Banksia Scrub Forest in the Sydney Basin Bioregion CEEC	Cumberland	A scrub community dominated by *Banksia integrifolia* subsp. *integrifolia*. Other canopy species include *Angophora subvelutina*. The shrubby understorey is diverse and includes species that usually occur in sandstone areas, such as *Ricinocarpus pinifolius*, *Pimelea linifolia* subsp. *linifolia* and *Brachyloma daphnoides*. Floristic associations and soil types in the development site do not generally conform to this community.	No

Scientific name	Associated IBRA subregion within SEARs	Assessment of habitat within the development site	Requires further assessment
Shale Sandstone Transition Forest in the Sydney Basin Bioregion CEEC	Cumberland	This CEEC occurs where clay soils from the shale rock intergrade with earthy and sandy soils from sandstone, or where shale caps overlay sandstone. The boundaries are indistinct, and the species composition varies depending on the soil influences. The main tree species include *Eucalyptus tereticornis*, *Eucalyptus punctata*, *Eucalyptus globoidea*, *Eucalyptus eugenioides, Eucalyptus fibrosa* and *Eucalyptus crebra*). Areas of low sandstone influence have an understorey that is closer to Cumberland Plain Woodland. Floristic associations and soil types are present within in the development site. Note this TEC is only excluded from consideration when within Cumberland IBRA subregion.	No further assessment required when within Cumberland IBRA subregion.

5.5 Field surveys

The field survey requirements and effort for this assessment have been carried out as part of the field survey requirements and effort for the upstream assessment. As such, some of the survey effort has been undertaken outside of the development site boundary, within the upstream operational assessment survey area.

5.5.1 Habitat assessment

A general fauna habitat assessment was undertaken within the development site and adjoining land in December 2017. Fauna habitat assessments included consideration of important indicators of habitat condition and complexity including the occurrence of microhabitats such as tree hollows, fallen logs, bush rock and wetland/riparian areas and the presence of mistletoe and flowering trees for nectivorous bird species. Hollows were used as a general indication of habitat quality for arboreal fauna and for hollow dependent birds and bats.

5.5.2 Targeted threatened species surveys

5.5.2.1 Flora

Targeted threatened flora surveys were not completed within the development site, although incidental observations of threatened flora species were recorded using a GPS. Prescribed burns had been carried out within areas of the development site in 2018, preventing targeted surveys within these areas. Furthermore, as a result of the drought conditions, presence was assumed for those threatened flora species that cannot be ruled out as requiring further assessment in line with Section 6.5.1.9 of the FBA.

5.5.2.2 Fauna

General fauna surveys were conducted within the development site over five days and four nights during December 2017. Additional nights were surveyed using cameras (Table 5-7). Fauna field surveys were based on the survey effort recommendations of *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities - Working Draft* (DEC 2004) and relevant Commonwealth survey guidelines. Reference was made to the size of the development site, broad scale vegetation communities and major sampling stratification units. Surveys were undertaken assuming each area of suitable habitat was one stratification unit of less than 50 hectares. A more detailed description of each survey technique is provided below. The locations of threatened fauna surveys are shown in Figure 5-1.

Ultrasonic call detection

Ultrasonic call detectors (SongMeter4BAT ZC/FS, Wildlife Acoustics, USA) were deployed all night (minimum eight hours) for a minimum of two nights per site. Locations were chosen as having suitable flyways to maximise the potential for bat detection. Recorded calls were converted to zero crossing using Kaleidoscope (Version 4.1.0a, Wildlife Acoustics, USA), sorted and sent to Dr Bradley Law (NSW Primary Industries), a recognised expert in this bat call identification, for analysis.

Small-mammal traps

Forty Elliot B-style traps were placed on the ground within suitable habitat. Traps were placed in groups of 10 hidden within vegetation or sheltering material such as logs (as places the target species was likely to move to) and set approximately 10 metres apart. Each hair tube was baited with balls of oats, peanut butter and truffle oil, and dry leaves were adding as nesting material for warmth. Traps were set at dusk and checked at dawn for a total of 160 trap nights of survey effort.

Remote sensing cameras

Ground-dwelling mammals were targeted using infrared motion and heat activated cameras (PC900 Hyperfire, Reconyx, USA). Cameras targeting the Brush-tailed Rock-wallaby were placed beneath sandstone caves/overhangs as the preferred habitat for this species.

Diurnal bird surveys

Dawn and dusk surveys for diurnal birds were carried out by two observers within three hours of sunrise or sunset. Surveys lasted a minimum of 30 minutes and involved a random meander from the start point where suitable habitat occurred within a two-hectare area. Birds were identified visually or aurally through their vocalisations using Morcombe (Cool Ideas LLC 2014) as a reference guide.

Pitfall traps

Four lines of pitfall traps were placed in habitat where the Common Planigale had been previously recorded. Each line consisted of three traps placed five to ten metres apart and connected by a drift fence. Traps were left open for three nights and closed during the day to minimise captures of non-target fauna.

Incidental observations

Any vertebrate fauna species that were otherwise incidentally observed, heard calling, or detected based on tracks or signs were recorded on the total species list for the development site.

Table 5-7. Summary of fauna survey effort

Method	Target species	Dates	Recommended survey effort (for <50 ha)	Actual survey effort
Small-mammal traps	Common Planigale	11-15 December 2017	100 traps nights (over 3-4 nights)	160 trap nights (over 4 nights)
Diurnal bird surveys	Regent Honeyeater	13 December 2017	Minimum 20-minute search	2 hours
Ultrasonic call detection	Large-eared Pied Bat	11-15 December 2017	2 nights	6 nights
Remote sensing cameras	Brush-tailed Rock-wallaby	13 December 2017 - 15 March 2018	100 nights (based on trapping requirements)	184 nights
Pitfall traps	Common Planigale	11-15 December 2017	24 trap nights (over 3-4 nights)	36 trap nights (over 4 nights)

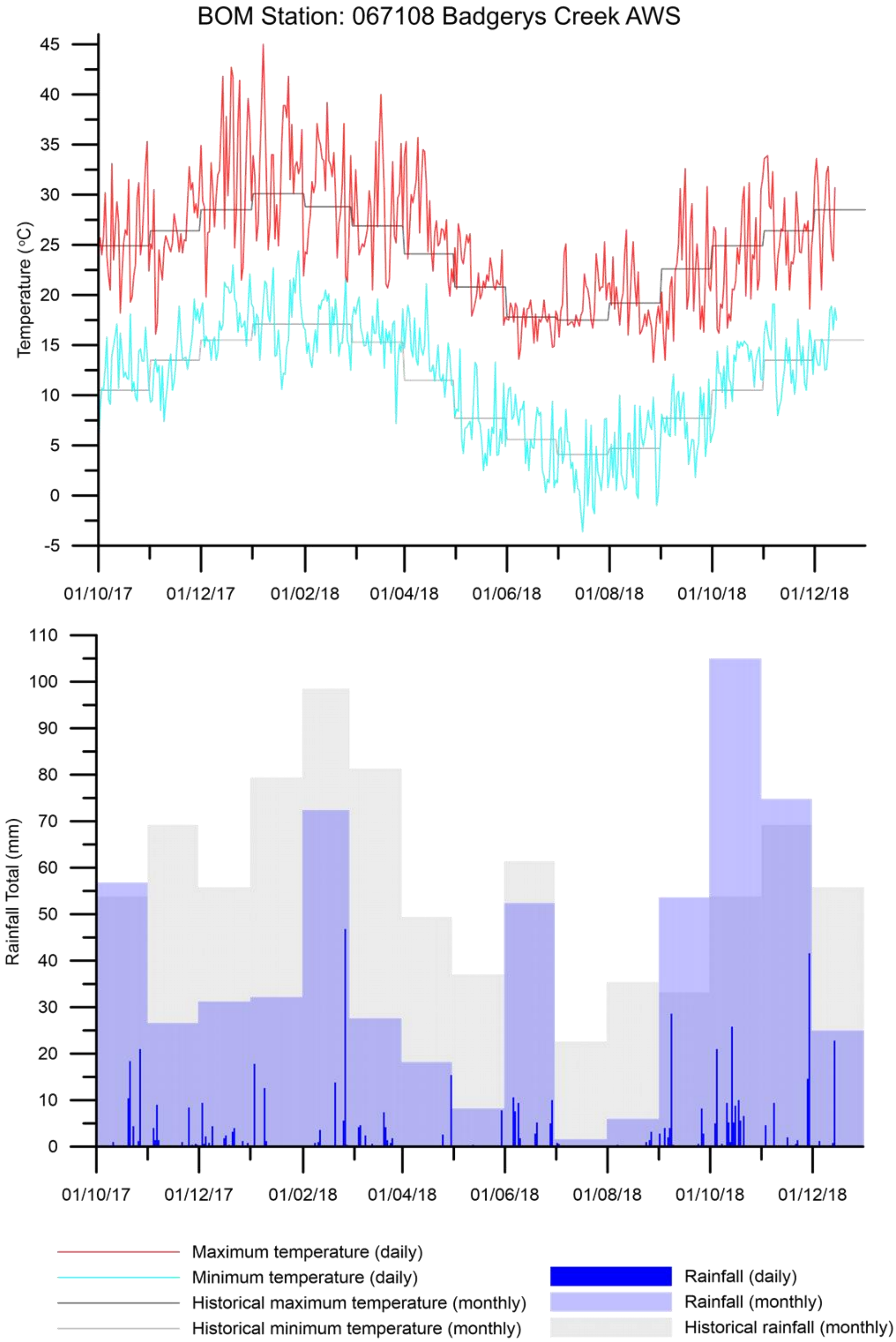
Figure 5-1. Threatened fauna survey locations

5.5.3 Weather conditions

Weather during the period of survey was generally warm and dry with temperatures being above average and rainfall below average.

A summary of the weather conditions during the survey effort is shown in Figure 5-2.

Figure 5-2. Weather conditions during survey period



5.5.4 Survey Limitations

Field surveys were conducted over 94 days and 93 nights in summer 2017-2018, two days in winter 2018 and two days in spring 2018. The field survey requirements and effort for this assessment have been carried out as part of the field survey requirements and effort for the upstream assessment. As such, some of the survey effort has been undertaken outside of the development site boundary, within the upstream biodiversity assessment survey area. In addition to the surveys undertaken, the full spectrum of flora and fauna species and ecological processes likely to occur in the development site were considered by identifying potential habitats for such species and assessing the potential for these species to occur in the development site based on previous records, the type and condition of habitats present, the land use of the development site and its landscape context.

As stated by the DEC (2004) '*The absence of a species from survey data does not necessarily mean it does not inhabit the survey area. It may simply mean that the species was not detected at that time with the survey method adopted and the prevailing seasonal or climatic conditions*'. On this basis, a precautionary approach was used in assessing the potential presence of species and the species was presumed present where survey guidelines had not been met.

The survey was limited at the construction site due to the following constraint:

- Prescribed burns were carried out across areas of the development site prior to vegetation mapping being complete.

Vegetation mapping within these areas has relied on a combination of broadscale vegetation mapping and identification of canopy trees where available.

5.6 Fauna habitats within the development site

Fauna habitats of the development site are assessed in two main categories for the current survey:

- Fauna habitat features and resources at a locality scale which form part of the broader landscape of the development site to a five-kilometre radius
- Site specific fauna habitat features and resources which provide the key elements required by native fauna for the maintenance of life cycles.

Fauna habitats identified in the current survey are discussed below.

5.6.1 Dry sclerophyll forest

The canopy of the dry sclerophyll forest is typically up to 20 metres high and is dominated by Red Bloodwood (*Corymbia gumifera*), Scribbly Gums (*Eucalyptus haemastoma* and *E. racemosa*), Narrow-leaved Stringybark (*E. oblonga*) and Grey Gum (*E. punctata*). The mid-storey includes *Acacia*, *Banksia*, *Persoonia* and *Leptospermum* species.

The flooding of the Burragorang Valley by the construction of Warragamba Dam has resulted in an atypical distribution of habitat that would normally occur around waterways, namely habitat that would usually occur only on ridgetops, occurs close to the surface level of the lake. Dry sclerophyll forest is the most common fauna habitat within the study area, occurring throughout the development site and to the lake edges.

Fallen logs and leaf litter are common. Rocks are abundant throughout this habitat, providing sheltering habitat for small mammals and reptiles. Overhangs and cliffs also provide habitat for microbats. Hollow-bearing trees are present, although likely to occur at a lower abundance due to historical logging. Threatened woodland birds are likely to use this habitat for foraging, nesting and roosting as are hollow roosting microbats.

5.6.2 Wet sclerophyll forest

This tall, open forest occurs in on the western side of the Warragamba River, below the dam wall. The canopy is dominated by Turpentine (*Syncarpia glomulifera*), Grey Gum (*Eucalyptus punctata*), Blackbutt (*E. pilularis*) and Smooth-barked Apple (*Angophora costata*). The mid-storey is open, comprising of shrubs and small trees including Pittosporum, Acacia, Allocasuarina and Leucopogon species. The understorey is formed by a diverse array of shrubs, grasses and graminoids.

Within this habitat, fallen logs, leaf litter and rocks are common. As is the case with other habitats in the development site, hollow-bearing trees are present, although likely to occur at a lower abundance due to historical logging. This vegetation provides suitable nesting, roosting and foraging habitat for threatened woodland birds and foraging and roosting habitat for microchiropteran bats.

5.6.3 Cleared/modified land

Cleared and modified areas provide habitat where scattered canopy trees occur over grassland, including areas used for recreation and areas that have been impacted by construction and operation of the dam and spillway. Trees provide foraging and sheltering habitat for birds and microbats that can occupy disturbed habitat. The Large-eared Pied Bat was detected in modified vegetation near the spillway.

5.6.4 Aquatic habitat

WaterNSW (2015) reports that Lake Burragorang supports an abundance of aquatic flora and fauna. Within the development site, a small, high gradient rocky stream connecting Warragamba River to Lake Burragorang occurs. This stream is important fish habitat, providing the only upstream movement corridor for juvenile eels into Lake Burragorang, as reported in the BMT Aquatic Ecology and Water Quality Report prepared for the EIS. Immediately below the dam, some aquatic vegetation occurs amongst the rocky river bed. Flows are limited by the daily volumes released from the dam.

5.7 Presence of threatened species

5.7.1 Predicted ecosystem credit species

Four ecosystem credit species were recorded within one kilometre of the development site during field surveys completed for the Project (Table 5-8). The locations of these records are shown in Figure 5-1. A full list of fauna species recorded during the survey effort can be found in Appendix E of this report.

Table 5-8. Ecosystem credit species recorded within the development site

Scientific name	Common name	BC Act status[1]	EPBC Act status[2]
FAUNA			
Haliaeetus leucogaster	White-bellied Sea-eagle	V	-
Miniopterus australis	Little Bent-winged Bat*	V	-
Micronomus norfolkensis	Eastern Coastal Free-tailed Bat*	V	-
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	-

[1] BC Act Status: CE Critically Endangered (Schedule 1A); E1 – Endangered (Schedule 1); V – Vulnerable (Schedule 2).

[2] EPBC Act Status: CE – Critically Endangered; E – Endangered; V – Vulnerable

* Breeding habitat listed as species credit, however, no breeding habitat was identified within the development site.

5.7.2 Candidate species credit species

Three species credit species were recorded within the development site during recent field surveys (Table 5-9). The locations of these records are shown in Figure 5-3. The additional species credit species surveyed for (as outlined in Table 5-7) were not recorded as part of the current survey effort.

Table 5-9. Species credit species recorded within the development site

Scientific name	Common name	BC Act status[1]	EPBC Act status[2]
FLORA			
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	V	V
FAUNA			
Chalinolobus dwyeri	Large-eared Pied Bat	V	V
Pseudophryne australis	Red-crowned Toadlet	V	-

[1] BC Act Status: CE Critically Endangered (Schedule 1A); E1 – Endangered (Schedule 1); V – Vulnerable (Schedule 2).

[2] EPBC Act Status: CE – Critically Endangered; E – Endangered; V – Vulnerable

Species assumed as being present on the development site are listed in Table 5-10.

Table 5-10. Species credit species to be assumed present within the development site

Species name	Common name	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
FLORA						
Acacia baueri subsp. *aspera*	*Acacia baueri* subsp. *aspera*	-	✓	-	-	-
Acacia bynoeana	Bynoe's Wattle	✓	✓	✓	✓	-
Acacia flocktoniae	Flockton's Wattle	-	✓	✓	-	-
Acacia gordonii	*Acacia gordonii*	-	✓	-	-	-
Acacia pubescens	Downy Wattle	-	✓	✓	✓	-
Ancistrachne maidenii	*Ancistrachne maidenii*	✓	✓	-	-	-
Asterolasia elegans	*Asterolasia elegans*	✓	✓	-	-	-
Astrotricha crassifolia	Thick-leaf Star-hair	-	✓	-	-	-
Caesia parviflora subsp. *parviflora*	Small Pale Grass-lily	✓	✓	-	-	-
Cryptostylis hunteriana	Leafless Tongue-orchid	-	✓	-	-	-
Darwinia biflora	*Darwinia biflora*	✓	✓	-	-	-
Darwinia peduncularis	*Darwinia peduncularis*	-	✓	-	-	-
Dillwynia tenuifolia	*Dillwynia tenuifolia*	✓	✓	-	-	-
Epacris purpurascens var. purpurascens	*Epacris purpurascens var. purpurascens*	✓	✓	-	-	-
Genoplesium baueri	Bauer's Midge Orchid	-	✓	-	-	-
Grammitis stenophylla	Narrow-leaf Finger Fern	-	-	-	✓	-
Grevillea evansiana	Evan's Grevillea	-	✓	-	-	-
Gyrostemon thesioides	*Gyrostemon thesioides*	✓	-	-	-	-
Haloragodendron lucasii	Hal	-	✓	-	-	-
Hibbertia puberula	*Hibbertia puberula*	✓	✓	✓	✓	-
Hygrocybe anomala subsp. *ianthinomarginata*	*Hygrocybe anomala* subsp. *ianthinomarginata*	-	✓	-	✓	-
Kunzea rupestris	*Kunzea rupestris*	✓	✓	-	-	-
Lastreopsis hispida	Bristly Shield Fern	-	-	-	✓	-
Leucopogon exolasius	Woronora Beard-heath	✓	✓	✓	-	-
Leucopogon fletcheri subsp. *fletcheri*	*Leucopogon fletcheri* subsp. *fletcheri*	✓	✓	-	-	-
Melaleuca deanei	Deane's Paperbark	✓	✓	-	-	-
Melaleuca groveana	Grove's Paperbark	-	✓	-	-	-
Micromyrtus blakelyi	*Micromyrtus blakelyi*	✓	✓	-	-	-
Olearia cordata	*Olearia cordata*	✓	✓	-	-	-
Persoonia acerosa	Needle Geebung	-	✓	✓	-	-
Persoonia hirsuta	Hairy Geebung	✓	✓	✓	✓	-
Pimelea curviflora var. curviflora	*Pimelea curviflora var. curviflora*	✓	✓	-	✓	-

Species name	Common name	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Pomaderris brunnea	Brown Pomaderris	✓	-	-	-	-
Pterostylis saxicola	Sydney Plains Greenhood	✓	✓	-	-	-
Pultenaea glabra	Smooth Bush-Pea	-	✓	✓	-	-
Pultenaea parviflora	*Pultenaea parviflora*	-	✓	-	-	-
Pultenaea sp. Olinda	*Pultenaea sp.* Olinda	-	✓	-	-	-
Rhodamnia rubescens	Scrub Turpentine	-	-	-	✓	-
Syzygium paniculatum	Magenta Lilly Pilly	-	-	-	✓	-
Tetratheca glandulosa	*Tetratheca glandulosa*	✓	✓	✓	✓	-
Velleia perfoliata	*Velleia perfoliata*	✓	✓	-	-	-
Zieria involucrata	*Zieria involucrata*	-	-	-	✓	-
Zieria murphyi	Velvet Zieria	-	✓	-	-	-
FAUNA						
Anthochaera phrygia	Regent Honeyeater	✓	✓	✓	✓	-
Cercartetus nanus	Eastern Pygmy-possum	✓	✓	✓	✓	-
Heleioporus australiacus	Giant Burrowing Frog	✓	✓	✓	✓	-
Hoplocephalus bungaroides	Broad-headed Snake	✓	✓	✓	✓	-
Isoodon obesulus subsp. *obesulus*	Southern Brown Bandicoot (eastern)	-	✓	-	-	-
Meridolum corneovirens	Cumberland Plain Land Snail	-	-	-	✓	-
Petaurus norfolcensis	Squirrel Glider	-	✓	✓	✓	-
Petrogale penicillata	Brush-tail Rock-wallaby	-	✓	✓	-	-
Phascogale tapoatafa	Brush-tailed Phascogale	✓	✓	-	✓	-
Phascolarctos cinereus	Koala	✓	✓	✓	✓	-
Varanus rosenbergi	Rosenberg's Goanna	✓	✓	✓	✓	-

Figure 5-3. Threatened species records

5.8 Biodiversity requiring further consideration

The SEARs provided by OEH required consideration of eight additional threatened entities, one of which were recorded within the development site during the field surveys (refer Table 5-11). The rest are assumed to be present in line with Section 6.5.1.9 of the FBA.

Table 5-11. Biodiversity requiring further consideration recorded within the development site

Species name	Species, population or EEC	BC Act status[1]	EPBC Act status[2]	Included within attachment c of SEARs (Y/N)?	Applicable IBRA subregion (SEARS)	Recorded during current surveys (Y/N)?	Justification for inclusion as matter of further consideration
Ancistrachne maidenii	Species	V	-	Y	Wollemi	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Dillwynia tenuifolia	Species	V	-	Y	Wollemi	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Epacris purpurascens var. *purpurascens*	Species	V	-	Y	Wollemi, Burragorang, Cumberland	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Gyrostemon thesioides	Species	E	-	Y	Burragorang, Cumberland	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Hibbertia puberula	Species	E	-	Y	Wollemi, Burragorang,	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Rhodamnia rubescens	Species	CE	-	N	-	Assumed present	Species is listed as Critically Endangered thus meets the requirements for inclusion as per Section 9.2.4.1 of the FBA.
Tetratheca glandulosa	Species	V	-	Y	Burragorang	Assumed present	Threatened species has been specifically nominated Attachment C of the SEARs.
Shale Sandstone Transition Forest CEEC	TEC	CE	CE	N	Wollemi	Yes	TEC is listed as Critically Endangered thus meets the requirements for inclusion as per Section 9.2.4.1 of the FBA. Note this TEC is only excluded from consideration when within Cumberland IBRA subregion.

[1] BC Act Status: CE Critically Endangered (Schedule 1A); E1 – Endangered (Schedule 1); V – Vulnerable (Schedule 2).

[2] EPBC Act Status: CE – Critically Endangered; E – Endangered; V – Vulnerable.

6 Avoid and minimise impact

This chapter outlines the actions that have been undertaken to demonstrate that reasonable measures have been taken to avoid and minimise the potential direct and indirect impacts of the development Project on biodiversity values.

6.1 Measures to avoid

Chapter 4 of the EIS discusses the proposed options and alternatives that were considered for flood mitigation in the Hawkesbury-Nepean Valley, including:

- infrastructure upgrades to enhance drainage or protect downstream communities
- new flood mitigation dams, including new dams built and operated only for flood mitigation
- operational alternatives using existing infrastructure
- evacuation road upgrades
- non-infrastructure alternatives, such as changes to planning controls, improved flood monitoring and response and better coordination between agencies.
- strategies combining two or more of the above alternatives.

6.1.1 Avoidance of direct impacts

Under the FBA, a proponent must seek to avoid the direct impacts of a Major Project on all biodiversity values at the development site including impacts on:

- endangered ecological communities (EECs) and critically endangered ecological communities (CEECs)
- PCTs that contain threatened species habitat
- areas that contain habitat for vulnerable, endangered or critically endangered threatened species or populations
- an area of land that the Minister for Environment has declared as critical habitat in accordance with section 47 of the TSC Act
- the riparian areas of 4th order or higher streams and rivers, important wetlands and estuaries
- state significant biodiversity links.

Demonstration of these avoidance measures is summarised in Table 6-1.

Table 6-1. Avoidance of direct impacts on biodiversity values at the development site

Direct impacts	Avoidance mechanism proposed
Impacts to endangered ecological communities (EECs) and critically endangered ecological communities (CEECs)	The scale and nature of the development type means that options to avoid impacts to EECs within the development site are very limited. The development site is necessarily tied to the current dam wall and direct impacts resulting from the footprint of any newly built section of dam wall cannot be avoided.
Impacts to PCTs that contain threatened species habitat	Due to the location, size and nature of the development, impacts associated with the dam, including abutments and spillway, cannot be avoided. However, where feasible, ancillaries such as batch plants, laydowns, and worker amenities have been located within areas which do not contain native vegetation or threatened species habitat.
Impacts to areas that contain habitat for vulnerable, endangered or critically endangered threatened species or populations	Due to the location, size and nature of the development, impacts associated with the dam, including abutments and spillway, cannot be avoided. However, where feasible, ancillaries such as batch plants, laydowns, and worker amenities have been located within areas which do not contain native vegetation or threatened species habitat.
Impacts to an area of land that the Minister for Environment has declared as critical habitat in accordance with section 47 of the TSC Act	There are no areas of critical habitat within the development site.

Direct impacts	Avoidance mechanism proposed
Impacts to the riparian areas of 4th order or higher streams and rivers, important wetlands and estuaries	As the Project is situated at Warragamba Dam, and surrounding Lake Burragorang, which is a 9th order stream at that point along its extent. As such, any impacts to the riparian buffers of a 4th order stream or higher cannot be avoided.
Impacts to state significant biodiversity links	There is no record available of any state significant biodiversity link within or adjacent to the development site. No information regarding such links has been provided in the SEARS. It should be noted that in accordance with Appendix 4 of the FBA, the connectivity value class 'State significant biodiversity link' includes impacts to riparian buffers of 6th order stream or higher. The Project will impact upon the riparian buffer of Lake Burragorang, which is a 9th order stream at that point along its extent.

6.1.2 Site selection

The Project is to raise Warragamba Dam. As such, this site is fixed and there are no options for an alternative site.

6.1.3 Incorporating principles of avoidance and minimising Impacts to biodiversity during planning phase

Once a suitable development site was selected, further analysis of the biodiversity constraints of the proposed development site were used to inform concept planning, project siting and design. This includes the proposed location of temporary construction infrastructure such as roads, camps and stockpile sites. All temporary construction works will be located within the development site, so will not have any impacts above and beyond those assessed within this report. Also, the area around the dam where construction facilities are planned have mostly been disturbed during the construction of the dam and the auxiliary spillway.

A summary of considerations during site planning in accordance with Sections 8.3.2.7 and 8.3.2.8 of the FBA is shown in Table 6-2.

Table 6-2. Consideration of the proposed development during site planning

FBA Section	FBA Criteria	Considerations of the FBA guidelines at the site
8.3.2.8 (a)	The Major Project should be located in areas where the native vegetation or threatened species habitat is in the poorest condition, or which avoid an EEC or CEEC	Due to the location, scale and nature of the development, impacts to Shale Sandstone Transition Forest CEEC cannot be avoided. However, ancillary activities such as batch plants, laydowns, and worker amenities have been located within areas which do not contain the CEEC. There will be opportunities to further reduce the impact on the CEEC during detailed design.
8.3.2.8 (b)	The Major Project and associated construction infrastructure should be located in areas that do not have native vegetation, or in areas that require the least amount of vegetation to be cleared, and/or in areas where other impacts to biodiversity will be lowest.	Due to the location, size and nature of the development, impacts associated with the dam, including abutments and spillway, cannot be avoided. However, where feasible, ancillary activities such as batch plants, laydowns, and worker amenities have been located within areas which do not contain native vegetation or threatened species habitat.
8.3.2.8 (c)	Major Projects can impact on the connectivity and movement of species through areas of adjacent habitat. Minimisation measures may include providing structures that allow movement of species across barriers or hostile gaps.	The proposed development will widen a hostile barrier created when the dam wall was built. A drainage line which enable eels to migrate from the base of the dam to Lake Burragorang, to facilitate the movement of this species across the hostile barrier. No additional fauna crossing structures are proposed. The drainage line that provides for eel movement would be reinstated if damaged during construction.
8.3.2.8 (d)	Any other constraints that the assessor has considered in determining the siting and layout of the Major Project.	No additional constraints have been considered. A discussion of Project siting is included within Chapter 4 of the EIS.

6.2 Measures to minimise impacts

The Proponent will implement reasonable measures to avoid and minimise any impacts that may occur during the construction and operational phases of the proposed development, which are additional to the impacts that occurred during the site selection and planning phases. As part of the proposed development, a construction environmental management plan (CEMP) will be prepared, including a flora and fauna management plan (FFMP) that will provide a framework for all biodiversity management and mitigation for the proposed development. The flora and fauna management plan will detail the management requirements for the following:

- vegetation pre-clearance and clearance supervision
- rehabilitation and habitat restoration
- sediment and erosion control
- weed and feral animal management
- required ecological monitoring.

6.2.1 Minimising impacts during construction phase

Consideration has been given to minimising impacts during the construction phase, including:

- method of clearing
- clearing operations protocols
- timing of construction
- other measures that minimise inadvertent impacts of the proposed development on the biodiversity values during the construction phase.

Details of each of these methods are provided in Table 6-3.

In addition to measures proposed to minimise direct impacts to biodiversity, measures proposed to minimise indirect impacts during the construction phase are shown in Table 6-4.

6.2.2 Minimising impacts during operational phase

The matters described in Table 6-5 should be considered to avoid and minimise direct impacts on biodiversity values during the operational phase.

Table 6-3. Considerations to minimise direct impacts of the proposed development during construction

FBA section	FBA criterion	Considerations of the FBA guidelines at the site
8.3.2.10 (a)	Method of clearing – using a method of clearing during the construction phase that avoids damage to retained native vegetation and reduces soil disturbance. For example, removal of native vegetation by chain-saw, rather than heavy machinery, is preferable in situations where partial clearing is proposed	The majority of clearing will be completed by heavy machinery. Chainsaws will be used within 10 metres of clearing boundaries to ensure that damage to retained vegetation and soil disturbance is minimised. Where the presence of fauna is confirmed during additional surveys and pre-clearing surveys the method of clearing will be modified, with the changes detailed in the Flora and Fauna Management Plan. An example would be to use tree climbers to remove detected fauna and so minimise direct impacts to fauna.
8.3.2.10 (b)	Clearing operations – minimising direct harm to native fauna during actual construction operations through onsite measures such as undertaking pre-clearing surveys, daily fauna surveys and the presence of a trained ecologist during clearing events	Following pre-clearing surveys, the direct clearing of vegetation will take place in two stages. During Stage 1 all habitat trees will be marked and left standing, while the vegetation surrounding them would be cleared. This will be followed by an interim period of 24 to 48 hours where the site is left undisturbed to allow any fauna using the hollows to vacate the areas. Stage 2 will occur after the interim period has finished and will involve the felling of the habitat trees. The two-stage clearing process allows for minimised disturbance whilst clearing occurs around habitat trees, and allows fauna a chance to self-relocate upon nightfall, prior to the habitat tree being removed. In areas of mapped frog habitat, the two-stage clearing protocol includes nocturnal active searches and relocating of individuals, followed by active searches the following day before clearing takes place. A licensed wildlife carer and/or ecologist will capture and/or remove fauna that have the potential to be disturbed as a result of clearing activities. Disturbed fauna will be relocated into habitat that has been designated by relevant experts as suitable for release of the captured fauna (not all areas will work for all species). This work will be undertaken by a carer/ecologist with demonstrated previous experience in handling and relocating the fauna likely to be present and must have animal ethics approval to handle and relocate native fauna. Where fauna habitat has been identified, fencing should be installed at the boundary of this habitat and the clearing area to prevent fauna sheltering within the construction area and compounds. An ecologist with demonstrated experience, skill and licensing in relevant fauna handling will also be present during all clearing activities to rescue animals injured during the operation. Any unharmed fauna found will be captured and relocated to nearby remnant vegetation and released (if a nocturnal species) after nightfall and in a suitably sheltered habitat to minimise the risk of predation by diurnal predators. Any animals that are injured will be taken to the nearest prequalified veterinary clinic (to be nominated prior to clearing commencing) for treatment. If assessed by a vet as unlikely to survive, it will be humanely euthanized. Otherwise, once healed, fauna will be released at the nearest suitable location from their capture point, again taking into consideration of the timing of release and the location having suitable cover. All persons working on the vegetation clearing will be briefed about the possible fauna present at the time of construction, and what procedures should be undertaken in the event of an animal being injured or disturbed. This briefing would be included within an induction to be completed before workers commence work on site. Results and outcomes of pre-clearing and clearing fauna surveys shall be documented by the nominated project ecologist and submitted to the proponent. The clearing protocol will be clearly outlined in the FFMP included within the CEMP.

FBA section	FBA criterion	Considerations of the FBA guidelines at the site
8.3.2.10 (c)	Timing of construction – identifying reasonable measures that minimise the impacts on biodiversity. For example, timing construction activities for when migratory species are absent from the site, or when particular species known to or likely to use the habitat on the site are not breeding or nesting, can minimise the impacts of construction activities on biodiversity.	Where feasible, vegetation clearing should be timed to minimise disturbance when fauna is at their most sensitive to disturbance. For most species, this is during breeding season, but it also includes periods of low activity (that is, torpor) for microchiropteran bats. The breeding/low activity seasons of fauna species are outlined below: ▪ Giant Burrowing Frog: most often in late summer or autumn following heavy rains ▪ Red-crowned Toadlet: warmer months, following heavy rains ▪ Dusky Woodswallow: August – January ▪ Gang-Gang Cockatoo: October – January ▪ Glossy Black-cockatoo: March – August ▪ Varied Sittella: September – January ▪ White-bellied Sea-eagle: June – January ▪ Powerful Owl: May – September ▪ Eastern Coastal Free-tailed Bat: July – January ▪ Common Planigale: October – January ▪ Threatened microchiropteran bats: July – August. Given that it is not feasible to avoid breeding seasons for all threatened species recorded within the development site, it is recommended that the majority of clearing is undertaken as far as is practicable in autumn, to minimise impacts on breeding activities of the majority of threatened species. The timing of the vegetation will be clearly detailed within the flora and fauna management plan.
8.3.2.10 (d)	Other measures that minimise inadvertent impacts of the Major Project on the biodiversity values – measures such as installing temporary fencing to protect significant environmental features such as riparian zones, promoting the hygiene of construction vehicles to minimise spread of weeds or pathogens, appropriately training and inducting project staff and contractors so that they can implement all measures that minimise inadvertent adverse impacts of the Major Project on biodiversity values.	Temporary fencing should be installed prior to clearing works to delineate impact from protected areas. The location of temporary fencing and signage will be outlined within the flora and fauna management plan. Nest boxes should be installed to provide short-term replacement for the loss of habitat for displaced hollow-dependent fauna. Nest box requirements are further discussed in Table 6-5. All mobile plant and equipment being brought onto the development site must be inspected and cleaned prior to commencing work to prevent the spread of weeds or pathogens. Training will be undertaken of environmental personnel on the identification of priority weed species for the Greater Sydney region so that the development site can be monitored for the introduction or spread of priority weed species every 12 weeks during April – September and 4 weeks during October - March. Any outbreak of priority weeds will be controlled and eradicated as required under the *Biosecurity Act 2015* by a suitably qualified bush regeneration contractor. Weed management requirements including treatment methods, timing, and monitoring will clearly detailed within the Flora and Fauna Management Plan.

Table 6-4. Considerations to minimise indirect impacts of the proposed development during construction

Indirect impact	Proposed measure to minimise impact
Sedimentation and runoff	Sediment barriers, sedimentation ponds, and detention basins will be incorporated into the project design to protect adjacent waterways from sediment and run-off. This measure will protect surrounding vegetation and the Warragamba, Nepean and Hawkesbury Rivers. Erosion and sediment control measures are to be implemented during the construction phase, would be in accordance with the guidelines set out in the 'Blue Book' (Landcom 2004). The construction contractor should include daily checks of all sediment and erosion controls and their sediment and erosion plan will include additional checks when high rainfall and strong winds are forecast. Sediment and erosion controls would be included in monthly environmental audits for the Project. Specific requirements pertaining to sedimentation and run-off will be included within the CEMP.
Noise, dust or light spill	Where feasible, construction should mitigate for noise and light spill impacts to nocturnal fauna in adjacent vegetation.
Blasting and vibration	Habitats sensitive to vibration such as sandstone rock outcrops should be monitored for deterioration of structural integrity and loss of habitat value. The risk to rock hangs would be identified within the Construction Noise and Vibration Management Plan.
Inadvertent impacts on adjacent habitat or vegetation	Fencing should be erected to delineate the extent of the clearing boundary, development site and protect adjacent vegetation from impacts such as vehicular traffic. Additional fencing and signage should be erected around areas of TECs. Set down areas and lay down areas that are located outside of areas of native vegetation, should be prioritised for use. If vegetation clearing is required, it should be demonstrably minimised.
Pest, weed and/or pathogen encroachment into vegetation on land adjoining the development site	Light vehicles and mobile plant should all be clean when entering the development site to prevent the introduction of pathogens that may impact vegetation outside the development site. Stockpiles will be separated to avoid contamination The CEMP will include reference to guidelines to manage weeds and pathogens that would include, but not be confined to: ▪ Management of *Phytophthora* for biodiversity conservation in Australia: Part 2 - National Best Practice Guidelines (O'Gara et al. 2005) ▪ Hygiene protocol for the control of disease in frogs, Information Circular Number 6 (Wellington and Haering 2008) ▪ Management of Myrtle Rust on national parks estate (OEH 2011) ▪ New South Wales Weed Control Handbook – A guide to weed control in non-crop, aquatic and bushland situations 7th Edition (NSW DPI 2018). A weed management plan for the Project should include progressive weed management and monitoring within the development site and adjacent bushland throughout construction and for a period post-construction, with a particular focus on managing weeds within the threatened ecological communities that occur on adjoining land.

Table 6-5. Considerations to minimise direct impacts of the proposed development during operation

FBA section	FBA criterion	Considerations of the FBA guidelines at the site
8.3.2.12a	Seasonal impacts – whether there are likely to be any impacts that occur during specific seasons. Minimisation measures may include amending operational times to minimise impacts on biodiversity during periods when seasonal events such as breeding, or species migration occur.	The timing and flood mitigation operations of these events will be dependent on dam levels, flow and upstream precipitation.
8.3.2.12b	Artificial habitats – using 'artificial habitats' for fauna where they may be effective in minimising impacts on such fauna. These include nest boxes, glider-crossings or habitat bridges.	Nest boxes are useful in reducing the impact to fauna habitat within the development site. Equivalent nest boxes should be erected for each natural hollow that is removed during the construction phase. Replacement nest boxes should be suitable for all the threatened and non-threatened fauna inhabiting the development site. Nest boxes are to be erected before removal of hollow bearing trees. Prior to vegetation clearing, a nest box plan should be prepared. The nest box plan should sit as a sub-plan within the Flora and Fauna Management Plan. The nest box plan should provide the following details: ▪ the number and size of the hollow bearing trees to be removed as part of the clearing works ▪ the number and types (target species) of boxes required to compensate for the loss of both threatened and protected fauna habitat ▪ specifications of nest box size and material ▪ details for nest box monitoring, maintenance, and replacement. This is particularly important as the life of nest boxes is well below that of the time taken to produce new hollow and a schedule of replacement is required to ensure that the number of hollows available is monitored and maintained. Where feasible replacement habitat should be consistent with existing plans and programs run by WNSW with National Parks and Wildlife Service.
8.4.2.4f	Impacts during the operational phase – measures to avoid or minimise the indirect impacts on threatened species and threatened species habitat on land adjoining the development site, migratory species or flight pathways as a result of the operation of the development. Such measures may include those adopted to avoid and minimise: (i) trampling of threatened flora species (ii) rubbish dumping (iii) noise (iv) light spill (v) weed encroachment (vi) nutrient run-off (vii) increased risk of fire, and (viii) Pest animals.	Signs warning workers of the presence of threatened species and their habitat will be placed in relevant areas of the development site. The proposed development will also have suitable security measures in place to prevent illegal dumping. Noise will be managed onsite in line with the CEMP. No long-term increased light spill is anticipated to result from this Project. There will not be an increased long-term risk of fire as a result of the development. The dam wall will only be raised and so represent the same level of impact as is currently in place. Weed encroachment and nutrient run-off are to be managed through the provisions in the CEMP. The occurrence of feral cats and foxes might increase as a result of the proposed development. A feral animal management plan will be incorporated into the FFMP, which will include fencing, baiting or trapping options for the control of feral animals.

6.3 Summary of measures

Although the Project has sought to avoid and minimise impacts, not all biodiversity impacts can be avoided. The broad sets of measures being provided to minimise impacts are brought together and described in Table 6-6. These will be implemented to mitigate impacts as far as is possible during construction and operation.

Table 6-6. Summary of measures to minimise direct impacts of the proposed development during all phases

Impact	Mitigation measure	Outcome	Timing	Responsibility
General flora and fauna	A flora and fauna management plan (FFMP) would be prepared as part of the CEMP. Native vegetation clearing would not occur until the flora and fauna management plan is approved.	Flora and fauna would be managed in accordance with the requirements of the Flora and Fauna Management Plan	Pre-construction and construction	Proponent and Construction Contractor
	The FFMP would be prepared to manage the vegetation retained within the development site. The plan would include details on weed and pest management, nest boxes and fauna habitat maintenance and monitoring procedures.	The vegetation within the development site surrounding the storage area would be managed in accordance with the FFMP	Pre-construction, construction and post-construction phases	Proponent and Construction Contractor
Degradation of freshwater wetland habitats	Install appropriate drainage infrastructure (for example, sediment basins, diversion drains), sediment and erosion controls prior to the commencement of construction.	Prevention of sedimentation and erosion leading to a reduction in water quality and degradation of aquatic habitats	Pre-construction	Proponent and Construction Contractor
	Clearing of vegetation would be timed to avoid periods when rain is forecast	Prevention of sedimentation and erosion leading to a reduction in water quality and degradation of aquatic habitats	Pre-construction and construction	Proponent and Construction Contractor
	Stabilisation of disturbed areas, including revegetation in accordance with the FFMP, is to be undertaken as soon as practicable after disturbance.	Prevents sedimentation and erosion leading to a reduction in water quality and degradation of aquatic habitats	Pre-construction, construction and post-construction phases	Proponent and Construction Contractor
	Emergency response protocols and procedures for implementation in the event of a contaminant spill or leak to be clearly articulated in the construction and operational environmental management plans.	Prevents pollution of waterways.	Pre-construction and construction	Proponent and Construction Contractor
	Spill kits to be located to allow for timely response to uncontained spills. Site inductions are to include a briefing on the use of spill kits.	Prevents pollution of waterways.	Pre-construction and construction	Proponent and Construction Contractor
Vegetation removal or disturbance	Clearly identifying sensitive areas ('no-go zones') which cannot be impacted by construction and managing clearing such that clearing activities are constrained to these approved areas only.	Prevention of over clearing of vegetation.	Pre-construction and construction	Construction Contractor
	Site inductions are to include a briefing regarding the local threatened species and communities on the site, and	Prevention of impacts to threatened species and communities.	Construction and post-construction.	Proponent and Construction Contractor

Impact	Mitigation measure	Outcome	Timing	Responsibility
	protocols to be undertaken if they are encountered.			
Weed invasion and spread	Management of weeds in and adjacent to cleared areas will occur in accordance with the FFMP, CEMP, and operational environmental management plan (OEMP). The plan would include details relating to the monitoring, management, and where necessary, eradication of weeds, disposal of green waste, and vehicle/plant weed wash down protocols, if required.	Prevention of weed establishment and weed invasion.	Pre-construction, construction, and post-construction.	Proponent and Construction Contractor
	Management of noxious weeds is to be undertaken in accordance with the Biosecurity Act 2015.	Prevention of weed establishment and weed invasion	Pre-construction and construction	Proponent and Construction Contractor
	Equipment used for treating weed infestation will be cleaned prior to moving to a new area within the development site to minimise the likelihood of transferring any plant material and soil.	Prevention of weed spread	Pre-construction and construction	Proponent and Construction Contractor
	Soil stripped and stockpiled from areas containing known weed infestations are to be stored on cleared land at least 40 m from native vegetation.	Prevention of weed establishment and weed invasion	Construction	Construction Contractor
Impacts to fauna and flora	Fauna microhabitat such as hollow logs and dead trees should be removed from areas to be cleared and relocated to adjacent woodland habitat.	Retaining fauna habitat resources	Pre-construction and construction	Construction Contractor
	A nest box and connectivity management strategy would be prepared prior to clearing of hollow bearing trees and connecting links. The strategy would inform the installation of nest boxes and fauna crossings in and between retained native vegetation adjacent to the site, and the on-going monitoring and maintenance of nest boxes and crossings through the construction and operational phases. This strategy would be included within the FFMP.	Replaces lost hollow resources in the landscape	Pre-construction and construction	Construction Contractor
	High visibility plastic fencing is to be installed to clearly define the limits of the works area.	Prevents disturbance or over clearing of fauna habitat and native vegetation outside the construction area	Construction	Construction Contractor
	Undertake a prestart-up check for sheltering native fauna of all infrastructure, plant and equipment and/or during relocation of stored construction materials.	Prevents fauna injury/mortality	Construction	Construction Contractor
	Site inductions are to include a briefing regarding the local fauna of the site	Prevents fauna injury/mortality	Construction	Construction Contractor

Impact	Mitigation measure	Outcome	Timing	Responsibility
	and protocols to be undertaken if fauna is encountered.			
	If any animal is injured, contact the relevant local wildlife rescue agency (for example, WIRES) and/or prequalified veterinary surgery as soon as practical. Until the animal can be cared for by a suitably qualified animal handler, minimise stress to the animal and reduce the risk of further injury by: ▪ Handling fauna with care and as little as possible ▪ Covering larger animals with a towel or blanket and placing in a large cardboard box ▪ Placing smaller animals in a cotton bag or plastic bag (smaller reptiles and frogs), tied at the top ▪ Keeping the animal in a quiet, warm and ventilated space.	Prevents fauna injury/mortality	Pre-construction, construction, and post-construction.	Proponent and Construction Contractor
	If any pits/trenches are to remain open overnight, they are to be securely covered, where reasonable and feasible. Alternatively, fauna ramps (logs or wooden planks) are to be installed to provide an escape for trapped fauna. Pits will be inspected prior to work recommencing and any fauna removed by the project ecologist or designated suitably qualified and licensed representative.	Prevents fauna injury/mortality	Construction	Construction Contractor
	The extent of vegetation clearing is to be clearly identified on construction plans.	Prevents impacts to fauna habitat and native vegetation outside the development footprint	Pre-construction	Proponent and Construction Contractor
	In circumstances where native vegetation or mature tree clearing is required outside of the biodiversity development site, the project ecologist will inspect the proposed area and provide advice on the impact to flora and fauna and appropriate management.	Prevents impacts to fauna habitat and native vegetation outside the development footprint	Construction	Proponent, Construction Contractor, and appointed project ecologist
	Directional lighting will be used where lighting is required in construction areas.	Minimises disruption to fauna foraging, nesting or roosting behaviours	Construction	Construction Contractor
	Maintenance of construction machinery and plant will be undertaken to minimise unnecessary noise.	Prevents fauna injury/mortality	Construction	Construction Contractor
	Speed limits will be developed so as to minimise the potential for fauna to be struck by a vehicle within the development site. All vehicles and plant in operation during construction	Prevents fauna injury/mortality	Construction	Construction Contractor

Impact	Mitigation measure	Outcome	Timing	Responsibility
	are to adhere to site rules relating to speed limits.			
	Where suitable for the species, and in line with established conservation programs (such as Saving our Species), threatened species translocation will be carried for species occurring within the development site (Red-crowned Toadlet and *Grevillea parviflora* subsp. *parviflora*). Translocation will be carried out in line with Office of Environment and Heritage Translocation operational policy (OEH 2019l) and will involve stakeholders from relevant government agencies, and subject matter experts.	Minimising impacts to threatened species, and securing populations of threatened species	Pre-construction	Proponent and appointed project ecologist
Bushfire risk connectivity	Bushfire awareness included in staff induction and in toolbox talks pre-commencement.	Reduces risk of possible bushfire events impacting on biodiversity values	Pre-construction and construction	Construction Contractor
Invasion and spread of pathogens and disease	Implementation of hygiene protocols to minimise risk of spreading pathogens and disease. Mitigations include vehicle and equipment washdowns, and follow relevant guidelines including: ▪ *Best Practice Management Guidelines for Phytophthora cinnamomic within the Sydney Metropolitan Catchment Management Authority Area* (Suddaby & Liew, 2008) ▪ *Hygiene protocol for the control of disease in frogs* (DECC, 2008) ▪ *Management plan for myrtle rust on national parks estate* (OEH, 2011).	Prevents the spread and establishment of disease and pathogens	Pre-construction and construction	Construction Contractor

6.4 Identification of final project footprint

The layout for the Project has been refined through the consideration of a number of alternatives as outlined within Section 6.1.1 of this report and Chapter 4 of the EIS which have reduced the potential for adverse impacts to the environment, including specific impacts on threatened ecological communities. The final footprint is referred to as the development site and is shown in Figure 1-4.

7 Impact assessment

7.1 Introduction

Both the construction and operational phases of the Project would result in impacts to native vegetation and fauna habitat. Both direct and indirect impacts associated with the operation of the project would occur upstream and downstream of dam spillway. Upstream and downstream impacts associated with the operational phase of the Project are discussed in two separate reports. This report is limited to a discussion of the direct and indirect impacts associated with the construction phase of the Project, being those impacts arising from the construction of the proposed dam spillway, buttress and ancillary infrastructure areas.

7.1.1 Direct impacts

As per the FBA, direct impacts on biodiversity values are an impact that is a direct result of vegetation clearance from a development. Biodiversity values include the composition, structure and function of ecosystems, and includes (but is not limited to) threatened species, populations and ecological communities, and their habitats. Direct impacts relating to the development site include:

- loss and fragmentation of native vegetation
- loss of threatened ecological communities
- loss of threatened flora species and their habitat
- loss of threatened fauna species and their habitat
- fauna mortality
- degradation of riparian and aquatic habitats
- changes to natural fire regimes
- cumulative impacts.

The direct impacts associated with the Project are discussed further in Section 7.2.

7.1.2 Indirect impacts

As per the FBA, indirect impacts on biodiversity values occur when development related activities affect threatened species, threatened species habitat, populations or ecological communities in a manner other than direct impacts.

Indirect impacts of the Project during the construction and operation phases include:

- loss and fragmentation of native vegetation
- loss of threatened ecological communities
- loss of threatened flora species and their habitat
- loss of threatened fauna species and their habitat
- fauna mortality
- degradation and changes to hydrology including surface water, groundwater, riparian and aquatic habitats
- edge effects
- weed invasion and encroachment
- creating habitat conducive to invasive animals
- introduction or spread of diseases and pathogens
- alteration of noise environment
- alteration of light environment
- dust impacts
- effects of blasting and vibration
- erosion and sedimentation
- changes to natural fire regimes
- cumulative impacts.

The indirect impacts associated with the Project are discussed further in Section 7.2.

7.1.3 Summary of impacts

The impacts predicted to occur as a result of the construction works are summarised in Table 7-1.

Table 7-1. Summary of impacts

Likely impacts	Direct	Indirect	Details	Extent/scale
Loss and fragmentation of native vegetation	Y	Y	Clearing of wet and dry sclerophyll forest communities.	A total of 22.42 ha of native vegetation would be cleared..
Loss of threatened ecological communities	Y	Y	Clearing of HN604, which is equivalent to Shale Sandstone Transition Forest in the Sydney Basin Bioregion, listed as a CEEC under the BC Act and EPBC Act.	A total of 1.64 ha of Shale Sandstone Transition Forest in the Sydney Basin Bioregion CEEC would be cleared.
Loss of threatened flora species and their habitat	Y	Y	*Grevillea parviflora* subsp. *parviflora*, listed as Vulnerable under both the BC Act and EPBC Act were recorded within the development site and may be affected by clearing. This species is known to reproduce by suckering, making an assessment of numbers difficult without genetic testing. Potentially suitable habitat for 41 threatened flora species (as defined as having a moderate or higher likelihood of occurrence) has also been identified within the development site and so may be affected by clearing.	A total of 14.19 ha of suitable habitat for *Grevillea parviflora* subsp. *parviflora* will be cleared. A total of 22.42 ha of suitable habitat (inclusive of the 20.06 ha) for other threatened flora species would be cleared.
Loss of threatened fauna species and their habitat	Y	Y	Two individual Red-crowned Toadlets (*Pseudophryne australis*), listed as Vulnerable under the BC Act, were recorded within the development site. Suitable habitat is widespread and may be impacted by the development. Suitable habitat (by PCT) for 49 threatened fauna species has also been identified within the development site and may be impacted by the development.	About 8.25 ha of habitat suitable for Red-crowned Toadlet (*Pseudophryne australis*) would be cleared. A total of 22.42 ha of habitat suitable for other threatened fauna species would be cleared.
Fauna mortality	Y	Y	Clearance works, earthworks or collisions with machinery could cause fauna mortality.	Fauna mortality is most likely to occur during vegetation clearance activities.
Degradation and changes to hydrology including surface water, groundwater, riparian and aquatic habitats	Y	Y	Caused by changes in run-off, infiltration, pollution and erosion.	7.01 hectares of riparian vegetation (as the riparian buffer) would be cleared. Impacts to aquatic habitat are described in detail in the aquatic ecology assessment. There will be both direct and indirect impacts to GDEs as a result of the Project.
Edge effects	N	Y	The completed section of raised dam wall will not increase any edge effects over what is currently present. The impact of the construction works will cause at	May occur during clearance activities.

Likely impacts	Direct	Indirect	Details	Extent/scale
			least temporary changes to edge areas.	
Weed invasion and encroachment	N	Y	Vehicles and plant may transport weed propagules into the development site.	May occur during construction and post-construction phases.
Creating habitat conducive to invasive and overabundant fauna	N	Y	Clearing of native vegetation and increased human activity increase the risk of pest animal species increasing.	May occur during construction and operational phases.
Introduction or spread of diseases and pathogens	N	Y	Vehicles and plant may transport pathogens into the development site.	May occur during construction and post-construction phases.
Alteration of noise environment	N	Y	May impact upon the roosting, breeding and foraging activities of locally occurring fauna.	Temporary and localised scale of impacts during construction.
Alteration of light environment	N	Y	May impact upon the roosting, breeding and foraging activities of locally occurring fauna.	Temporary and localised scale of impacts during construction.
Dust impacts	N	Y	May impact upon plant functionality	Temporary and localised scale of impacts during construction.
Effects of blasting and vibration	N	Y	May impact upon the roosting, breeding and foraging activities of locally occurring fauna.	Temporary and localised impact during construction of the raised dam wall and spillway.
Erosion and sedimentation	N	Y	Disturbance of native vegetation and ground increases risk of erosion and sedimentation.	May occur during construction phases.
Changes to natural fire regimes	N	N	No changes are proposed the management of bushfires at the Dam.	It is not anticipated that the construction of the Project will result in any change to the management of bushfires or natural fire regimes.

7.2 Assessment of direct impacts

7.2.1 Loss and fragmentation of native vegetation

The project would clear 22.42 hectares of native vegetation as part of the construction works. This direct clearing includes four different vegetation communities, one of which is threatened under both the BC and EPBC Acts. Direct impacts on biodiversity values are the result of this vegetation clearing as summarised in Table 7-1. The area of each vegetation community being cleared within the construction development site, and the area of each community retained in the development site and within the study area is provided in Table 7-2.

The clearing of native vegetation within the development site will fragment both native vegetation generally, and discrete plant community types, through the creation of discontinuities of vegetation extent.

Table 7-2. Summary of areas in hectares of PCTs within the development site to be cleared by the Project

Vegetation	TSC Act status	EPBC Act status	Area cleared in development site	Area retained in development site	Total area of PCT in study area
HN564: Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion.	-	-	2.76	14.20	21.64
HN566: Red Bloodwood – Scribbly Gum heathy	-	-	12.25	12.53	38.40

Vegetation	TSC Act status	EPBC Act status	Area cleared in development site	Area retained in development site	Total area of PCT in study area
woodland on sandstone plateaux of the Sydney Basin Bioregion.					
HN568: Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion.	-	-	5.77	2.84	17.03
HN604: Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion.	Shale Sandstone Transition Forest in the Sydney Basin Bioregion (CE)	Shale Sandstone Transition Forest of the Sydney Basin Bioregion (CE)	1.64	3.24	8.12
Total area of all PCTs (hectares)			**22.42**	**32.81**	**85.19**

7.2.2 Loss of threatened ecological communities

As discussed above, 1.64 hectares of HN604 will be directly cleared during the construction phase. This PCT is considered a component of Shale Sandstone Transition Forest in the Sydney Basin Bioregion, listed as Critically Endangered under both the BC Act and EPBC Act. This 1.64 hectares of Shale Sandstone Transition Forest will be directly cleared as part of the clearing area immediately adjacent to the downstream area of the existing dam wall.

7.2.3 Loss of threatened flora species and their habitat

While no targeted threatened flora species surveys were carried out in the development site, incidental observations of *Grevillea parviflora* subsp. *parviflora*, listed as Vulnerable under both the BC Act and EPBC Act was recorded within the development site and may be affected by clearing. As this species can reproduce by suckering, the species may persist in disturbed areas as well as more intact extents of PCTs. BioNet lists this species as being associated with the PCTs HN564, HN566 and HN604. The combined area of these three associated PCTs that will be directly cleared in the (i.e. the development footprint) in the development site is 16.65 hectares (as per Table 7-2).

Potentially suitable habitat for 41 threatened flora species (as defined as having a moderate or higher likelihood of occurrence) has also been identified within the development site and so may be affected by clearing.

It is recommended that targeted surveys be carried out in line with relevant guidelines for threatened flora species currently assumed as present within the development site. Targeted surveys should focus on areas that had been subject to recent prescribed burning within the development footprint. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project.

Threatened species polygons were derived for each of the threatened flora candidate species in accordance with Section 6.5.1.14 of the FBA based on the following filters:

- associated PCTs in BioNet Vegetation Classification System and Threatened Biodiversity Data Collection
- associated PCTs based on field observations
- distribution patterns from field observations
- distributions patterns further refined by geographical/abiotic features/barriers
  - known and/or predicted IBRA subregions
  - species-specific habitat features or components listed within the Threatened Species Profile Database
  - catchments
  - landforms
  - soils

- aspect
- known microhabitats where known (that is, riparian areas, cliffs, etc).

Threatened species habitat polygons for flora candidate species are provided in Appendix B

7.2.4 Loss of threatened fauna species and their habitat

Fauna habitat features that will be removed by the project include:

- Understorey vegetation: this includes the clearing of grasses, sedges, forbs, herbs and, small shrubs. This understorey vegetation could be used as foraging habitat, breeding habitat and shelter by invertebrates, amphibians, reptiles, small birds and terrestrial mammals.
- Fallen logs, woody debris and leaf litter: intact vegetation within the development footprint has produced large amounts of fallen logs, woody debris and leaf litter. These habitat features may be used as foraging habitat, breeding habitat and shelter by invertebrates, amphibians, reptiles, small birds and terrestrial mammals.
- Hollow-bearing living trees and stags: are used as habitat by a range of fauna species which may rely on them for shelter, breeding or roosting. Loss of mature hollow-bearing trees has the potential to impact on breeding and shelter habitat for threatened species of birds, arboreal mammals, frogs, reptiles and microbats.
- Nectar-producing trees and shrubs: these are a food resources for blossom-dependant birds, arboreal mammals and mega chiropteran bats.
- Ephemeral drainage lines: used for shelter and breeding habitat for threatened amphibians.

During surveys, at least two individual Red-crowned Toadlets (*Pseudophryne australis*), listed as Vulnerable under the BC Act, were recorded within the development site. Suitable habitat is widespread and may be impacted by the development. The PCTs HN564, HN566 and HN568 are listed by BioNet as associated with this species. About 8.25 hectares of suitable habitat for Red-crowned Toadlet (*Pseudophryne australis*) would be cleared. Suitable habitat (by PCT) for 49 threatened fauna species has also been identified within the development site and may be impacted by the development. A total of 22.42 hectares of suitable habitat for other threatened fauna species would be cleared.

It is recommended that targeted surveys be carried out in line with relevant guidelines for threatened flora species currently assumed as present within the development site. Targeted surveys should focus on areas that have been subject to resent prescribed burning within the development footprint. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project.

Threatened species polygons were derived for each of the threatened flora candidate species in accordance with Section 6.5.1.14 of the FBA based on the following filters:

- associated PCTs in BioNet Vegetation Classification System and Threatened Biodiversity Data Collection
- associated PCTs based on field observations
- distribution patterns from field observations
- distributions patters further refined by geographical/abiotic features/barriers
  - known and/or predicted IBRA subregions
  - species-specific habitat features or components listed within the Threatened Species Profile Database,
  - catchments
  - landforms
  - soils
  - aspect
  - known microhabitats where known (that is, riparian areas, cliffs, etc).

Threatened species habitat polygons for flora candidate species are provided in Appendix B

7.2.5 Fauna mortality

Vegetation clearance and vehicle access to the site may result in fauna mortality during construction. Examples could include injury to roosting animals during tree removal or vehicular strike.

7.3 Assessment of indirect impacts

7.3.1 Loss and fragmentation of native vegetation

Indirect impacts such as edge effects, changes to hydrology, weed invasion and encroachment, introduction or spread of diseases and pathogens and erosion and sedimentation may impact native vegetation areas in addition to those areas directly impacted by clearing.

7.3.2 Loss of threatened ecological communities

Indirect impacts to Shale Sandstone Transition Forest in the Sydney Basin Bioregion would be limited to edge effects where adjoining vegetation would be directly cleared. These indirect impacts to Shale Sandstone Transition Forest could include edge effects, weed invasion and encroachment, introduction or spread of diseases and pathogens, erosion and sedimentation and changes to natural fire regimes.

7.3.3 Loss of threatened flora species and their habitat

Grevillea parviflora subsp. *parviflora*, listed as vulnerable under both the BC Act and EPBC Act, was incidentally identified in the development site. Forty (40) other threatened flora species have been identified as having a medium or high likelihood of occurring in the development site. These species that may be indirectly impacted through degradation and changes to hydrology, edge effects, weed invasion and encroachment, creating habitat conducive to invasive fauna, introduction or spread of diseases and pathogens and dust impacts.

7.3.4 Loss of threatened fauna species and their habitat

The construction of the Project may indirectly impact fauna and their habitats. Fauna habitat features that may be indirectly impacted include

- Adjacent vegetation:
- Sandstone caves, cliffs and overhangs: The blasting used in the construction phase may cause vibrations that have the potential to damage sandstone caves, crevices, cliffs and overhangs that could be used as habitat for threatened microchiropteran bats, reptiles and mammals such as the Brush-tailed Rock-wallaby. The vibrations themselves may disturb roosting bats regardless of any damage that may occur to their habitat.
- Sandstone drainage lines: The blasting used in the construction phase may cause vibrations that have the potential to damage ephemeral drainage lines occurring on sandstone. The vibrations have the potential to break off or dislodge sandstone, disturbing the fauna habitat within these drainage lines. The Red-crowned Toadlet is an example that could be affected by the disturbance of sandstone drainage lines.

7.3.5 Fauna mortality

Fauna mortality in habitat adjacent to the construction footprint may continue in the short term after vegetation clearance due to stress and competition leading to illness, injury and disease. The presence of large areas of habitat adjacent to the site should reduce the potential for this to occur. There may be an increase in roadkill due to increase traffic outside of the construction site.

7.3.6 Degradation and changes to hydrology including surface water, groundwater, riparian and aquatic habitats

The proposed construction activities have the potential to alter the overland and subterranean water flows through the development site and study area. Potential impacts to water quality could occur from erosion and sedimentation, accidental spillage of chemicals, fuels, lubricating and hydraulic oils from mobile construction equipment, and runoff from equipment and vehicle wash-down. Introduction of pollutants into surrounding waterways may cause:

- changes to pH, electrical conductivity, dissolved oxygen and temperature
- reduction of light penetration due to increased sediments
- increased sediment load, organic matter and turbidity
- introduction of pollutants such as construction fuels, oil, grease and chemicals.

There is the potential for indirect impacts on remaining areas of GDEs adjacent to the construction area due to changes in groundwater levels from the Project. However, given the temporary and minor impacts on groundwater levels from the construction of the proposal, negligible risk or impacts are expected on remaining GDE areas adjacent to the proposal.

7.3.7 Edge effects

Edge effects are identifiable changes in soil moisture, light intensity and microclimate within areas of vegetation that may to lead to secondary changes in plant and animal densities (Murcia 1995). Edge effects may be created as a result of vegetation clearance. However, the extent of the effect is difficult to predict as this is often highly variable and dependent on many factors such as vulnerability of edge ecosystem, degree of change in land use, intensity of this use and chance events (Murcia 1995). Clearing for construction would create new edges noting that the existing dam and operational facilities have created existing edges between operational land and native vegetation.

7.3.8 Weed invasion and encroachment

Machinery and vehicles may introduce and disperse weed species (Khan *et al.* 2017). Vehicles, plant and equipment may transport weed propagules into the development site or spread existing weed propagules that may impact on adjacent vegetation.

7.3.9 Creating habitat conducive to invasive fauna

Clearing may offer increased opportunity for invasive species to move into the development site and subsequently adjacent vegetation..

7.3.10 Introduction or spread of diseases and pathogens

Vehicles and plant may transport pests and pathogens such as Amphibian Chytrid Fungus, *Phytophthora cinnamomi* and myrtle rust into the development site. The vegetation in the development site or study area does not appear to be affected by dieback and hence may potentially become susceptible to infection with *Phytophthora cinnamomi* should appropriate hygiene measures not be adopted where construction vehicles move from infected to non-infected areas.

The vegetation within the development site and study area did not appear to be affected by myrtle rust. Myrtle rust is a serious pathogens which affect plants belonging to the family Myrtaceae including Australian natives like bottle brush (*Callistemon* spp.), tea tree (*Melaleuca* spp.) and eucalypts (*Eucalyptus* spp.). These plants occur throughout both the development site and study area. Appropriate mitigation measures should be taken to minimise the risk of myrtle rust being spread into the development site and study area.

Red-crowned Toadlets were recorded within the development site. Amphibians are susceptible to the amphibian chytrid fungus. Activities associated with this Project have the potential risk of introducing or spreading chytrid to the study sites so appropriate mitigation measures to manage the possibility of introduction of this disease should be taken.

7.3.11 Alteration of noise environment

The operation of vehicles, plant and equipment may create additional noise in the vicinity of the development site. Blasting would also occur. This may impact upon the roosting, breeding and foraging activities of locally occurring fauna outside of the construction site. This impact would occur during the construction of the raised dam wall and spillway and during operation of ancillary equipment such as the batch plants. Noise sources related to construction would cease following construction, and therefore impacts from construction related noise would be a short-term impact.

7.3.12 Alteration of light environment

The operation of vehicles, plant and equipment may create additional light in the vicinity of the development site. There also may be extended periods of night works in summer months. This may impact upon the roosting, breeding and foraging activities of locally occurring fauna. This impact would occur during the construction of the raised dam wall and spillway and during operation of ancillary equipment such as the batch plants. Light sources related to construction would cease following construction, and therefore impacts from alterations to the light environment would be a short-term impact.

7.3.13 Dust impacts

Dust resulting from batch plant operation, materials movement and storage, vegetation clearance, road use and exposed soil, may settle on vegetation and habitats. The extent of dust deposition would variably impact plants through soil and foliar deposition pathways, dependant on stochastic inputs such as failure of mitigation methods, wind direction and aerodynamics. Responses to exposure would vary between different plant species, soil buffering capacities, drainage, slope, cumulative impacts of ongoing exposure regimes, and input of other impacts. The impacts would be principally be in or around the development footprint. Dust related impacts would cease following construction, and therefore would be a short-term impact.

7.3.14 Effects of blasting and vibration

Blasting may disturb cave-roosting microchiropteran bats. Excessive vibrations may damage sandstone habitat for threatened fauna such as the Large-eared Pied-bat, Red-crowned Toadlet and Brush-tailed Rock-wallaby. Blasting would occur at certain times during construction, and therefore would be a short-term impact.

7.3.15 Erosion and sedimentation

Disturbance to vegetation and soil, movement and storage of materials, and changes to hydrological flow could increase risks of erosion and/or sedimentation within habitats. Erosion and sediment control planning will reduce this risk, but stochastic events will retain some risk. During construction, risks would be temporary and related primarily to movement and storage of materials, vegetation clearance and earthworks. Risks associated with operation would be limited to failed mitigation measures or other stochastic impacts such as adverse weather.

7.3.16 Changes to natural fire regimes

It is not anticipated that the construction of the Project will result in any change to the management of bushfires or natural fire regimes.

7.4 Cumulative impacts

Cumulative impacts on biodiversity values from the Project across the construction area, upstream operational area, and downstream area, as well as projects and proposals within the same IBRA subregions as the Project have been considered. Table 7-3 provides a summary of these projects and their respective assessed/anticipated impacts.

With regard to potential cumulative impacts on TECs, construction of the Project would remove 1.64 hectares of Shale Sandstone Transition Forest in the Sydney Basin Bioregion CEEC would be cleared. Operation of the Project may affect this TEC in the downstream study area as follows:

- 73.76 ha within the FMZ discharge area
- 91.20 ha between 10% AEP changed flood extent.

So potentially, up to about 93 hectares may be affected.

Table 7-4 and Table 7-5 provide details of the potential cumulative impacts on threatened flora and fauna respectively with regard to the overall Project and the major infrastructure project noted in Table 7-3. This assessment is not a comprehensive assessment of all other proposed or determined projects within the IBRA subregions associated with the Project. Further, only impacts to threatened biota across multiple projects, or areas of the Project (upstream area vs downstream area) are included within the cumulative impact assessment tables.

Table 7-3. Past, present, and future projects

Project	Construction impact	Operational Impact
Warragamba Dam Raising – Upstream ▪ Upstream operational impacts associated within the Project.	▪ Appendix F1(Upstream BAR) ▪ No construction impacts anticipated	▪ Appendix F1 (Upstream BAR)
Warragamba Dam Raising – Construction ▪ Construction impacts associated within the Project.	▪ Appendix F3 (Biodiversity assessment report - construction area – this report)	▪ N/A
Warragamba Dam Raising – Downstream ▪ Downstream operational impacts associated within the Project.	▪ Appendix F2 (Downstream ecological assessment) ▪ No construction impacts anticipated	▪ Appendix F2
Western Sydney Airport ▪ Located approximately 8.5 km east of Warragamba Dam. ▪ Construction commenced.	▪ Removal of 318.5 ha of native vegetation. ▪ Removal of 141.8 ha of fauna habitat. ▪ Direct and indirect impacts to threatened biota.	▪ Bird and bat strike. ▪ Terrestrial fauna strike. ▪ Noise and vibration. ▪ Light. ▪ Alterations to hydrology and GDEs.
M12 Motorway ▪ 16 km motorway between M7 at Cecil Hills and Northern Road, Luddenham. ▪ Located approximately 10 km east of Warragamba Dam. ▪ Proposal under assessment.	▪ Removal of 118.0 ha of native vegetation. ▪ Removal of 334 threatened plants. ▪ Removal of 1.6 ha of threatened fauna habitat.	▪ Changes to hydrology. ▪ Habitat fragmentation. ▪ Edge effects. ▪ Fauna mortality. ▪ Risk of establishment of weeds and pathogens.
Northern Road Upgrade ▪ Upgrade of Northern Road between Mersey Road, Bringelly and Glenmore Parkway, Glenmore Park. ▪ Located approximately 10 km east of Warragamba Dam. ▪ Construction commenced.	▪ Removal of 39.6 ha of native vegetation. ▪ Removal of threatened flora and fauna habitat. ▪ Removal of 39 threatened plants.	▪ Changes to hydrology. ▪ Habitat fragmentation. ▪ Edge effects. ▪ Fauna mortality. ▪ Establishment of weeds and pathogens.
Hume Coal Project ▪ Development of an underground mine to extract metallurgical and industrial coal. ▪ Located approximately 70 km south-west of Warragamba Dam. ▪ Proposal under assessment.	▪ Removal of 64 paddock trees. ▪ Removal of 8.3 ha of threatened fauna habitat.	▪ Potential changes to surface and subterranean hydrology. ▪ Habitat fragmentation. ▪ Edge effects. ▪ Fauna mortality. ▪ Establishment of weeds and pathogens.
Gunlake Quarry Extension ▪ Extension of operations at Gunlake Quarry. ▪ Located approximately 170 km south-west of Warragamba Dam. ▪ Proposal determined.	▪ Removal of 54.1 ha of native vegetation. ▪ Removal of threatened flora and fauna habitat.	▪ Erosion and sedimentation. ▪ Habitat fragmentation. ▪ Edge effects. ▪ Fauna mortality. ▪ Establishment of weeds and pathogens.

Table 7-4. Cumulative impacts on threatened flora species

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Acacia baueri subsp. *aspera*	V	-	2.61 ha (20% AEP) 12.40 ha (1% AEP) (22.24 PMF)	12.25 ha (development footprint)	-	-
Acacia bynoeana	E	V	14.48 ha (20% AEP) 69.82 ha (1% AEP) 132.53 ha (PMF)	19.96 ha	1,195.70 ha within FMZ discharge area 625.85 ha between 10% AEP changed flood extents 699.30 ha between changed PMF extent	-
Acacia flocktoniae	V	V	154.43 ha (20% AEP) 752.78 ha (20% AEP) 1366.11 ha (PMF)	6.07 ha	-	-
Acacia gordonii	E	E	3.49 ha (20% AEP) 17.14 ha (1% AEP) 29.61 ha (PMF)	12.25 ha	-	-
Acacia pubescens	V	V	14.48 ha (20% AEP) 69.82 ha (1% AEP) 132.53 ha	19.66 ha	726.91 ha within FMZ discharge area 485.11 ha between 10% AEP changed flood extents 215.71 ha between changed PMF extent	Western Sydney Airport: 5.00 ha
Acrophyllum australe	V	V	5.65 ha (20% AEP) 25.95 ha (1% AEP) 44.94 ha (PMF)	-	-	-

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Asterolasia elegans	E	E	2.31 ha (20% AEP) 11.76 ha (1% AEP) 21.94 ha (PMF)	12.55 ha	-	-
Astrotricha crassifolia	V	V	3.00 ha (20% AEP) 15.46 ha (1% AEP) 29.00 ha (PMF)	12.25 ha	-	-
Baloskian longipes	V	V	45.64 ha (20% AEP) 77.34 ha (1% AEP) 145.28 ha (PMF)	-	-	-
Callistemon linearifolius	V	-	5.14 ha (20% AEP) 37.16 ha (1% AEP) 64.34 ha (PMF)	-	11.64 ha within FMZ discharge area 138.09 ha between 10% AEP changed flood extents 215.71 ha between changed PMF extent	-
Callistemon megalongensis	CE	CE	1.77 ha (20% AEP) 14.13 ha (1% AEP) 57.04 (PMF)	-	-	-
Calomnion complanatum	E	-	0.13 ha (20% AEP) 0.66 ha (1% AEP) 1.01 ha (PMF)	-	-	-
Cynanchum elegans	E	E	-	-	5.08 ha within FMZ discharge area 9.58 ha between 10% AEP changed flood extents 6.49 ha between changed PMF extent	Western Sydney Airport: 289.90 ha

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Darwinia biflora	V	V	3.49 ha (20% AEP) 17.14 ha (1% AEP) 29.61 ha (PMF)	12.55 ha	122.30 ha within FMZ discharge area 104.34 ha between 10% AEP changed flood extents 3.50 ha between changed PMF extent	-
Darwinia peduncularis	V	-	5.44 ha (20% AEP) 28.08 ha (1% AEP) 52.80 (PMF)	12.25 ha	-	-
Dillwynia tenuifolia	V	-	0.89 ha (20% AEP 4.74 ha (1% AEP) 7.37 (PMF)	12.55 ha	1,288.72 ha within FMZ discharge area 684.31 ha between 10% AEP changed flood extents 884.08 ha between changed PMF extent	Western Sydney Airport: 5 ha M12 Motorway: 244 plants
Epacris hamiltonii	E	E	0.52 ha (20% AEP) 3.72 ha (1% AEP) 7.78 (PMF)	-	-	-
Epacris purpurascens var. purpurascens	V	-	300 plants	300 plants	203.22 ha within FMZ discharge area 155.48 ha between 10% AEP changed flood extents 41.36 ha between changed PMF extent	-
Epacris sparsa	V	V	0.39 ha (20% AEP) 3.06 (1% AEP) 6.76 (PMF)	-	-	-

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Eucalyptus benthamii	V	V	10.76 ha (20% AEP) 107.39 (1% AEP) 205.51 (PMF)	-	206.90 ha within FMZ discharge area 126.60 ha between 10% AEP changed flood extents 435.78 ha between changed PMF extent	-
Eucalyptus glaucina	V	V	474.79 ha (20% AEP) 2244.36 ha (1% AEP) 4163.71 ha (PMF)	-	-	-
Eucalyptus pulverulenta	V	V	0.56 ha (20% AEP) 2.56 ha (1% AEP) 4.66 (PMF)	-	-	-
Euphrasia bowdeniae	V	V	1.01 ha (20% AEP 5.60 ha (1% AEP) 10.89 (PMF)	-	-	-
Genoplesium superbum	E	-	3.99 ha (20% AEP) 18.56 ha (1% AEP) 32.87 ha (PMF)	-	-	-
Grevillea evansiana	V	V	2.61 ha (20% AEP) 12.40 ha (1% AEP) 22.24 (PMF)	12.25 ha	-	-
Grevillea juniperina subsp. *juniperina*	V	-	-	-	1,118.33 ha within FMZ discharge area 698.10 ha between 10% AEP changed flood extents 942.13 ha between changed PMF extent	Western Sydney Airport: 255.70 ha

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Grevillea parviflora subsp. parviflora	V	V	3.66 ha (20% AEP) 18.37 ha (1% AEP) 32.52 (PMF)	14.19 ha	32.80 ha between changed PMF extent	Western Sydney Airport: 5 ha
Hakea dohertyi	E	E	87.13 ha (20% AEP) 393.77 ha (1% AEP) 648.41 (PMF)	-	-	-
Haloragodendron lucasii	E	E	3.00 ha (20% AEP) 15.46 ha (1% AEP) 29.00 ha (PMF)	12.25 ha	-	-
Hibbertia puberula	E	-	14.48 ha (20% AEP) 69.82 ha (1% AEP) 132.53 ha (PMF)	19.96 ha	44.03 ha within FMZ discharge area 93.28 ha between 10% AEP changed flood extents 213.54 ha between changed PMF extent	-
Hygrocybe anomala subsp. *ianthinomarginata*	V	-	101.29 ha (20% AEP) 535.01 ha (1% AEP) 927.14 ha (PMF)	13.89 ha	-	-
Hygrocybe aurantipes	V	-	14.72 ha (20% AEP) 70.09 ha (1% AEP) 127.01 (PMF)	-	-	-
Hygrocybe reesiae	V	-	14.72 ha (20% AEP) 70.09 ha (1% AEP) 127.01 (PMF)	-	-	-

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Isopogon fletcheri	V	V	0.90 ha (20% AEP) 5.13 ha (1% AEP) 10.11 (PMF)	-	-	-
Kunzea rupestris	V	V	3.49 ha (20% AEP) 17.14 ha (1% AEP) 29.61 ha (PMF)	12.55 ha	616.40 ha within FMZ discharge area 280.88 ha between 10% AEP changed flood extents 19.09 ha between changed PMF extent	-
Lastreopsis hispida	E	-	9.67 ha (20% AEP) 45.08 ha (1% AEP) 80.97 (PMF)	5.79	-	-
Leionema lachnaeoides	E	E	0.03 ha (20% AEP) 0.13 ha (1% AEP) 0.22 ha (PMF)	-	-	-
Lepidosperma evansianum	V	-	0.03 ha (20% AEP) 0.13 ha (1% AEP) 0.22 ha (PMF)	-	-	-
Leucopogon exolasius	V	V	16.57 ha (20% AEP) 96.32 ha (1% AEP) 169.11 ha (PMF)	18.32 ha	117.22 ha within FMZ discharge area 78.88 ha between 10% AEP changed flood extents 121.23 ha between changed PMF extent	-
Marsdenia viridiflora subsp. *viridiflora* – endangered population	E	-	-	-	125.17 ha between changed PMF extent	Western Sydney Airport: 142 plants, 255.70 ha Northern Road Upgrade: 35 plants

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Melaleuca deanei	V	V	3.66 ha (20% AEP) 18.37 ha (1% AEP) 32.52 ha (PMF)	12.55 ha	220.86 ha within FMZ discharge area 118.47 ha between 10% AEP changed flood extents 4.44 ha between changed PMF extent	-
Melaleuca groveana	V	-	2.61 ha (20% AEP) 12.40 ha (1% AEP) 22.24 ha (PMF)	13 plants	-	-
Persoonia acerosa	V	V	13.59 ha (20% AEP) 65.08 ha (1% AEP) 125.15 ha (PMF)	18.02 ha	-	-
Persoonia hirsuta	E	E	14.48 ha (20% AEP) 69.82 ha (1% AEP) 132.53 ha (PMF)	19.96 ha	1,199.46 ha within FMZ discharge area 668.44 ha between 10% AEP changed flood extents 609.08 ha between changed PMF extent	-
Pimelea curviflora var. curviflora	V	V	3.49 ha (20% AEP) 17.14 ha (1% AEP) 29.61 ha (PMF)	14.19 ha	578.05 ha within FMZ discharge area 337.92 ha between 10% AEP changed flood extents 53.03 ha between changed PMF extent	-
Pimelea spicata	E	E	-	-	122.05 ha within FMZ discharge area 107.06 ha between 10% AEP changed flood extents 374.41 ha between changed PMF extent	Western Sydney Airport: 247.80 ha

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Pomaderris brunnea	E	V	513.12 ha (20% AEP) 2,377.01 ha (1% AEP) 4,213.47 ha (PMF)	0.31 ha	159.25 ha within FMZ discharge area 20.88 ha between 10% AEP changed flood extents 393.60 ha between changed PMF extent	-
Pultenaea glabra	V	V	13.59 ha (20% AEP) 65.08 ha (1% AEP) 125.15 ha (PMF)	18.02	-	-
Pultenaea parviflora	E	V	2.61 ha (20% AEP) 12.40 ha (1% AEP) 22.24 ha (PMF)	12.25 ha	1,041.28 ha within FMZ discharge area 590.54 ha between 10% AEP changed flood extents 873.38 ha between changed PMF extent	Western Sydney Airport: 4 plants, 247.80 ha M12 Motorway: 90 plants Northern Road Upgrade: 4 plants
Pultenaea sp. Olinda	E	-	2.61 ha (20% AEP) 12.40 ha (1% AEP) 22.24 ha (PMF)	12.25 ha	-	-
Rhizanthella slateri	V	E	9.67 ha (20% AEP) 45.08 ha (1% AEP) 80.97 ha (PMF)	-	-	-
Rhodamnia rubescens	CE	-	34.75 ha (20% AEP) 160.37 ha (1% AEP) 324.15 ha (PMF)	1 plant	447.16 ha within FMZ discharge area 123.09 ha between 10% AEP changed flood extents 0.52 ha between changed PMF extent	-

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Syzygium paniculatum	E	V	-	10 plants	553.94 ha within FMZ discharge area 299.33 ha between 10% AEP changed flood extents 183.91 ha between changed PMF extent	-
Velleia perfoliata	V	V	7.32 ha (20% AEP) 35.91 ha (1% AEP) 64.04 ha (PMF)	12.55 ha	99.92 ha within FMZ discharge area 16.18 ha between 10% AEP changed flood extents	-
Zieria involucrata	E	V	9.15 ha (20% AEP) 41.36 ha (1% AEP) 73.20 ha (PMF)	1.64 ha	425.46 ha within FMZ discharge area 149.31 ha between 10% AEP changed flood extents 0.52 ha between changed PMF extent	-
Zieria murphyi	V	V	2.61 ha (20% AEP) 12.40 ha (1% AEP) 22.24 ha (PMF)	12.55 ha	-	-

Table 7-5. Cumulative impacts on threatened fauna species

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Anthochaera phrygia	CE	CE	585.36 ha within 20% AEP 2,610.80 ha within 1% AEP 4,805.86 ha within PMF	19.96 ha	1,554.63 ha within FMZ discharge area 723.57 ha between 10% AEP changed flood extent 982.39 ha between changed PMF	Northern Road Upgrade: 26.25 ha
Chalinolobus dwyeri	V	V	558.82 ha within 20% AEP 2,484.39 ha within 1% AEP 4,450.33 ha within PMF	19.96 ha	1,262.63 ha within FMZ discharge area 662.96 ha between 10% AEP changed flood extent 376.08 ha between changed PMF	Gunlake Quarry Extension: 12.20 ha
Heleioporus australiacus	V	V	558.82 ha within 20% AEP 2,484.39 ha within 1% AEP 4,450.33 ha within PMF	3.60 ha	73.69 ha within FMZ discharge area 514.14 ha between 10% AEP changed flood extent 427.29 ha between changed PMF	
Hoplocephalus bungaroides	E	V	80.77 ha within 20% AEP 260.21 ha within 1% AEP 445.32 ha within PMF	10.24 ha	-	-
Isoodon obesulus subsp. *obesulus*	E	E	499.89 ha within 20% AEP 2,389.12 ha within 1% AEP 4,346.14 ha within PMF	12.25 ha	-	-
Ixobrychus flavicollis	V	-	0.39 ha within 20% AEP 3.06 ha within 1% AEP 6.76 ha within PMF	-	1,205.22 ha within FMZ discharge area 495.87 ha between 10% AEP changed flood extent 291.76 ha between changed PMF	Western Sydney Airport: 62.7 ha

Species	Status (BC Act)	Status (EPBC Act)	Approved and proposed clearing requirements for a selection of projects in the IBRA Subregions common to this proposal			
			WDR -upstream operational area	WDR -construction area	WDR -downstream operational area	Other major projects
Meridolum corneovirens	V	-	-	1.64 ha	94.05 ha within FMZ discharge area 695.57 ha between 10% AEP changed flood extent 967.15 ha between changed PMF	Western Sydney Airport: 141.80 ha M12 Motorway: 1.6 ha Northern Road Upgrade: 13 ha
Petrogale penicillata	E	V	182.36 ha within 20% AEP 847.09 ha within 1% AEP 1,614.31 ha within PMF	17.38 ha (development footprint)	-	-
Phascogale tapoatafa	V	-	15.46 ha within 20% AEP 67.21 ha within 1% AEP 1,17.23 ha within PMF	13.89 ha (development footprint)	-	-
Phascolarctos cinereus	V	V	634.18 ha within 20% AEP 2,863.23 ha within 1% AEP 5,213.90 ha within PMF	19.96 ha	910.55 ha within FMZ discharge area 869.09 ha between 10% AEP changed flood extent 967.15 ha between changed PMF	Hume Coal Project: 8.3 ha

7.5 Key threatening processes

In accordance with Section 6.4 of the SEARs, the assessment must identify whether the Project as a whole, or any component of the Project, would be classified as a key threatening process (KTP) in accordance with the listings in the TSC Act, FM Act or EPBC Act.

Under Part 2 of the TSC Act, KTPs are described as those threatening processes that are most likely to jeopardise the survival of those species, populations and ecological communities listed under that Act. Under section 4.32 of the BC Act, a threatening process is eligible to be listed as a KTP if, in the opinion of the Scientific Committee:

- it adversely affects threatened species or ecological communities, or
- it could cause species or ecological communities that are not threatened to become threatened.

DECC (2007c, p. 11) requires consideration as to 'whether the action proposed constitutes or is part of a key threatening process or is likely to result in the operation of, or increase the impact of, a key threatening process'. Schedule 3 of the TSC Act provides a list of KTPs, with Schedule 4 of the BC Act listing KTPs under that Act. There is one additional KTP listed under the BC Act compared to the TSC Act, namely Habitat degradation and loss by Feral Horses (brumbies, wild horses), *Equus caballus* Linnaeus 1758, which has also been considered in the current report.

Impacts to KTPs associated with the FM Act are provided in the Aquatic Ecology Report prepared by BMT, appended to the Warragamba Dam Raising EIS.

Under the EPBC Act a threatening process is defined as a KTP if it threatens or may threaten the survival, abundance or evolutionary development of a native species or ecological community. A process can be listed as a key threatening process if it could:

- cause a native species or ecological community to become eligible for inclusion in a threatened list (other than the conservation dependent category); or
- cause an already listed threatened species or threatened ecological community to become more endangered; or
- adversely affect two or more listed threatened species or threatened ecological communities.

All KTPs listed under the EPBC Act that are associated with the project have adequately equivalent KTPs listed under the BC Act, however not all KTPs listed under the BC Act have equivalent KTPs listed on the EPBC Act.

The Project would result in actions that constitute, or are part of, or may result in the operation of or increase the impact of one KTP as noted in Table 7-6.

Table 7-6. Key threatening processes associated with the Project

Key threatening process	TSC Act	BC Act	EPBC Act equivalent	Details
Clearing of native vegetation	Yes	Yes	Land clearance	The construction of the Project would result in the removal of 22.42 ha of native vegetation.

Changes to vegetation community and structure that may result from temporary inundation may create conditions more conducive to the operation of a range of additional KTPs (refer Table 7 7). The operation of these KTPs would depend on a range of factors including presence of catchment sources for weeds, pests and diseases and the extent to which the inundation makes the vegetation communities or species more susceptible to the threatening process.

Table 7-7. Other key threatening processes

Key threatening process	TSC Act	BC Act	EPBC Act equivalent
Aggressive exclusion of birds from woodland and forest habitat by abundant Noisy Miners (*Manorina melanocephala*).	Yes	Yes	Aggressive exclusion of birds from potential woodland and forest habitat by over-abundant noisy miners (*Manorina melanocephala)*
Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands.	Yes	Yes	-
Anthropogenic climate change	Yes	Yes	Loss of climatic habitat caused by anthropogenic emissions of greenhouse gases

Key threatening process	TSC Act	BC Act	EPBC Act equivalent
Competition and grazing by the feral European Rabbit, *Oryctolagus cuniculus* (L.)	Yes	Yes	Competition and land degradation by rabbits
Competition and habitat degradation by Feral Goats, *Capra hircus* Linnaeus 1758	Yes	Yes	Competition and land degradation by unmanaged goats
Competition from feral honey bees, *Apis mellifera* L.	Yes	Yes	-
Forest eucalypt dieback associated with over-abundant psyllids and Bell Miners	Yes	Yes	-
Habitat degradation and loss by Feral Horses (brumbies, wild horses), *Equus caballus* Linnaeus 1758	No	Yes	-
Herbivory and environmental degradation caused by feral deer	Yes	Yes	-
High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition	Yes	Yes	Not listed (Fire regimes that cause biodiversity decline currently on the finalised priority assessment list)
Infection by Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species and populations	Yes	Yes	Psittacine Circoviral (beak and feather) Disease affecting endangered psittacine species
Infection of frogs by amphibian chytrid causing the disease chytridiomycosis	Yes	Yes	Infection of amphibians with chytrid fungus resulting in chytridiomycosis
Infection of native plants by *Phytophthora cinnamomi*	Yes	Yes	Dieback caused by the root-rot fungus (*Phytophthora cinnamomi*)
Introduction and establishment of Exotic Rust Fungi of the order Pucciniales pathogenic on plants of the family Myrtaceae	Yes	Yes	-
Invasion and establishment of exotic vines and scramblers	Yes	Yes	-
Invasion and establishment of Scotch Broom (*Cytisus scoparius*)	Yes	Yes	-
Invasion of native plant communities by African Olive *Olea europaea* subsp. *cuspidata* (Wall. ex G. Don) Cif.	Yes	Yes	-
Invasion of native plant communities by *Chrysanthemoides monilifera*	Yes	Yes	-
Invasion of native plant communities by exotic perennial grasses	Yes	Yes	-
Invasion, establishment and spread of Lantana (*Lantana camara* L. *sens*. Lat)	Yes	Yes	-
Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants	Yes	Yes	Loss and degradation of native plant and animal habitat by invasion of escaped garden plants, including aquatic plants
Loss of hollow-bearing trees	Yes	Yes	-
Predation by *Gambusia holbrooki* Girard 1859 (Plague Minnow or Mosquito Fish)	Yes	Yes	-
Predation by the European Red Fox *Vulpes vulpes* (Linnaeus 1758)	Yes	Yes	-
Predation by the Feral Cat *Felis catus* (Linnaeus 1758)	Yes	Yes	-

Key threatening process	TSC Act	BC Act	EPBC Act equivalent
Predation, habitat degradation, competition and disease transmission by Feral Pigs, *Sus scrofa* Linnaeus 1758	Yes	Yes	Predation, Habitat Degradation, Competition and Disease Transmission by Feral Pigs
Removal of dead wood and dead trees	Yes	Yes	-

7.6 Thresholds for assessing unavoidable impacts

The unavoidable construction impacts of the Project have been considered and a determination made of the assessment and offsetting requirements of such impacts. These requirements are:

(i) impacts that require further consideration by the consent authority

(ii) impacts for which the assessor is required to determine an offset

(iii) impacts for which the assessor is not required to determine an offset

(iv) impacts that do not require further assessment.

A discussion of each of these components is provided in Table 7-8 and their location is shown on Figure 7-1. The Biodiversity Credit Report generated by the Project is provided in Appendix A of this report.

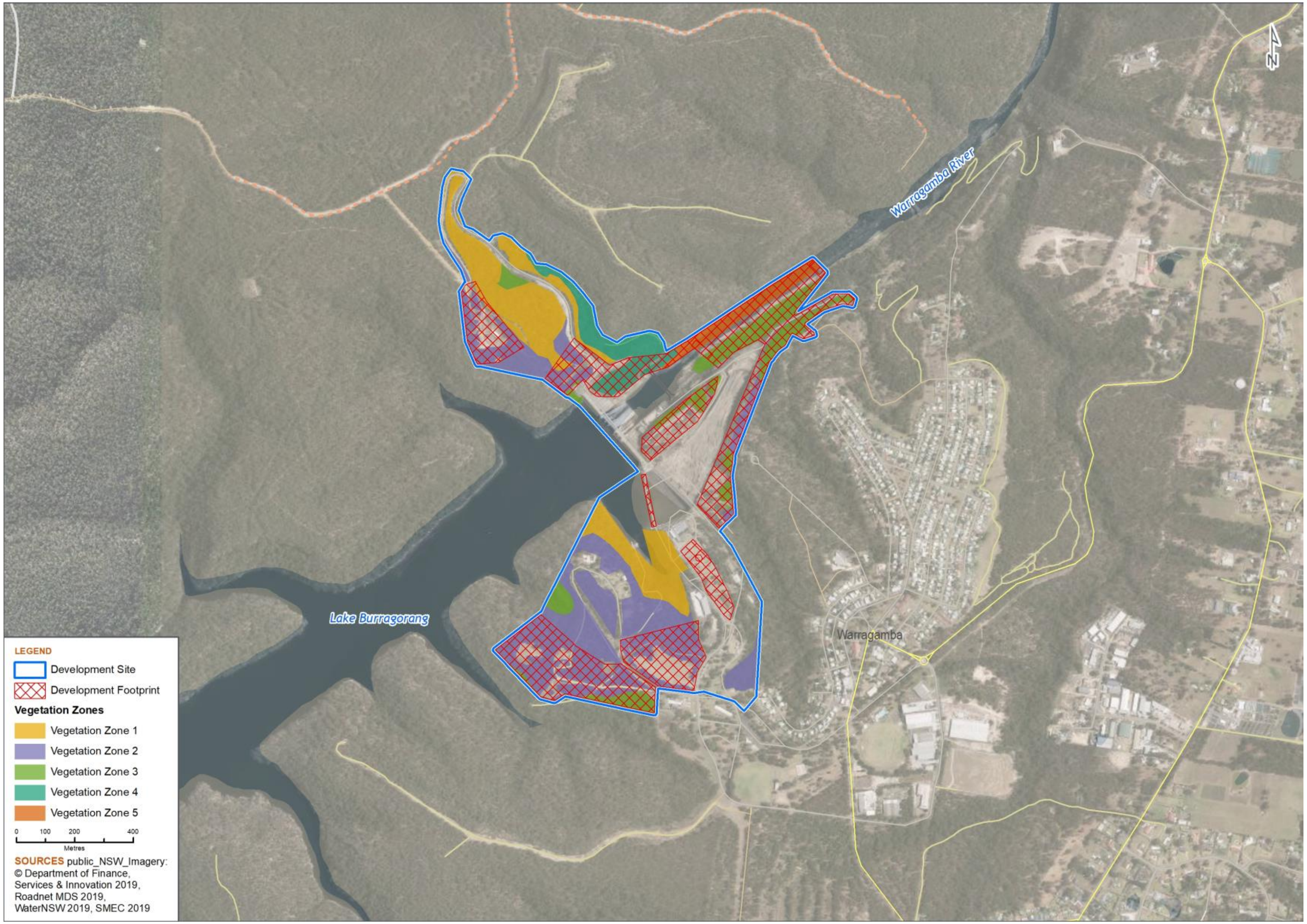
Table 7-8. Summary of areas directly impacted by the proposed works

Threshold	Biodiversity value	Criterion	Applicable to the project
I. Impacts that require further consideration by the consent authority	Landscape Features	Impacts that will substantially reduce the width of vegetation in the riparian buffer zone bordering rivers and streams 4th order or greater.	Yes – the Project will impact and remove vegetation within the riparian buffer zone of a 9th order stream.
		Impacts in state biodiversity links.	No.
		Impacts on important wetlands and their buffers.	No.
		Impacts in the buffer zone along estuaries.	No.
	Native Vegetation	Any impact on a CEEC (unless specifically excluded in the SEARs) because it is likely to: ▪ cause the extinction of the CEEC from the IBRA subregion, or ▪ significantly reduce the viability of the CEEC.	Yes – the Project will impact upon HN604 which is a component PCT of Shale Sandstone Transition Forest CEEC nominated within the SEARs. The occurrence of SSTF is considered an important area of the CEEC being on the edge of the community's range. As such, the Project has the potential to significantly reduce the viability of the CEEC in the IBRA subregion.
		Any impact on an EEC nominated in the SEARs because it is likely to: ▪ cause the extinction of the EEC from the IBRA subregion, or ▪ significantly reduce the viability of the EEC.	No.
	Species and Populations	Impacts on areas of land that the Minister for Environment has declared as critical habitat in accordance with section 46 of the TSC Act and which is listed on the Register of Critical Habitat in NSW.	No.
		Any impact on a critically endangered species (unless specifically excluded in the SEARs).	No.

Threshold	Biodiversity value	Criterion	Applicable to the project
		Any impact on a threatened species or population nominated in the SEARs because it is likely to: ▪ cause the extinction of a species or population from an IBRA subregion, or ▪ significantly reduce the viability of a species or population.	No.
		Any impact on a threatened species or population that has not previously been recorded in the IBRA subregion according to records in the NSW Wildlife Atlas.	No.
II. Impacts for which the assessor is required to determine an offset	Landscape Features	Not applicable to the FBA.	N/A
	Native Vegetation	Impacts on CEECs that are specifically excluded from requiring further consideration in the SEARS.	No. The Shale Sandstone Transition Forest CEEC occurring within the Wollemi IBRA subregion is not excluded from further consideration in the SEARS.
		Impacts on PCTs that are EECs not specifically nominated as requiring further consideration in the SEARs.	No.
		Impacts on PCTs associated with threatened species habitat and which have a site value score ≥17.	Yes. All PCTs have a site value score of ≥17 and are associated with threatened species habitat.
	Species and populations	Impacts on a critically endangered species that is specifically excluded from requiring further consideration in the SEARS.	No.
		Impacts on threatened species, populations and threatened species habitat not specifically nominated as requiring further consideration in the SEARs.	Yes. The Project will impact upon threatened species and their habitat not specifically nominated requiring further consideration in the SEARs.
		Impacts on threatened species habitat associated with a PCT and which has a site value score of ≥17.	Yes. All PCTs have a site value score of ≥17 and are associated with threatened species habitat.
III. Impacts for which the assessor is not required to determine an offset	Landscape Features	Not applicable to the FBA.	N/A
	Native Vegetation	Impacts on PCTs that: ▪ have a site value score <17, or ▪ are not identified as CEECs/EECs.	No – all PCTs have a site value score >17.
		Impacts on PCTs that are not associated with threatened species habitat and are not identified as CEECs / EECs.	No – all PCTs within the development site are associated with threatened species habitat.
	Species and Populations	Impacts on non-threatened species and populations that do not form part of a CEEC or EEC.	Yes – the Project will impact upon non-threatened species within the three non-threatened PCTs.
		Impacts on threatened species habitat associated with a PCT within a vegetation zone with a site value score of <17.	No – all PCTs have a site value score >17.
IV. Impacts that do not require further	Landscape Features	Areas of land without native vegetation, unless the area of land requires assessment under the SEARs issued for the Major Project.	No areas of cleared land have been specifically outlined within the SEARs are requiring assessment.

Threshold	Biodiversity value	Criterion	Applicable to the project
assessment by the assessor	Native Vegetation	Areas of land without native vegetation, unless the area of land requires assessment under the SEARs issued for the major project.	No areas of cleared land have been specifically outlined within the SEARs are requiring assessment.
	Species and populations	Not applicable since all areas of land must be assessed for threatened species, even if they do not contain native vegetation.	N/A

Figure 7-1. Unavoidable impacts



7.7 Impacts that require further consideration

7.7.1 Landscape features

7.7.1.1 Impacts reducing the width of riparian buffer of important rivers, streams, and estuaries

This consideration applies to impacts of development on areas within native vegetation within:

a. 20 metres either side of 4th or 5th order stream
b. 50 metres either side of a 6th order stream or higher
c. 50 metres around an estuarine area.

The Project will impact upon native vegetation within 50 metres of the riparian buffer of a 9th order stream (the Warragamba River). As such, the following matters outlined within Table 7-9 are to be considered.

Table 7-9. Further consideration of impacts to riparian buffers

FBA section	Criterion	Consideration
9.2.3.3	(a) The name and stream order of the riparian buffer being impacted.	Warragamba River is a 9th order stream at the extent at which the impact will occur.
	(b) The total area of the riparian buffer that is impacted by the Major Project, the extent to which the width of the link will be reduced and over what length, and size of the gaps being created or expanded.	The Project will remove 7.01 ha of the riparian buffer.
	(c) The PCT and condition of the vegetation in the riparian buffer being impacted.	The Project will remove a total of 7.01 ha of vegetation from within the riparian buffer. Specifically, this includes the removal of: ▪ 0.66 ha of HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion (moderate to good condition) ▪ 3.11 ha of HN568: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion (moderate to good condition) ▪ 3.06 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion (low condition) ▪ 0.18 ha of HN566: Red Bloodwood - Scribbly Gum Heathy woodland on sandstone plateaux of the Sydney Basin Bioregion (moderate to good condition).
	(d) Any direct impacts on wetlands or watercourses downstream of the development site.	A comprehensive Soil and Water Management Plan would be prepared which would include the following considerations to minimise downstream water quality impacts: ▪ Erosion and sedimentation control measures for cleared areas around the dam ▪ Water management systems for the concrete batch plant sites and other auxiliary construction features ▪ Coffers dams and water management systems for the concrete works on the dam wall ▪ Construction flood management plan.
	(e) Mitigation measures proposed to minimise the impact on the biodiversity values of the riparian or downstream area.	Mitigation measures proposed to minimise the impact on the biodiversity values of the riparian area are discussed in Chapter 6 of this report. Mitigation measures proposed to minimise the impact on the biodiversity values of the downstream area are discussed in a separate downstream BAR.

7.7.2 Native vegetation

Impacts on native vegetation that require further consideration include impacts on:

a) Any CEEC, unless the CEEC is specifically excluded by the SEARs
b) An EEC specifically nominated in the SEARs as an EEC that is likely to become extinct or have its viability significantly reduced in the IBRA subregion if it is impacted on by the development.

The Project would directly impact upon HN604: Turpentine – Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion, equivalent to Shale Sandstone Transition Forest in the Sydney Basin Bioregion, listed as an EEC under the BC Act and as a CEEC under the EPBC Act.

Table 7-10. Further consideration of impacts to Shale Sandstone Transition Forest CEEC

Criteria (FBA Section 9.2.4.2)	Consideration
(a) the area and condition of Shale Sandstone Transition Forest CEEC to be impacted directly and indirectly by the proposed development	The Project would clear 1.64 ha of moderate to good condition Shale Sandstone Transition Forest CEEC. A further 8.12 ha of moderate to good condition HN604 occurs within the study area and may be indirectly impacted by the Project as a result of edge effects if mitigation measures are not applied. It should be noted that there is the potential for impacts to the CEEC to be minimised during detailed design phase of the Project.
(b) the extent and overall condition of Shale Sandstone Transition Forest CEEC within an area of 1000 ha and then 10,000 ha surrounding the proposed development footprint.	The GIS layer 'Map of Critically Endangered Ecological Communities NSW Version 5' (OEH, 2018b) was used to calculate the area of Shale Sandstone Transition Forest CEEC within 1,000 ha and 10,000 ha of the development footprint. According to this mapping there is: ▪ 0 ha of the CEEC within a buffer of 1,000 ha of the development footprint ▪ 509.91 ha of the CEEC within a buffer of 10,000 ha of the development footprint. It should be noted that the Shale Sandstone Transition Forest CEEC within the study area was not mapped by the OEH GIS layer. As such, it is possible that additional extents of the CEEC occur within the 1,000 ha and 10,000 ha areas. The GIS layer 'Map of Critically Endangered Ecological Communities NSW Version 5' does not provide information on the 'vegetation condition' for each mapped occurrence of the CEEC. However, according to the Approved Conservation Advice, Shale Sandstone Transition CEEC '*has been identified as one of the most fragmented communities in the Sydney region, with substantial exposure of edges to cleared or degraded land*' (NSW Scientific Committee, 2014). A desktop analysis of the mapped occurrences of the CEEC within the 1,000 ha and 10,000 ha buffered areas identified many patches occurring as linear fragments along roads or fragmented patches occurring adjacent urban development or cleared land. Most of these mapped occurrences occur on private landholdings in Silverdale and Wallacia, to the east of the development site. The condition of these patches is likely to be of low quality due to disturbance regimes (i.e. mowing or grazing). Some of these mapped occurrences appear to be on land where the tree canopy cover is sparse. Of the total 509.91 ha of Shale Sandstone Transition Forest CEEC mapped within the 10,000 ha buffered areas, approximately 107 ha is conserved in Gulguer Nature Reserve. This patch of the CEEC within the 1,000 ha and 10,000 ha buffer is likely to be in good condition due to being largely intact with a relatively dense tree canopy cover.
(c) an estimate of the extant area and overall condition of Shale Sandstone Transition Forest CEEC remaining in the IBRA subregion after the impact of the proposed development has been taken into consideration	The GIS layer 'Map of Critically Endangered Ecological Communities NSW Version 5' was used to calculate the area of Shale Sandstone Transition Forest CEEC in the IBRA subregions which overlap with the development site. According to this mapping there is 0.001 ha of Shale Sandstone Transition Forest CEEC within the Burragorang IBRA subregion and 203.94 ha within the Wollemi IBRA subregion. The majority of Shale Sandstone Transition Forest CEEC occurs within the Cumberland IBRA subregion (11,313.78 ha). This GIS layer is likely to contain inaccuracies in extent and does not provide an indication of the condition of the mapped occurrences of the CEEC. It is likely that condition is variable depending on the level of disturbance within and surrounding the CEEC however it is believed that the majority of CEEC would be in a disturbed or degraded condition.

Criteria (FBA Section 9.2.4.2)	Consideration
(d) the development proposal's impact on: (i) abiotic factors critical to the long-term survival of Shale Sandstone Transition Forest CEEC. For example, will the impact lead to a reduction of groundwater levels or substantial alteration of surface water patterns?	It is not anticipated that, with the inclusion of appropriate mitigation measures, that the Project would alter abiotic factors critical to the long term survival of the CEEC.
(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	The Project would clear 1.64 ha of moderate to good condition Shale Sandstone Transition Forest CEEC resulting in a loss of all characteristic and functionally important species within that area. 8.12 ha of Shale Sandstone Transition Forest CEEC within the study area will be retained.
(iii) the quality and integrity of an occurrence of Shale Sandstone Transition Forest CEEC through impacts such as, *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 Shale Sandstone Transition Forest CEEC	8.12 ha of Shale Sandstone Transition Forest CEEC within the study area would be retained. Mitigation measures are proposed to avoid or minimise indirect impacts resulting from construction within the development site such as weed and disease control.. The CEEC within the study area was found to be moderate to good quality due to having high species diversity, structural intactness and a demonstrated resilience to existing disturbances posed by the current operation of the dam. It is not expected that operation of the dam would result in changes that may reduce the quality and integrity of remaining stands of the CEEC within the study area to some degree.
(e) direct or indirect fragmentation and isolation of an important area of the Shale Sandstone Transition Forest CEEC	An important area is defined in the FBA as being '*an area of the CEEC that is necessary for the entities' long-term persistence and recovery. This may include areas identified in recovery plans, and/or an area large in comparison to other stands of the CEEC or occurrences of the CEEC at the limit of the community's range*'. The Shale Sandstone Transition Forest within the study area meets the definition of 'important area' as defined by FBA because the occurrence of the CEEC within the development site occurs at the edge of the communities known range. Area of this CEEC near or at the limit of its range are also considered important as a result of its compositional rarity and potential genetic significance. The proposal will result in the direct removal of 1.64 ha. Given the connectivity of native vegetation to the north of the development site, the Project will not isolate the CEEC from other areas of native vegetation as the patch of Shale Sandstone Transition Forest will stay contiguous with vegetation around the development site.
(f) the measures proposed to contribute to the recovery of the Shale Sandstone Transition Forest CEEC in the IBRA subregion	Offsets will be provided for the impact on the CEEC in accordance with the BOS.

7.7.3 Threatened species and populations

Impacts on threatened species that require further consideration include impacts on:

a) any impacts on critically endangered species, unless the critically endangered species is specifically excluded in the SEARs
b) on a threatened species or population that is specifically nominated by the SEARs as a species or population that is likely to become extinct or have its viability significantly reduced in the IBRA subregion if it is impacted on by the development, or
c) where the survey or expert report undertaken confirms that the threatened species is present in the proposed development site, and the threatened species has not previously been recorded in the IBRA subregion according to records in the NSW Wildlife Atlas.

The Project will impact upon eight threatened species listed within Attachment C to the SEARs.

These species are:

- *Epacris purpurascens* var. *purpurascens*
- *Hibbertia puberula*
- *Melaleuca deanei*
- *Ancistrachne maidenii*
- *Tetratheca glandulosa*
- *Gyrostemon thesioides*
- *Dillwynia tenuifolia*
- *Rhodamnia rubescens*

Targeted threatened species searches were not undertaken because the size and extent of the areas to be impacted by the Project made this approach impractical. The above species were hence 'assumed present' based on the presence of suitable habitat within the development site and known records within the Wollemi IBRA subregion and Burragorang IBRA subregion.

7.7.3.1 Further consideration of impacts to *Epacris purpurascens* var. *purpurascens*

Table 7-11 details the further consideration of impacts to *Epacris purpurascens* var. *purpurascens* in accordance with Section 9.2.5 of the FBA.

Table 7-11. Further consideration of impacts to Epacris purpurascens *var.* purpurascens

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	The species is currently known from approximately 30 locations and the size of the populations, where known, vary from very small (1-5 plants) to greater than 1,000 individuals (NSW Scientific Committee 1999b). Populations are known from several reserves however the largest known populations occur within Sydney Catchment Authority areas, west of Wollongong (NSW Scientific Committee 1999b). In some instances, populations may occur locally as the dominant shrub, as localised small groupings, or be of high numbers/low frequency – the population being scattered over a wide area (NPWS, 2002a). The size of the local population affected by the Project is unknown. No individuals of *Epacris purpurascens* var. *purpurascens* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. As per Section 6.5.1.9 of the FBA, this species has been assumed to be present within the development site. According to a search of BioNet Atlas of NSW Wildlife Database, there is one record within 10 km of the study area. This record is within the Burragorang IBRA subregion approximately 4 km south west of the study area (OEH 2017b). In accordance with the FBA, 12.55 ha of suitable habitat would be cleared by the Project. This comprises: ▪ 0.31 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion ▪ 12.25 ha of HN566: Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion. It is recommended that targeted surveys be carried out in line with relevant guidelines for *E. purpurascens var. purpurascens* within the development site. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project for this species.
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant	A total of 12.55 ha of potential habitat for *E. purpurascens* var. *purpurascens* would be cleared from the development site for the project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects. The Project is expected to have some effect on the lifecycle, genetic diversity and long-term evolutionary development of *E. purpurascens* var. *purpurascens* as a reduction of suitable habitat will reduce the area of potential occupancy for the species. However this is not expected to be significant given the extent of suitable habitat in the surrounding area.

Criteria	Consideration
– pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle ▪ seedbanks ▪ recruitment, and ▪ interactions with other species (for example,. pollinators, host species, mycorrhizal associations)	The size of the local population affected by the Project is unknown. No individuals of *E. purpurascens* var. *purpurascen*s were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to a search of BioNet Atlas of NSW Wildlife Database, there are three records within 10 km of the study area, most recent being recorded in February 2019. Two records are within the Burragorang IBRA subregion approximately 4 km south west of the study area (OEH 2017b). This record occurs outside the study area and will not be directly impacted by the project. The third, more recent record occurs approximately 5 km south of the study area. The Project will clear land considered to be suitable habitat for this species. This will reduce areas of potential occupancy for the species may have implications for the pollination cycle, seedbanks, recruitment and interactions with other species although the extent of impact on these processes is unknown. However this is not expected to be significant given the extent of suitable habitat in the surrounding area.
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *E. purpurascens* var. *purpurascens* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to NPWS (2002a), the distance between groups of plants which creates isolation is unknown as pollinators are unknown. However, at least some interaction between individuals is likely over distances of up to 250 m given that wind and water are known dispersal mechanisms. It is unlikely that the Project will cause significant additional fragmentation and isolation of a local population (should it exist) given the availability of suitable habitat within the locality.
(e) the relationship of the local population to other populations of the species	It is not known the relationship of the local population (if any) to other populations of the species, including the BioNet Atlas of NSW Wildlife Database record that is four km south-west of the study area.
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	The size of the local population of *E. purpurascens* var. *purpurascens* is unknown. . It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects and weed invasion.
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*E. purpurascens* var. *purpurascens* has been allocated to the site-managed stream of the SoS program. This species requires site-based management in order to secure it from extinction in NSW for 100 years. There are no conservation sites for this species within the study area. Offsets will be provided for the impact on *E. purpurascens* var. *purpurascens* in accordance with the BOS.

7.7.3.2 Further consideration of impacts to *Hibbertia puberula*

Table 7-12 details the further consideration of impacts to *Hibbertia puberula* in accordance with Section 9.2.5 of the FBA.

Table 7-12. Further consideration of impacts to Hibbertia puberula

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	Early records of this species are from the Hawkesbury River area and Frenchs Forest in northern Sydney, South Coogee in eastern Sydney, the Port Hacking River area in south Sydney and the Blue Mountains (OEH 2019f). The size of the local population affected by the Project is unknown. No individuals of *Hibbertia puberula* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to a search of BioNet Atlas of NSW Wildlife Database, the nearest records are approximately 13 km to the north between Warrimoo and Blaxland in the lower Blue Mountains (OEH 2017b). These records fall within the Wollemi IBRA subregion. In accordance with the FBA, a total of 19.96 ha of potential habitat would be cleared by the Project. This comprises: ▪ 0.31 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion ▪ 12.25 ha of HN566: Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion ▪ 5.77 ha of HN568: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion ▪ 1.64 ha of HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion. It is recommended that targeted surveys be carried out in line with relevant guidelines for *H. puberula* within the development site. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project for this species.
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	A total of 19.96 ha of potential habitat for *H. puberula* would be cleared from the development site for the Project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects.
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle ▪ seedbanks ▪ recruitment, and	The size of the local population affected by the Project is unknown. No individuals of *H. puberula* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to a search of BioNet Atlas of NSW Wildlife Database, the nearest records of *H. puberula* are approximately 13 km to the north east where there are two records between Warrimoo and Blaxland in the lower Blue Mountains (OEH, 2017b). These records occur outside the study area and will not be impacted by the Project. However, the Project will clear areas considered to be potential habitat for this species. This will reduce areas of potential occupancy for the species and this may have implications for the pollination cycle, seedbanks, recruitment and interactions with other species although the extent of impact on these processes is unknown as there is no available information on how this species responds to disturbances. There is also no information on the pollination cycle, seedbanks and recruitment of this species.

Criteria	Consideration
▪ interactions with other species (e.g. pollinators, host species, mycorrhizal associations)	
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *H. puberula* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. It is unlikely that the Project will cause significant fragmentation and isolation of a local population (should it exist) given the availability of potential habitat within the locality.
(e) the relationship of the local population to other populations of the species	The size of the local population affected by the Project is unknown. No individuals of *H. puberula* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The relationship of the local population (if any) to other populations of the species is unknown as there is a lack of reliable distributional information (OEH, 2019f).
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	Existing habitat is threatened by urban or rural development while existing populations are threatened by habitat loss and weed invasion (OEH 2019f). *H. puberula* is also threatened by the very low number of records of records for the species suggesting that it would be threatened by demographic and environmental stochasticity (NSW Scientific Committee, 2003). The Project, without mitigation, may lead to an increase in threats and indirect impacts that may lead to a decrease in the viability of the local population. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects and weed invasion.
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*H. puberula* has been allocated to the site-managed stream of the SoS program. This species requires site-based management in order to secure it from extinction in NSW for 100 years. There are no conservation sites for this species within the study area. Offsets will be provided for the impact on *H. puberula* in accordance with the BOS.

7.7.3.3 Further consideration of impacts to *Melaleuca deanei*

Table 7-13 details the further consideration of impacts to *Melaleuca deanei* in accordance with Section 9.2.5 of the FBA.

Table 7-13. Further consideration of impacts to Melaleuca deanei

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	*Melaleuca deanei* is known mainly from the Ku-ring-gai/Berowra and Holsworthy/Wedderburn areas, but there are also isolated occurrences in the Blue Mountains, Nowra and Central Coast areas (OEH 2019b). It is known from approximately 94 populations(Bremner and Goeth 2010). The size of the local population affected by the Project is unknown. No individuals of *M. deanei* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. One individual was recorded incidentally outside the study area near Medlow Gap, approximately 32 km west from the study area. According to a search of BioNet Atlas of NSW Wildlife Database, the nearest records of *M. deanei* to the development site are approximately 15 km to the north, between Glenbrook and Blaxland. These records are within the Wollemi IBRA subregion (OEH 2017b). In accordance with the FBA, a total of 12.55 ha of suitable habitat would be cleared by the Project. This comprises:

Criteria	Consideration
	▪ 0.31 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion ▪ 12.25 ha of HN566: Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion. It is recommended that targeted surveys be carried out in line with relevant guidelines for *M. deanei* within the development site. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project for this species.
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	A total of 12.55 ha of potential habitat for *M. deanei* would be cleared from the development site for the Project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects.
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle ▪ seedbanks ▪ recruitment, and ▪ interactions with other species (e.g. pollinators, host species, mycorrhizal associations)	The size of the local population affected by the Project is unknown. No individuals of *M. deanei* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. *M. deanei* is a clonal species with the ability to re-sprout from a swollen rootstock (lignotuber) to produce coppiced growth, and it can also sucker from its rootstock (Felton 1993). The species seems to breed successfully very rarely and mostly subsists vegetatively as clones originating from lignotubers (Myerscough, 1998). The exact age at which *M. deanei* starts to produce flowers and seed is unknown, with a number of observers giving different estimates (Bremner & Goeth, 2010). It is also not known exactly how *M. deanei* is pollinated, though insects have been suggested and self-fertilisation cannot be ruled out (Turnball and Doran 1997 cited in Virtue (1991)). Seeds in *M. deanei* are produced in woody capsules held in the canopy for several years, until dehydration allows the capsules to open and release between 500-600 seeds (Felton 1993). Seed release is triggered by fire, occasionally also by drought or frost, and is dispersed by wind (Virtue 1991). It is unknown whether *M. deanei* possesses a persistent soil seedbank or if seeds retain viability beyond at least nine weeks (Felton, 1993). Fire and possibly other physical disturbances that increase light levels without impacting upon the soil may play a role in providing for the recruitment and long-term persistence of the species (Bremner and Goeth 2010). Clearing for the Project will reducing areas of potential habitat for *M. deanei*. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat for any residual plant populations within the study area through indirect impacts to habitat such as edge effects.
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *M. deanei* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. It is unlikely that the Project will cause significant fragmentation and isolation of a local population (should it exist) given the availability of suitable habitat within the locality.

Criteria	Consideration
(e) the relationship of the local population to other populations of the species	The size of the local population affected by the Project is unknown. No individuals of *M. deanei* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. One individual was recorded incidentally outside the study area near Medlow Gap, approximately 32 km west from the study area. It is not known the relationship of the local population (if any) to other populations of the species, including the closest record of the species being the BioNet Atlas of NSW Wildlife Database record that is approximately 15 km to the north of the study area (OEH 2017b) or the incidental record located near Medlow Gap, approximately 32 km west from the study area.
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	The risk of extinction to any local population of *M. deanei* is considered high due to low population numbers and the low fecundity and viability exhibited by the species where the species appears to have a limited capacity to regenerate or breed successfully, with infrequent flowering, poor seed production and poor seedling vigour (Myerscough 1998, Bremner and Goeth 2010). Other key threats to *M. deanei* include habitat loss, fragmentation and degradation due to infrastructure maintenance activities or urban development, weed spraying, rubbish dumping and creation of informal tracks by 4WDs and trail bikes, weed invasion, hybridisation with other species of *Melaleuca* and *Callistemon* and inappropriate fire regimes (Bremner and Goeth 2010). Without appropriate mitigation. the Project may lead to an increase in the indirect impacts that may lead to a decrease in the viability of the local population. However, with application of appropriate mitigation measures it is not expected that the Project will decrease the viability of a local population (if present).
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*M. deanei* has been allocated to the site-managed stream of the SoS program. This species requires site-based management in order to secure it from extinction in NSW for 100 years. There are no conservation sites for this species within the study area. A National and NSW State Recovery Plan under the EPBC Act and BC Act for *M. deanei* (DECCW 2010b) details eight objectives in order to recover the species: ▪ Coordinate the recovery of *M. deanei* ▪ Protect known occurrences of M. deanei using land-use and conservation planning mechanisms ▪ To identify and minimise the threats operating at *M. deanei* sites ▪ To improve awareness of *M. deanei* amongst operational staff working within easements, walking tracks and fire trails Offsets will be provided for the impact on *M. deanei* in accordance with the BOS.

7.7.3.4 Further consideration of impacts to *Ancistrachne maidenii*

Table 7-14 details the further consideration of impacts to *Ancistrachne maidenii* in accordance with Section 9.2.5 of the FBA.

Table 7-14. Further consideration of impacts to Ancistrachne maidenii *(A.A. Ham.) Vickery*

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	*Ancistrachne maidenii* (A.A. Ham.) Vickery is known from around northern Sydney, around St Albans, Mt White, Maroota, Berowra areas and to the Shannon Creek area south-west of Grafton (OEH 2017a). The size of the local population affected by the Project is unknown. No individuals of *A. maidenii* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The BioNet Atlas of NSW Wildlife Database contains one record for *A. maidenii* within 10 km of the study area. This record is approximately two km north west of the study area, within the Wollemi IBRA subregion (OEH 2017b). In accordance with the FBA, a total of 12.55 ha of suitable habitat would be cleared by the Project. This comprises: ▪ 0.31 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion ▪ 12.25 ha of HN566: Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion It is recommended that targeted surveys be carried out in line with relevant guidelines for *A. maidenii* within the development site. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project for this species.
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	A total of 12.55 ha of suitable habitat for *A. maidenii* would be cleared from the development site for the Project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects.
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle ▪ seedbanks ▪ recruitment, and ▪ interactions with other species (e.g. pollinators, host species, mycorrhizal associations)	The size of the local population affected by the Project is unknown. No individuals of *A. maidenii* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The Project will clear areas considered to be potential habitat for this species. This will reduce areas of potential occupancy for the species and this may have implications for the pollination cycle, seedbanks, recruitment and interactions with other species although the extent of impact on these processes is unknown. This is because there is little to no information available in scientific literature on how the species responds to disturbance as well as limited information on the general ecology and biology of the species.
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *A. maidenii* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The BioNet Atlas of NSW Wildlife Database contains one record for *A. maidenii* within 10 km of the study area. This record is approximately 2 km north west of

Criteria	Consideration
	the study area, within the Wollemi IBRA subregion (OEH 2017b). This record occurs outside the study area and will not be directly impacted by the Project. It is unlikely that the Project will cause additional significant fragmentation and isolation of a local population (should it exist) given the availability of suitable habitat within the locality.
(e) the relationship of the local population to other populations of the species	The size of the local population affected by the Project is unknown. No individuals of *A. maidenii* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The relationship of the local population (if any) to other populations of the species is unknown, including to the BioNet Atlas of NSW Wildlife Database record that is two km northwest of the study area (OEH 2017b). There is no information as to the genetic connectedness of populations.
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	Known threats to *A. maidenii* include habitat loss and degradation due to infrastructure maintenance activities or urban development, weed spraying and inappropriate fire regimes (OEH 2017a). Previous surveys undertaken by Botanists along urban creek lines have failed to record the species, suggesting that this species is sensitive to pollution or weed invasion (NSW Scientific Committee 1999a). The Project could lead to an increase in threats and indirect impacts that may lead to a decrease in the viability of the local population. Application of mitigation measures will reduce the likelihood of such indirect impacts occurring. The size and distribution of any local population of *A. maidenii* is unknown and therefore the extent to which the Project may affect the viability of the local population cannot be determined.
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*A. maidenii* has been allocated to keep-watch stream of the SoS program. The species action statement aims to ensure the security of this species in the long-term. There are no identified conservation sites for this species, but a number of state-wide actions have been identified as follows: ▪ Undertake surveys of potential habitat. ▪ Undertake conservation status review once surveys of potential habitat are completed. ▪ Develop actions for protection and management once surveys of potential habitat are completed. ▪ Ensure staff undertaking track and roadside maintenance activities are aware of species, its habitat and habitat requirements. ▪ Investigate habitat requirements. Offsets will be provided for the impact on *A. maidenii* in accordance with the BOS.

7.7.3.5 Further consideration of impacts to *Tetratheca glandulosa*

Table 7-15 details the further consideration of impacts to *Tetratheca glandulosa* in accordance with Section 9.2.5 of the FBA.

Table 7-15. Further consideration of impacts to Tetratheca glandulosa Sm.

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	There are approximately 150 known populations of *Tetratheca glandulosa* Sm. Known population occur at Sampsons Pass (Yengo National Park), West Pymble (Lane Cove National Park), Ingleside (Pittwater Local Government Area) and East Kurrajong (Wollemi National Park) (OEH 2019g). The size of the local population affected by the Project is unknown. No individuals of *T. glandulosa* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to a search of BioNet Atlas of NSW Wildlife Database, there are three records for *T. glandulosa* in the Blue Mountains National Park. Two of these

Criteria	Consideration
	records are approximately 13 km to the north west and one record is four kilometres to the north of the study area (OEH 2017b). All three of these records are in the Wollemi IBRA subregion. There are also three records for *T. glandulosa* in the Nattai National Park, approximately 20 km to the south of the study area in the Burragorang IBRA subregion (OEH 2017b). In accordance with the FBA, a total of 19.96 ha of potential habitat would be cleared by the Project. This comprises: ▪ 0.31 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion ▪ 12.25 ha of HN566: Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion ▪ 5.77 ha of HN568: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion ▪ 1.64 ha of HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion It is recommended that targeted surveys be carried out in line with relevant guidelines for *T. glandulosa* within the development site. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project for this species.
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	A total of 19.96 ha of suitable habitat for *T. glandulosa* would be cleared from the development site for the Project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects.
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle ▪ seedbanks ▪ recruitment, and ▪ interactions with other species (e.g. pollinators, host species, mycorrhizal associations)	The size of the local population affected by the Project is unknown. No individuals of *T. glandulosa* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The BioNet Atlas of NSW Wildlife Database contains three records for *T. glandulosa* in the Blue Mountains National Park. Two of these records are approximately 13 kilometres to the north west and one record is four kilometres to the north of the development site (OEH 2017b). All three of these records are in the Wollemi IBRA subregion. There are also three records for *T. glandulosa* in the Nattai National Park, approximately 20 km to the south of the development site in the Burragorang IBRA subregion (OEH 2017b). The records occur outside the study area and will not be directly impacted by the Project. The Project will clear areas considered to be suitable habitat for this species. This will reduce areas of potential occupancy for the species and this may have implications for the pollination cycle, seedbanks, recruitment and interactions with other species although the extent of impact on these processes is likely to be minimal due to the. presence of a broad area of linked suitable habitat within a 10 km radius.
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *T. glandulosa* were recorded during vegetation surveys and targeted threatened species searches were not undertaken.

Criteria	Consideration
	It is unlikely that the Project will cause significant fragmentation and isolation of a local population (should it exist) given the availability of suitable habitat within the locality.
(e) the relationship of the local population to other populations of the species	The size of the local population affected by the Project is unknown. No individuals of *T. glandulosa* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The relationship of the local population (if any) to other populations of the species is unknown, including the BioNet Atlas of NSW Wildlife Database record 4 km from the study area (OEH 2017b). However, Keith *et al*. (1997) use a 1 km 'rule of thumb' to define a local population i.e. all *T. glandulosa* individuals occurring within one km of the subject site (between which there is likely to be genetic exchange e.g. pollen exchange) will constitute the 'local population' (OEH 2019g). Assuming that the BioNet Atlas of NSW Wildlife Database record four km from the study area is accurate (i.e. not denatured), with little to no GPS error, then it is likely to assume that the relationship of *T. glandulosa* (if there are any) within the study area would bear little to no relationship with the nearest known population at least with regard to the exchange of genetic material.
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	Known threats to *T. glandulosa* include habitat loss through vegetation clearing and habitat degradation, habitat fragmentation, intensified run off, competition from weeds, soil erosion and sedimentation and fire control activities (in particular hazard reduction activities and access track construction and maintenance) (OEH 2019g) (OEH n.d.c). The fact that the full extent of population is unknown is also listed as a threat (OEH n.d.c). 'High frequency fire resulting in the disruption of life cycle processes in plants and animals and loss of vegetation structure and composition' is a listed KTP considered pertinent to this species (OEH 2019g). It is unlikely that the Project will lead to an increase in threats and indirect impacts to the local population (should it exist) that would lead to a decrease in the viability of the local population given the availability of suitable habitat within the locality.
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*T. glandulosa* has been allocated to the site-managed stream of the SoS program. This species requires site-based management in order to secure it from extinction in NSW for 100 years. There are no conservation sites for this species within the study area. Offsets will be provided for the impact on *T. glandulosa* in accordance with the BOS.

7.7.3.6 Further consideration of impacts to *Gyrostemon thesioides*

Table 7-16 details the further consideration of impacts to *Gyrostemon thesioides* in accordance with Section 9.2.5 of the FBA.

Table 7-16. Further consideration of impacts to Gyrostemon thesioides (Hook.f.) A.S.George

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	Within NSW, *Gyrostemon thesioides* (Hook.f.) A.S.George has only been recorded at three sites near the Georges and Nepean Rivers (OEH 2019e). However, the species has not been recorded from the Nepean River for almost 90 years and the Georges River area for almost 30 years, despite searches being undertaken by botanists (NSW Scientific Committee 1998a). There is little to no information in scientific literature on the ecology and biology of this species. The size of the local population affected by the Project is unknown. No individuals of *G. thesioides* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to a search of BioNet Atlas of NSW Wildlife Database, the closest record is approximately 20 km to the west of the study area, within the Burragorang IBRA subregion (OEH 2017b).

Criteria	Consideration
	In accordance with the FBA, a total of 1.95 ha of potential habitat would be cleared by the Project. This comprises: ▪ 0.31 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion ▪ 1.64 ha of HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	A total of 1.95 ha of potential habitat for *G. thesioides* would be cleared from the development site for the Project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects.
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle ▪ seedbanks ▪ recruitment, and ▪ interactions with other species (e.g. pollinators, host species, mycorrhizal associations)	The size of the local population affected by the Project is unknown. No individuals of *G. thesioides* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to a search of BioNet Atlas of NSW Wildlife Database, the closest record is 20 km to the west of the development site, within the Burragorang IBRA subregion (OEH 2017b). This record occurs outside the development site and will not be directly impacted by the Project. The Project will clear areas considered to be suitable habitat for this species. It is unlikely that the Project will cause significant impacts to a local population (should it exist) given the availability of suitable habitat within the locality.
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *G. thesioides* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. It is unlikely that the Project will cause significant fragmentation and isolation of a local population (should it exist) given the availability of suitable habitat within the broader area.
(e) the relationship of the local population to other populations of the species	The size of the local population affected by the Project is unknown. No individuals of *G. thesioides* were recorded during vegetation surveys. Targeted threatened species searches were not undertaken. It is not known the relationship of the local population (if any) to other populations of the species, including the BioNet Atlas of NSW Wildlife Database record that is 20 km west of the development site (OEH 2017b).
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	Key threats for *G. thesioides* include land clearing and altered fire regimes (OEH n.d.b). The local population of *G. thesioides* is unknown and therefore the extent to which the Project will affect the viability of the local population cannot be ascertained. It is unlikely that the Project will cause significant increase in threats or indirect impacts on local population (should it exist) given the availability of suitable habitat within the broader area.

Criteria	Consideration
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*G. thesioides* has been allocated to the data deficient stream of the SoS program. Management objectives for this species include: ▪ Search for the species in suitable habitat in areas that are proposed for development or management actions, protect any such site found. ▪ When populations are identified, assess threats and develop management requirements for each. ▪ Investigate life history dynamics, including seed set and seed viability. Offsets will be provided for the impact on *G. thesioides* in accordance with the BOS.

7.7.3.7 Further considerations of impacts to *Dillwynia tenuifolia*

Table 7-17 details the further consideration of impacts to *Dillwynia tenuifolia* in accordance with Section 9.2.5 of the FBA.

Table 7-17. Further considerations of impacts to Dillwynia tenuifolia DC.

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	*Dillwynia tenuifolia* DC. is primarily known from the Cumberland Plain from Windsor and Penrith east to Dean Park near Colebee (OEH 2019). Other populations in western Sydney are recorded from Voyager Point and Kemps Creek in the Liverpool LGA, Luddenham in the Penrith LGA and South Maroota in the Baulkham Hills Shire (OEH 2019). Disjunct localities outside the Cumberland Plain include the Bulga Mountains at Yengo in the north, and Kurrajong Heights and Woodford in the Lower Blue Mountains (OEH, 2019). The size of the local population affected by the Project is unknown. No individuals of *D. tenuifolia* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. According to a search of BioNet Atlas of NSW Wildlife Database, the nearest record for *D. tenuifolia* to the study area is approximately 6.5 km to the east. This record is within the Burragorang IBRA subregion (OEH 2017b). In accordance with the FBA, a total of 12.55 ha of suitable habitat would be cleared by the Project. This comprises: ▪ 0.31 ha of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion ▪ 12.25 ha of HN566: Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	A total of 12.55 ha of suitable habitat for *D. tenuifolia* would be cleared from the development site for the Project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects.

Criteria	Consideration
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle ▪ seedbanks ▪ recruitment, and ▪ interactions with other species (e.g. pollinators, host species, mycorrhizal associations)	The size of the local population affected by the Project is unknown. No individuals of *D. tenuifolia* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The BioNet Atlas of NSW Wildlife Database lists the nearest record for *D. tenuifolia* as approximately 6.5 km to the east of the study area. This record is within the Burragorang IBRA subregion (OEH 2017b). BioNet Atlas of NSW Wildlife Database records occur outside the study area and known plants will not be directly impacted by the Project. The Project will clear areas considered to be suitable habitat for this species. *D. tenuifolia* is a fire-sensitive species with a facultative breeding system (being both self- and cross-pollination compatible) (Rymer *et al*. 2002). Pollinators are unknown however one study suggests pollination by native bees (Rymer *et al*. 2002). Seeds are hard-coated and are persistent in the soil seed bank, primarily dispersing via dehiscence over a short distance (generally 0-2 m) (OEH 2019) (Rymer *et al.* 2002). Secondary seed dispersal is by ants however is localised (OEH 2017, Rymer *et al*. 2002). The Project will reduce areas of potential occupancy for the species and this may have implications for the pollination cycle, seedbanks, recruitment and interactions with other species although the extent of impact on these processes is unknown. It is unlikely that the Project will significantly affect the ecology of the local population (should it exist) given the availability of suitable habitat within the broader area.
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *D. tenuifolia* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. It is unlikely that the Project will cause significant fragmentation and isolation of a local population (should it exist) given the availability of suitable habitat within the broader area.
(e) the relationship of the local population to other populations of the species	The size of the local population affected by the Project is unknown. No individuals of *D. tenuifolia* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. It is not known the relationship of the local population (if any) to other populations of the species, including the BioNet Atlas of NSW Wildlife Database record that is 6.5 km east of the Development Site (OEH 2017b).
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	Known threats to *D. tenuifolia* include habitat loss and degradation due to infrastructure maintenance activities or urban development, invasive grasses, slashing, grazing, trampling, partial clearance (e.g. removal or thinning of canopy) which may impact vegetation structure and habitat modification through inappropriate fire regimes, urban runoff, weeds, rubbish dumping, indiscriminate vehicular and pedestrian access (OEH 2019, NPWS 2002b). With the implementation of appropriate mitigation measures, the Project is unlikely to lead to an increase in threats and indirect impacts that may lead to a decrease in the viability of the local population. However, the local population of *D. tenuifolia* is unknown and therefore the extent to which the Project will affect the viability of the local population cannot be ascertained.
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*D. tenuifolia* has been allocated to keep-watch stream of the SoS program. The species action statement aims to ensure the security of this species in the long-term. There are no identified conservation sites for this species, but a number of state-wide actions have been identified. These include, but are not limited to: ▪ In circumstances where impacts are unavoidable, as part of any consent, approval or license that is issued, ensure that offset measures are undertaken within the priority conservation lands where practicable. ▪ DPIE will review the priority conservation lands and assessment methodology within five years of the date of approval of the Cumberland Plain Recovery Plan. ▪ Preferentially target any future investment associated with management to the priority conservation lands where practicable.

Criteria	Consideration
	▪ Support and promote the adoption of best practice standards for bushland management and restoration (as specified in Appendix 2 of the Cumberland Plain Recovery Plan) on public and private lands within the Cumberland Plain. Offsets will be provided for the impact on *D. tenuifolia* in accordance with the BOS.

7.7.3.8 Further consideration of impacts to *Rhodamnia rubescens*

Table 7-18 details the further consideration of impacts to *Rhodamnia rubescens* in accordance with Section 9.2.5 of the FBA.

Table 7-18. Further consideration of impacts to Rhodamnia rubescens

Criteria	Consideration
(a) the size of the local population directly and indirectly impacted by the development	*Rhodamnia rubescens* is a shrub or small tree that is currently known to occur in coastal districts north from Batemans Bay in NSW, to areas inland of Bundaberg in QLD. The size of the local population affected by the Project is unknown. No individuals of *R. rubescens* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The BioNet Atlas of NSW Wildlife Database contains two records for *R. rubescens* within 10 kilometres of the study area. These records are located approximately 4 kilometres north-east of the development site, within the Cumberland IBRA subregion (OEH 2017b). In accordance with the FBA, a total of 1.64 hectares of suitable habitat would be cleared by the Project. It is recommended that targeted surveys be carried out in line with relevant guidelines for *R. rubescens* within the development site. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project for this species.
(b) the likely impact (including direct and indirect impacts) that the development will have on the habitat of the local population, including but not limited to: (i) an estimate of the change in habitat available to the local population as a result of the proposed development (ii) the proposed loss, modification, destruction or isolation of the available habitat used by the local population, and (iii) modification of habitat required for the maintenance of processes important to the species' life cycle (such as in the case of a plant – pollination, seed set, seed dispersal, germination), genetic diversity and long-term evolutionary development.	A total of 1.64 hectares of suitable habitat for *R. rubescens* would be cleared from the development site for the Project. It is not anticipated that, with the inclusion of effective mitigation measures, that the Project will reduce the viability of adjacent suitable habitat within the study area through indirect impacts to habitat such as edge effects.
(c) the likely impact on the ecology of the local population. (ii) for flora, address how the proposal is likely to affect the ecology and biology of any residual plant population that will remain post development including where information is available: ▪ pollination cycle	The size of the local population affected by the Project is unknown. No individuals of *R. rubescens* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The BioNet Atlas of NSW Wildlife Database contains two records for *R. rubescens* within 10 km of the study area. These records are located approximately 4 kilometres north-east of the development site, within the Cumberland IBRA subregion (OEH 2017b). This record occurs outside the study area and will not be directly impacted by the Project. The Project will clear areas considered to be

Criteria	Consideration
▪ seedbanks ▪ recruitment, and ▪ interactions with other species (e.g. pollinators, host species, mycorrhizal associations)	suitable habitat for this species. This will reduce areas of potential occupancy for the species and this may have implications for the pollination cycle, seedbanks, recruitment and interactions with other species although the extent of impact on these processes is unknown. This is because there is little to no information available in scientific literature on how the species responds to disturbance as well as limited information on the general ecology and biology of the species. It is unlikely that the Project will significantly affect the ecology of the local population (should it exist) given the availability of suitable habitat within the broader area
(d) a description of the extent to which the local population will become fragmented and isolated as a result of the proposed development	The size of the local population affected by the Project is unknown. No individuals of *R. rubescens* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. It is unlikely that the Project will cause additional significant fragmentation and isolation of a local population (should it exist) given the availability of suitable habitat within the locality. However, the Project will clear 1.64 hectares of suitable habitat which will reduce the area of potential occupancy of the species.
(e) the relationship of the local population to other populations of the species	The size of the local population affected by the Project is unknown. No individuals of *R. rubescens* were recorded during vegetation surveys and targeted threatened species searches were not undertaken. The relationship of the local population (if any) to other populations of the species is unknown, including to the BioNet Atlas of NSW Wildlife Database record that is four kilometres north-east of the study area (OEH 2017b). There is no information as to the genetic connectedness of populations.
(f) the extent to which the proposed development will lead to an increase in threats and indirect impacts, including impacts from invasive flora and fauna, that may in turn lead to a decrease in the viability of the local population	*R. rubescens* is severely threatened by the exotic rust fungus *Austropuccinia psidii*, which has caused a significant and rapid decline of the species since the introduction of the pathogen in 2010. The vector of *A. psidii* include transfer of spores by wind, water, fauna and people, infected nursery plants and associated plant growing material, and infected plant material in the environment (for example, fallen affected leaves). As there is currently no effective or practical chemical, biological, or management control for the rust fungus in the introduction of *A. psidii* would likely result in a significant decline in the health and viability of any *R. rubescens* occurring within the development site. Proposed mitigation measures to manage rust fungus would reduce the potential for spread into the site. Other proposed mitigation measures would reduce other potential threats and indirect impacts. The size and distribution of any local population of *R. rubescens* is unknown and therefore the extent to which the Project may affect the viability of the local population cannot be determined. It is unlikely, however, that the Project will significantly affect the ecology of the local population (should it exist) given the availability of suitable habitat within the broader area.
(g) the measure/s proposed to contribute to the recovery of the species in the IBRA subregion	*R. rubescens* has been allocated to the landscape species stream of the SoS program. This management stream aims to ensure that the species is secure in the wild in NSW and that its NSW geographic range is extended or maintained. The study area site falls within the management site for the species. Management objectives at this site include, but are not limited to: ▪ Undertake a desktop review of species records and historical survey data and engage with consultants, NGOs and volunteer 'spotters' to identify rapid survey sites. ▪ Complete rapid field surveys across the entire species range to determine rust impact, identify rust resistant populations, sites or individuals. Use standardised protocols for recording myrtle rust incidence, severity and demographic impacts. ▪ Undertake genetically representative germplasm collections. Collect genetic material (min. 6 individuals) from every germplasm collection site for genetic analysis of population structure and genetic representativeness of collections. ▪ Develop a long-term management plan for the eventual management/re-establishment of wild populations for the species.

Criteria	Consideration
	Offsets will be provided for the impact on *R. rubescens* in accordance with the BOS.

7.8 Impacts requiring offsetting

7.8.1 Native vegetation

Impacts of the Project that fall into the threshold of impacts that require offsetting are:

- The removal of 2.76 hectares of HN564: Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion
- The removal of 12.25 hectares of HN566: Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion
- The removal of 5.77 hectares of HN568: Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion
- The removal of 1.64 hectares of HN604: Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion

The offset requirement for the above PCTs were calculated using the BBCC. A summary of the vegetation zone impacted, threatened species associated with that vegetation zone, loss landscape value, loss in site value, and the number of ecosystem credits required for the impacts is detailed in Table 7-19.

Table 7-19. Ecosystem credit requirements of the proposed works

Vegetation zone	PCT	Condition	Area impacted (ha)	Current site value	Future site value	Credit requirement
1	HN564	Moderate/Good	0.31	60.63	0.00	16
2	HN566	Moderate/Good	12.25	77.08	0.00	691
3	HN568	Moderate/Good	5.77	91.06	0.00	430
4	HN604	Moderate/Good	1.64	60.14	0.00	84
5	HN564	Moderate/Good_poor	2.45	30.68	0.00	72

7.8.2 Species and populations

Three species credit species were recorded within the development site. However, as outlined in Section 5.7.2, 54 candidate species credit species are assumed to be present and their habitat offset. The offset requirement for the species credit species were calculated using the BBCC. It is recommended that targeted surveys be carried out in line with relevant guidelines for threatened flora species currently assumed as present within the development site. Targeted surveys should focus on areas that had been subject to resent prescribed burning, as well as within the development footprint. These surveys would likely refine the quantification of impacts and associated credit liability generated by the Project.

A summary of the vegetation zone impacted, threatened species associated with that vegetation zone, loss landscape value, loss in site value, and the number of ecosystem credits required for the impacts is detailed in Table 7-20.Table 7-8

Table 7-20. Credit requirement of the project for species credits

Species name	Common name	BC Act status	EPBC Act status	Area (ha) to be removed	Credit requirement
FLORA					
Acacia baueri subsp. *aspera*	*Acacia baueri* subsp. *aspera*	V	-	12.25	520
Acacia bynoeana	Bynoe's Wattle	E	V	19.96	520
Acacia flocktoniae	Flockton's Wattle	V	V	6.07	126
Acacia gordonii	*Acacia gordonii*	E	E	12.25	338
Acacia pubescens	Downy Wattle	V	V	19.66	380
Ancistrachne maidenii	*Ancistrachne maidenii*	V	-	12.55	286
Asterolasia elegans	*Asterolasia elegans*	E	E	12.55	234
Astrotricha crassifolia	Thick-leaf Star-hair	V	V	12.25	1,001
Caesia parviflora subsp. *parviflora*	Small Pale Grass-lily	E	-	12.55	182
Cryptostylis hunteriana	Leafless Tongue-orchid	V	V	12.25	520
Darwinia biflora	*Darwinia biflora*	V	V	12.55	260
Darwinia peduncularis	*Darwinia peduncularis*	V	-	12.25	234
Dillwynia tenuifolia	*Dillwynia tenuifolia*	V	-	12.55	234
Epacris purpurascens var. purpurascens	*Epacris purpurascens var. purpurascens*	V	-	300*	5,100
Genoplesium baueri	Bauer's Midge Orchid	V	E	12.25	169
Grammitis stenophylla	Narrow-leaf Finger Fern	E	-	1.64	26
Grevillea evansiana	Evan's Grevillea	V	V	12.25	195
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	E	-	14.19	210
Gyrostemon thesioides	*Gyrostemon thesioides*	E	-	1.95	154
Haloragodendron lucasii	Hal	E	E	12.25	1,001
Hibbertia puberula	*Hibbertia puberula*	E	-	19.96	800
Hygrocybe anomala subsp. *ianthinomarginata*	*Hygrocybe anomala* subsp. *ianthinomarginata*	V	-	13.89	1,078

Species name	Common name	BC Act status	EPBC Act status	Area (ha) to be removed	Credit requirement
Kunzea rupestris	*Kunzea rupestris*	V	V	12.55	338
Lastreopsis hispida	Bristly Shield Fern	E	-	5.79	462
Leucopogon exolasius	Woronora Beard-heath	V	V	18.32	266
Leucopogon fletcheri subsp. *fletcheri*	*Leucopogon fletcheri* subsp. *fletcheri*	E	-	12.55	208
Melaleuca deanei	Deane's Paperbark	V	V	12.55	1,001
Melaleuca groveana	Grove's Paperbark	V	-	13*	1,560
Micromyrtus blakelyi	*Micromyrtus blakelyi*	V	V	12.55	338
Olearia cordata	*Olearia cordata*	V	V	12.55	169
Persoonia acerosa	Needle Geebung	V	V	18.02	247
Persoonia hirsuta	Hairy Geebung	E	E	19.96	1,540
Pimelea curviflora var. curviflora	*Pimelea curviflora var. curviflora*	V	V	14.19	1,155
Pomaderris brunnea	Brown Pomaderris	V	V	0.31	15
Pterostylis saxicola	Sydney Plains Greenhood	E	E	12.55	520
Pultenaea glabra	Smooth Bush-Pea	V	V	18.02	285
Pultenaea parviflora	*Pultenaea parviflora*	E	V	12.25	180
Pultenaea sp. Olinda	*Pultenaea sp.* Olinda	E	-	12.25	520
Rhodamnia rubescens^#	Scrub Turpentine	CE	-	1*	154
Syzygium paniculatum	Magenta Lilly Pilly	E	V	10*	130
Tetratheca glandulosa	*Tetratheca glandulosa*	V	-	19.96	320
Velleia perfoliata	*Velleia perfoliata*	V	V	12.55	221
Zieria involucrata	*Zieria involucrata*	E	E	1.64	30
Zieria murphyi	Velvet Zieria	V	V	12.55	195

Species name	Common name	BC Act status	EPBC Act status	Area (ha) to be removed	Credit requirement
FAUNA					
Anthochaera phrygia	Regent Honeyeater	CE	CE	19.96	1,537
Cercartetus nanus	Eastern Pygmy-possum	V	-	19.32	386
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	19.96	259
Heleioporus australiacus	Giant Burrowing Frog	V	V	3.60	47
Hoplocephalus bungaroides	Broad-headed Snake	E	V	10.24	338
Isoodon obesulus subsp. *obesulus*	Southern Brown Bandicoot (eastern)	E	E	12.25	318
Meridolum corneovirens	Cumberland Plain Land Snail	E	-	1.64	21
Petaurus norfolcensis	Squirrel Glider	V	-	19.66	433
Petrogale penicillata	Brush-tail Rock-wallaby	E	V	17.38	452
Phascogale tapoatafa	Brush-tailed Phascogale	V	-	13.89	278
Phascolarctos cinereus	Koala	V	V	19.96	519
Pseudophryne australis	Red-crowned Toadlet	V	-	8.25	107
Varanus rosenbergi	Rosenberg's Goanna	V	-	19.96	659

**Credit requirement calculated by number of individuals impacted.*

^#Rhodamnia rubescens could not be entered into the BBCC. As such, the calculations have substituted in Acronychia littoralis with a multiplier of 7.7 into the BBCC to complete the offset calculation

7.9 Impacts not requiring further assessment

7.9.1 Native vegetation

All native vegetation relevant to the Project is required to be further assessed (see Section 7.2.1) or requires an offset (see Section 7.8).

7.9.2 Species and populations

A number of non-threatened species and populations have been recorded within the development. In accordance with Section 9.4.2 of the FBA these species do not require offsetting.

7.10 Impacts that do not require further assessment

The development site includes areas of paddocks and existing roads/tracks that are not considered to comprise native vegetation or habitat for threatened species and populations. In accordance with Section 9.5.1.1 of the FBA this area of land does not require further assessment.

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Appendix A BioBanking credit report

BioBanking Credit Calculator

Ecosystem credits

Proposal ID : 174/2019/4968MP

Proposal name : SMEC - Warragamba Construction Area V3

Assessor name : Rachel Musgrave

Assessor accreditation number : 174

Tool version : v4.0

Report created : 19/09/2019 22:45

Assessment circle name	Landscape score	Vegetation zone name	Vegetation type name	Condition	Red flag status	Management zone name	Management zone area	Current site value	Future site value	Loss in site value	Credit required for bio diversity	Credit required for TS	TS with highest credit requirement	Average species loss	Species TG Value	Final credit requirement for management zone
1	25.20	HN564_Moderate/Good	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate/Good	Yes	1	0.31	60.63	0.00	60.63	0	16	Masked Owl	25.00	3.00	16
1	25.20	HN564_Moderate/Good_Poor	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate/Good_Poor	Yes	2	2.45	30.68	0.00	30.68	0	72	Masked Owl	25.00	3.00	72
1	25.20	HN566_Moderate/Good	Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Moderate/Good	Yes	3	12.25	77.08	0.00	77.08	0	691	Spotted-tailed Quoll	41.67	2.60	691
1	25.20	HN568_Moderate/Good	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Moderate/Good	Yes	4	5.80	91.06	0.00	91.06	0	433	Masked Owl	58.33	3.00	433
1	25.20	HN604_Moderate/Good	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Moderate/Good	Yes	5	1.70	60.14	0.00	60.14	87	87	Barking Owl	33.33	3.00	87

BioBanking Credit Calculator

Species credits

Proposal ID : 174/2019/4968MP

Proposal name : SMEC - Warragamba Construction Area V3

Assessor name : Rachel Musgrave

Assessor accreditation number : 174

Tool version : v4.0

Report created : 19/09/2019 22:45

Scientific name	Common name	Species TG value	Identified population?	Can Id. popn. be offset?	Area / number of loss	Negligible loss	Red flag status	Number of credits
Acacia baueri subsp. aspera	Acacia baueri subsp. aspera	4.00	No		13.00	0.00	Yes	520
Acacia bynoeana	Bynoe's Wattle	7.70	No		13.00	0.00	Yes	1,001
Acacia bynoeana	Bynoe's Wattle	7.70	No		13.00	0.00	Yes	1,001
Acacia flocktoniae	Flockton Wattle	1.80	No		7.00	0.00	Yes	126
Acacia gordonii	Acacia gordonii	2.60	No		13.00	0.00	Yes	338
Acacia pubescens	Downy Wattle	1.90	No		20.00	0.00	Yes	380
Acronychia littoralis	Scented Acronychia	7.70	No		2.00	0.00	Yes	154
Ancistrachne maidenii	Ancistrachne maidenii	2.20	No		13.00	0.00	No	286
Asterolasia elegans	Asterolasia elegans	1.80	No		13.00	0.00	Yes	234
Astrotricha crassifolia	Thick-leaf Star-hair	7.70	No		13.00	0.00	Yes	1,001
Caesia parviflora subsp. minor	Small Pale Grass-lily	1.40	No		13.00	0.00	Yes	182
Cryptostylis hunteriana	Leafless Tongue Orchid	4.00	No		13.00	0.00	Yes	520
Darwinia biflora	Darwinia biflora	2.00	No		13.00	0.00	Yes	260

Scientific name	Common name	Species TG value	Identified population?	Can Id. popn. be offset?	Area / number of loss	Negligible loss	Red flag status	Number of credits
Darwinia peduncularis	Darwinia peduncularis	1.80	No		13.00	0.00	Yes	234
Dillwynia tenuifolia	Dillwynia tenuifolia	1.80	No		13.00	0.00	Yes	234
Epacris purpurascens subsp. purpurascens	Epacris purpurascens subsp. purpurascens	1.70	No		300.00	0.00	Yes	5,100
Grammitis stenophylla	Narrow-leaf Finger Fern	1.30	No		2.00	0.00	No	26
Grevillea evansiana	Evans Grevillea	1.50	No		13.00	0.00	Yes	195
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	1.40	No		15.00	0.00	Yes	210
Gyrostemon thesioides	Gyrostemon thesioides	7.70	No		2.00	0.00	Yes	154
Haloragodendron lucasii	Haloragodendron lucasii	7.70	No		13.00	0.00	Yes	1,001
Hibbertia puberula	Hibbertia puberula	4.00	No		21.00	0.00	No	840
Hygrocybe anomala subsp. ianthinomarginata	Hygrocybe anomala subsp. ianthinomarginata	7.70	No		14.00	0.00	Yes	1,078
Kunzea rupestris	Kunzea rupestris	2.60	No		13.00	0.00	Yes	338
Lastreopsis hispida	Bristly Shield Fern	7.70	No		6.00	0.00	Yes	462
Leucopogon exolasius	Woronora Beard-heath	1.40	No		19.00	0.00	Yes	266
Leucopogon fletcheri subsp. fletcheri	Leucopogon fletcheri subsp. fletcheri	1.60	No		13.00	0.00	Yes	208
Melaleuca deanei	Deane's Paperbark	7.70	No		13.00	0.00	Yes	1,001
Melaleuca groveana	Grove's Paperbark	13.00	No		12.00	0.00	Yes	1,560
Micromyrtus blakelyi	Micromyrtus blakelyi	2.60	No		13.00	0.00	Yes	338
Olearia cordata	Olearia cordata	1.30	No		13.00	0.00	Yes	169
Persoonia acerosa	Needle Geebung	1.30	No		19.00	0.00	Yes	247
Persoonia hirsuta	Hairy Geebung	7.70	No		21.00	0.00	Yes	1,617
Pimelea curviflora subsp. curviflora	Pimelea curviflora subsp. curviflora	7.70	No		15.00	0.00	Yes	1,155
Pomaderris brunnea	Brown Pomaderris	1.50	No		1.00	0.00	Yes	15

Scientific name	Common name	Species TG value	Identified population?	Can Id. popn. be offset?	Area / number of loss	Negligible loss	Red flag status	Number of credits
Pterostylis saxicola	Sydney Plains Greenhood	4.00	No		13.00	0.00	Yes	520
Pultenaea glabra	Smooth Bush-Pea	1.50	No		19.00	0.00	Yes	285
Pultenaea parviflora	Pultenaea parviflora	1.50	No		13.00	0.00	Yes	195
Pultenaea sp. Olinda	Pultenaea sp. Olinda	4.00	No		13.00	0.00	Yes	520
Rhizanthella slateri	Eastern Australian Underground Orchid	7.70	No		20.00	0.00	Yes	1,540
Syzygium paniculatum	Magenta Lilly Pilly	1.30	No		10.00	0.00	Yes	130
Tetratheca glandulosa	Tetratheca glandulosa	1.60	No		21.00	0.00	Yes	336
Velleia perfoliata	Velleia perfoliata	1.70	No		13.00	0.00	Yes	221
Zieria involucrata	Zieria involucrata	1.50	No		2.00	0.00	Yes	30
Zieria murphyi	Velvet Zieria	1.50	No		13.00	0.00	Yes	195
Genoplesium baueri	Bauer's Midge Orchid	1.30	No		13.00	0.00	Yes	169
Heleioporus australiacus	Giant Burrowing Frog	1.30	No		3.66	0.00	No	48
Hoplocephalus bungaroides	Broad-headed Snake	3.30	No		10.24	0.00	Yes	338
Petrogale penicillata	Brush-tailed Rock-wallaby	2.60	No		17.38	0.00	Yes	452
Pseudophryne australis	Red-crowned Toadlet	1.30	No		8.25	0.00	No	107
Varanus rosenbergi	Rosenberg's Goanna	3.30	No		20.06	0.00	No	662
Cercartetus nanus	Eastern Pygmy-possum	2.00	No		19.38	0.00	No	388
Chalinolobus dwyeri	Large-eared Pied Bat	1.30	No		20.06	0.00	No	261
Isoodon obesulus subsp. obesulus	Southern Brown Bandicoot (eastern)	2.60	No		12.25	0.00	Yes	318
Meridolum corneovirens	Cumberland Plain Land Snail	1.30	No		1.70	0.00	No	22
Petaurus norfolcensis	Squirrel Glider	2.20	No		19.75	0.00	No	434
Phascogale tapoatafa	Brush-tailed Phascogale	2.00	No		13.95	0.00	Yes	279
Phascolarctos cinereus	Koala	2.60	No		20.06	0.00	No	522

Scientific name	Common name	Species TG value	Identified population?	Can Id. popn. be offset?	Area / number of loss	Negligible loss	Red flag status	Number of credits
Anthochaera phrygia	Regent Honeyeater	7.70	No		20.06	0.00	No	1,545

Biodiversity credit report

This report identifies the number and type of biodiversity credits required for a major project.

Date of report: 19/09/2019 Time: 10:47:15PM Calculator version: v4.0

Major Project details

Proposal ID:	174/2019/4968MP
Proposal name:	SMEC - Warragamba Construction Area V3
Proposal address:	Level 5 20 Berry Street North Sydney NSW 2060
Proponent name:	SMEC
Proponent address:	Level 5 20 Berry Street NSW 2060
Proponent phone:	+61 2 9925 5596
Assessor name:	Rachel Musgrave
Assessor address:	Level 5, 20 Berry Street North Sydney NSW 2010
Assessor phone:	02 9900 7115
Assessor accreditation:	174

Summary of ecosystem credits required

Plant Community type	Area (ha)	Credits created
Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	2.76	88.00
Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	12.25	691.00
Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	5.80	433.00
Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	1.70	87.39
Total	22.51	1,299

Credit profiles

1. Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion, (HN604)

Number of ecosystem credits created	87
IBRA sub-region	Wollemi - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion, (HN604) Broad-leaved Ironbark - Melaleuca decora shrubby open forest on clay soils of the Cumberland Plain, Sydney Basin Bioregion, (HN513)	Wollemi - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

2. Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN564)

Number of ecosystem credits created	88
IBRA sub-region	Wollemi - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN564) Yellow Bloodwood - ironbark shrubby woodland of the dry hinterland of the Central Coast, Sydney Basin Bioregion, (HN612)	Wollemi - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

3. Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion, (HN566)

Number of ecosystem credits created	691
IBRA sub-region	Wollemi - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion, (HN566) Smooth-barked Apple - Sydney Peppermint - Turpentine heathy open forest on plateaux areas of the Sydney Basin Bioregion, (HN587) Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, Sydney Basin Bioregion, (HN586) Spotted Gum - Grey Ironbark open forest in the Pittwater and Wagstaffe area, Sydney Basin Bioregion, (HN642) Sydney Peppermint - White Stringybark - Smooth-barked Apple forest on shale outcrops, Sydney Basin Bioregion, (HN644)	Wollemi - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

4. Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion, (HN568)

Number of ecosystem credits created	433
IBRA sub-region	Wollemi - Hawkesbury/Nepean

Offset options - Plant Community types	Offset options - IBRA sub-regions
Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion, (HN568) Yellow Bloodwood - ironbark shrubby woodland of the dry hinterland of the Central Coast, Sydney Basin Bioregion, (HN612) Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion, (HN564)	Wollemi - Hawkesbury/Nepean and any IBRA subregion that adjoins the IBRA subregion in which the development occurs

Summary of species credits required

Common name	Scientific name	Extent of impact Ha or individuals	Number of species credits created
Acacia baueri subsp. aspera	Acacia baueri subsp. aspera	13.00	520
Small-flower Grevillea	Grevillea parviflora subsp. parviflora	15.00	210
Red-crowned Toadlet	Pseudophryne australis	8.25	107
Flockton Wattle	Acacia flocktoniae	7.00	126
Acacia gordonii	Acacia gordonii	13.00	338
Downy Wattle	Acacia pubescens	20.00	380
Ancistrachne maidenii	Ancistrachne maidenii	13.00	286
Asterolasia elegans	Asterolasia elegans	13.00	234
Thick-leaf Star-hair	Astrotricha crassifolia	13.00	1,001
Small Pale Grass-lily	Caesia parviflora subsp. minor	13.00	182
Leafless Tongue Orchid	Cryptostylis hunteriana	13.00	520
Darwinia biflora	Darwinia biflora	13.00	260
Darwinia peduncularis	Darwinia peduncularis	13.00	234
Bauer's Midge Orchid	Genoplesium baueri	13.00	169
Narrow-leaf Finger Fern	Grammitis stenophylla	2.00	26
Evans Grevillea	Grevillea evansiana	13.00	195
Gyrostemon thesioides	Gyrostemon thesioides	2.00	154
Hibbertia puberula	Hibbertia puberula	21.00	840
Hygrocybe anomala subsp. ianthinomarginata	Hygrocybe anomala subsp. ianthinomarginata	14.00	1,078
Kunzea rupestris	Kunzea rupestris	13.00	338
Bristly Shield Fern	Lastreopsis hispida	6.00	462
Woronora Beard-heath	Leucopogon exolasius	19.00	266
Leucopogon fletcheri subsp. fletcheri	Leucopogon fletcheri subsp. fletcheri	13.00	208
Deane's Paperbark	Melaleuca deanei	13.00	1,001
Grove's Paperbark	Melaleuca groveana	12.00	1,560
Velvet Zieria	Zieria murphyi	13.00	195
Zieria involucrata	Zieria involucrata	2.00	30
Tetratheca glandulosa	Tetratheca glandulosa	21.00	336
Magenta Lilly Pilly	Syzygium paniculatum	10.00	130
Eastern Australian Underground Orchid	Rhizanthella slateri	20.00	1,540

Pultenaea sp. Olinda	Pultenaea sp. Olinda	13.00	520
Pultenaea parviflora	Pultenaea parviflora	13.00	195
Smooth Bush-Pea	Pultenaea glabra	19.00	285
Sydney Plains Greenhood	Pterostylis saxicola	13.00	520
Brown Pomaderris	Pomaderris brunnea	1.00	15
Pimelea curviflora subsp. curviflora	Pimelea curviflora subsp. curviflora	15.00	1,155
Hairy Geebung	Persoonia hirsuta	21.00	1,617
Needle Geebung	Persoonia acerosa	19.00	247
Olearia cordata	Olearia cordata	13.00	169
Eastern Pygmy-possum	Cercartetus nanus	19.38	388
Giant Burrowing Frog	Heleioporus australiacus	3.66	48
Broad-headed Snake	Hoplocephalus bungaroides	10.24	338
Southern Brown Bandicoot (eastern)	Isoodon obesulus subsp. obesulus	12.25	318
Cumberland Plain Land Snail	Meridolum corneovirens	1.70	22
Squirrel Glider	Petaurus norfolcensis	19.75	434
Brush-tailed Phascogale	Phascogale tapoatafa	13.95	279
Koala	Phascolarctos cinereus	20.06	522
Rosenberg's Goanna	Varanus rosenbergi	20.06	662
Large-eared Pied Bat	Chalinolobus dwyeri	20.06	261
Dillwynia tenuifolia	Dillwynia tenuifolia	13.00	234
Epacris purpurascens subsp. purpurascens	Epacris purpurascens subsp. purpurascens	300.00	5,100
Bynoe's Wattle	Acacia bynoeana	13.00	1,001
Bynoe's Wattle	Acacia bynoeana	13.00	1,001
Velleia perfoliata	Velleia perfoliata	13.00	221
Micromyrtus blakelyi	Micromyrtus blakelyi	13.00	338
Haloragodendron lucasii	Haloragodendron lucasii	13.00	1,001
Brush-tailed Rock-wallaby	Petrogale penicillata	17.38	452
Regent Honeyeater	Anthochaera phrygia	20.06	1,545
Scented Acronychia	Acronychia littoralis	2.00	154

Appendix B Threatened species habitat polygons

Figure B-1. Acacia baueri subsp. aspera *species polygon*

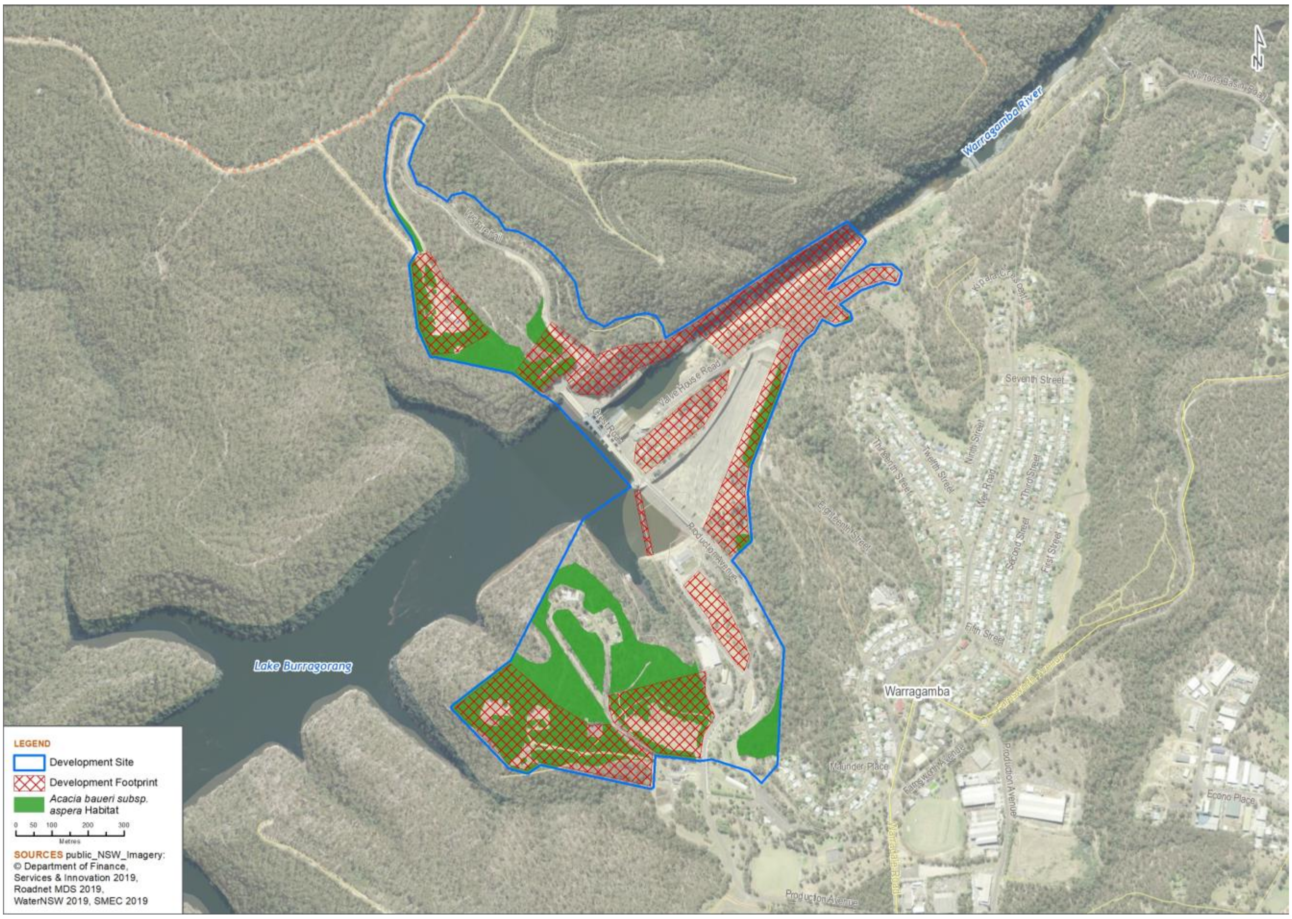


Figure B-2. Acacia bynoeana *species polygon*

Figure B-3. Acacia flocktoniae *species polygon*

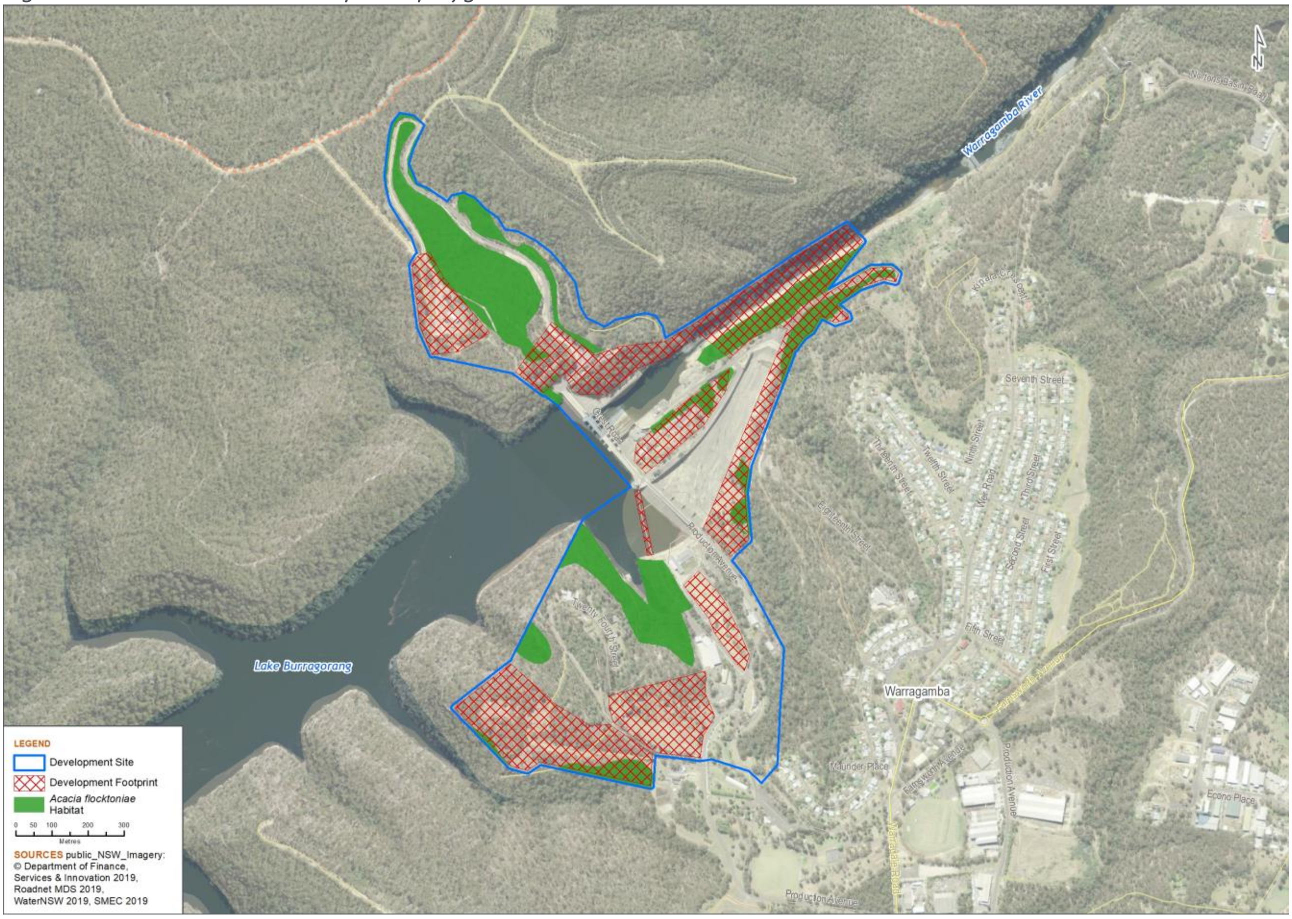


Figure B-4. Acacia gordonii *species polygon*

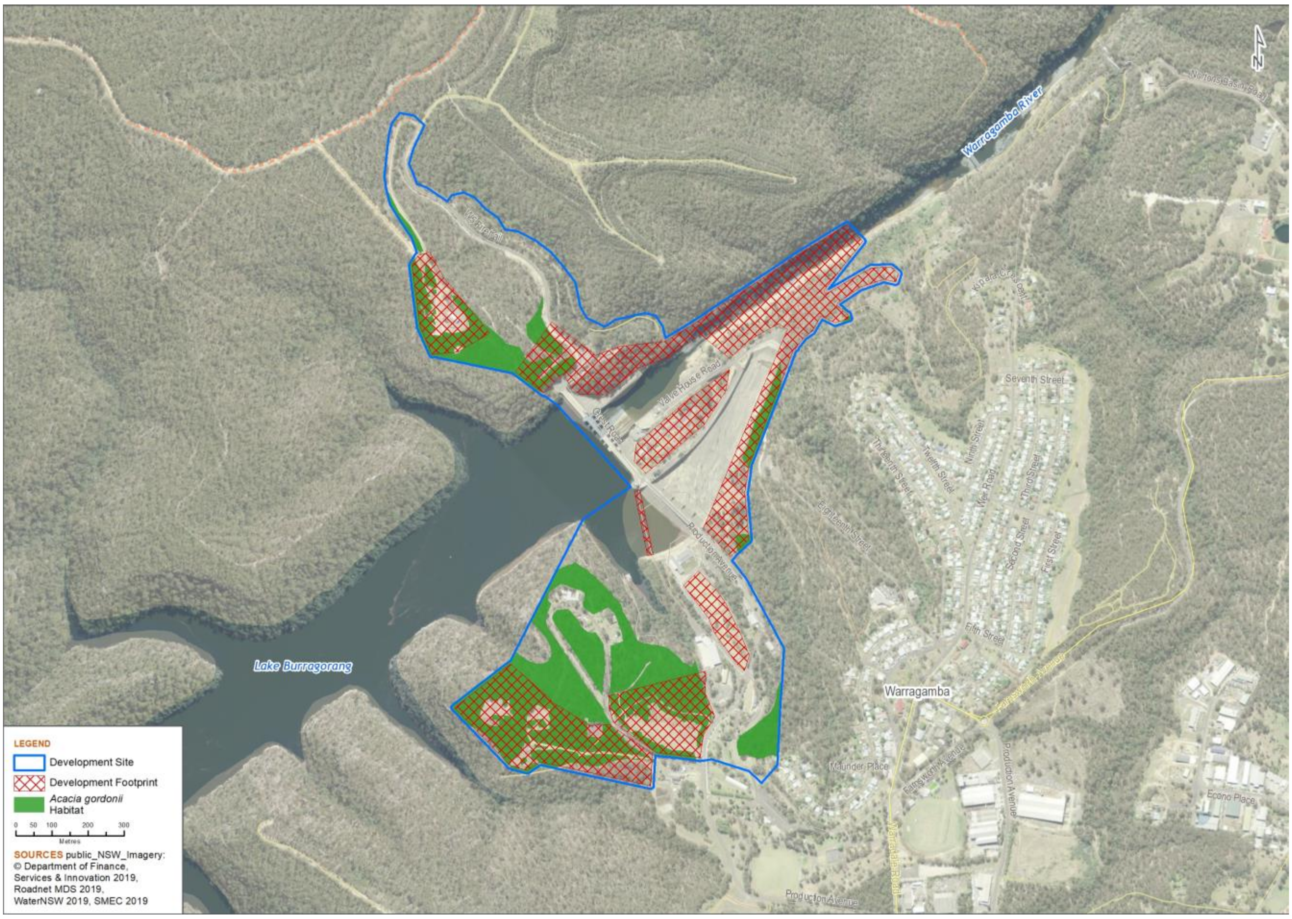


Figure B-5. Acacia pubescens *species polygon*

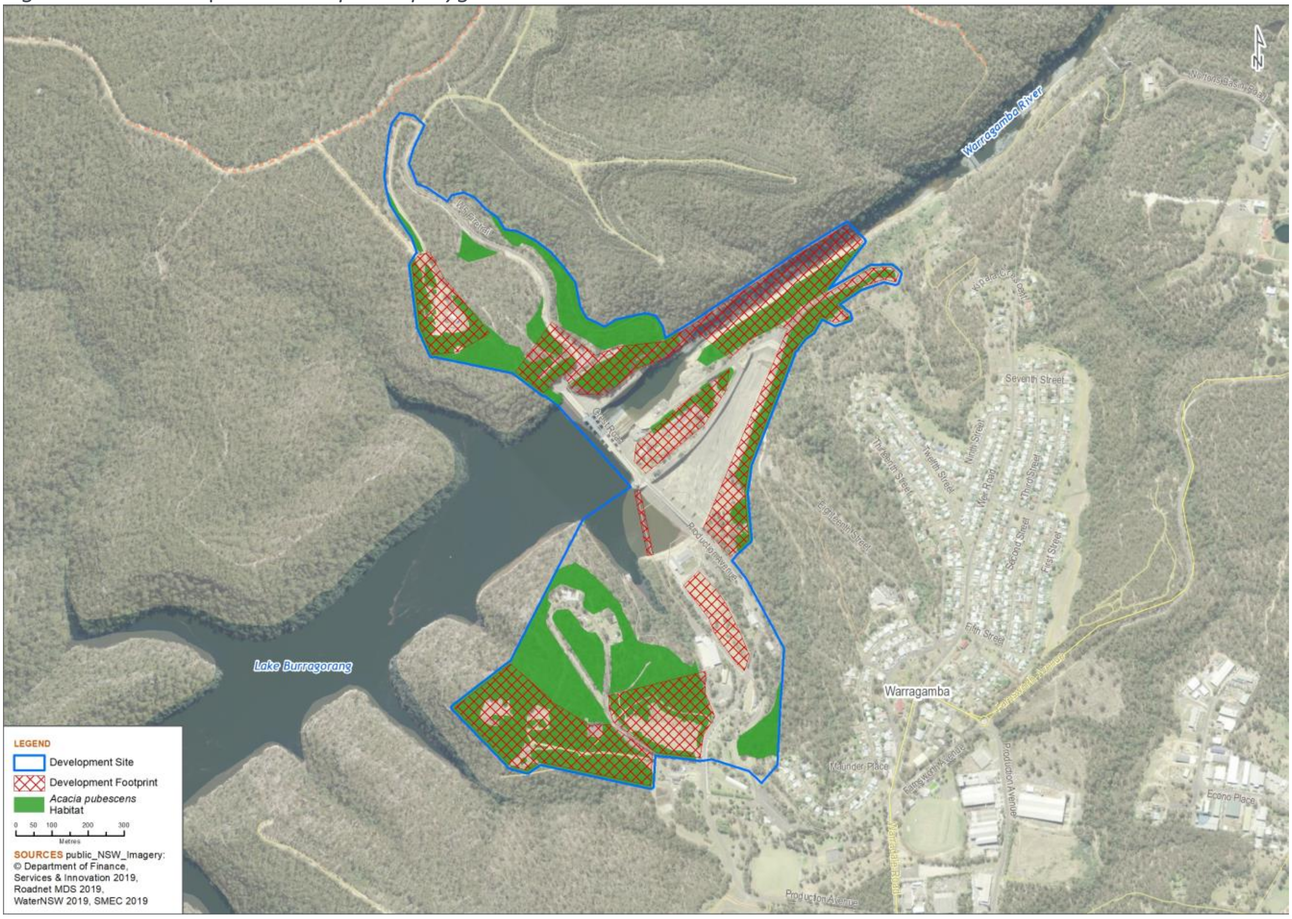


Figure B-6. Ancistrachne maidenii *species polygon*

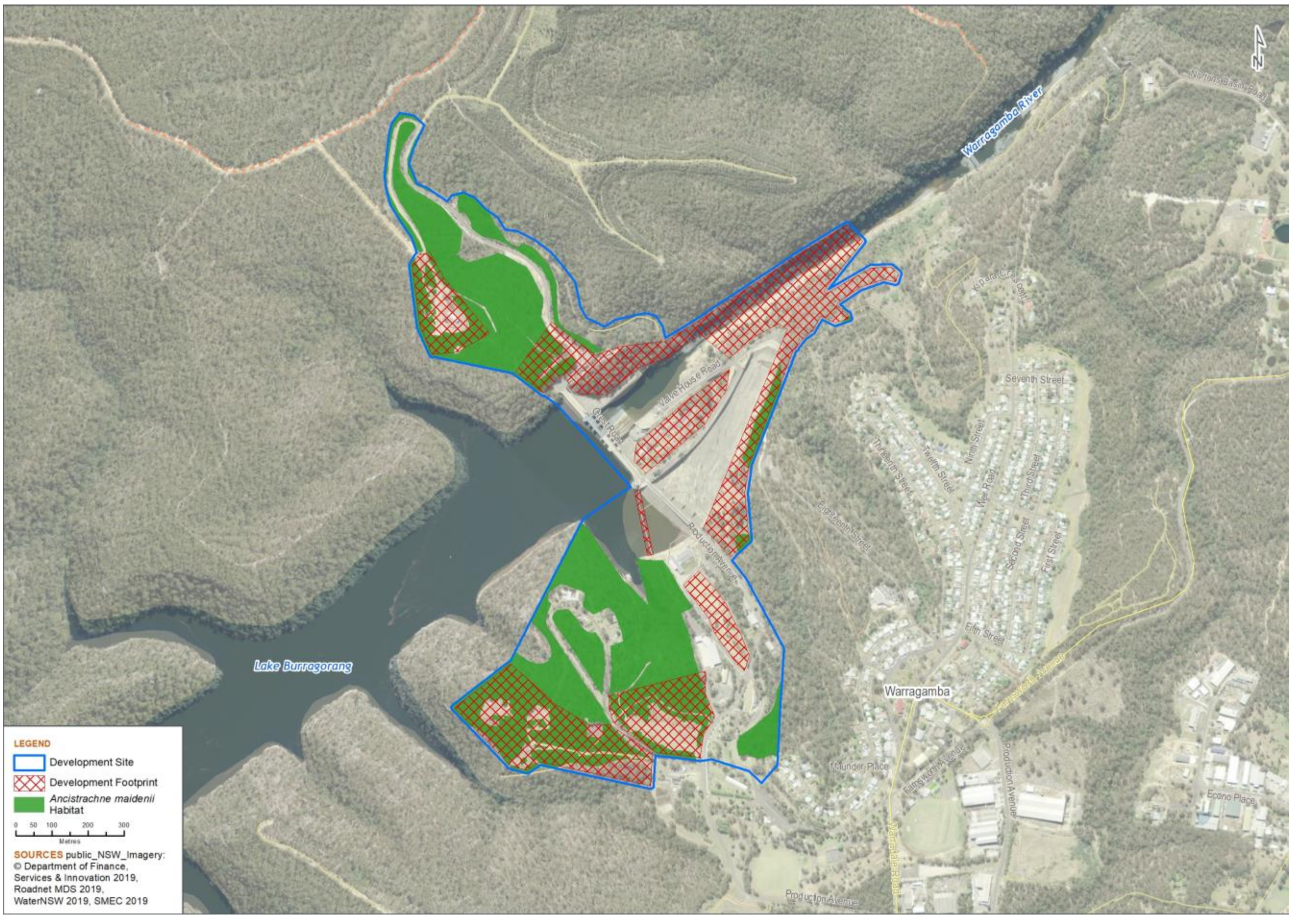


Figure B-7. Asterolasia elegans *species polygon*

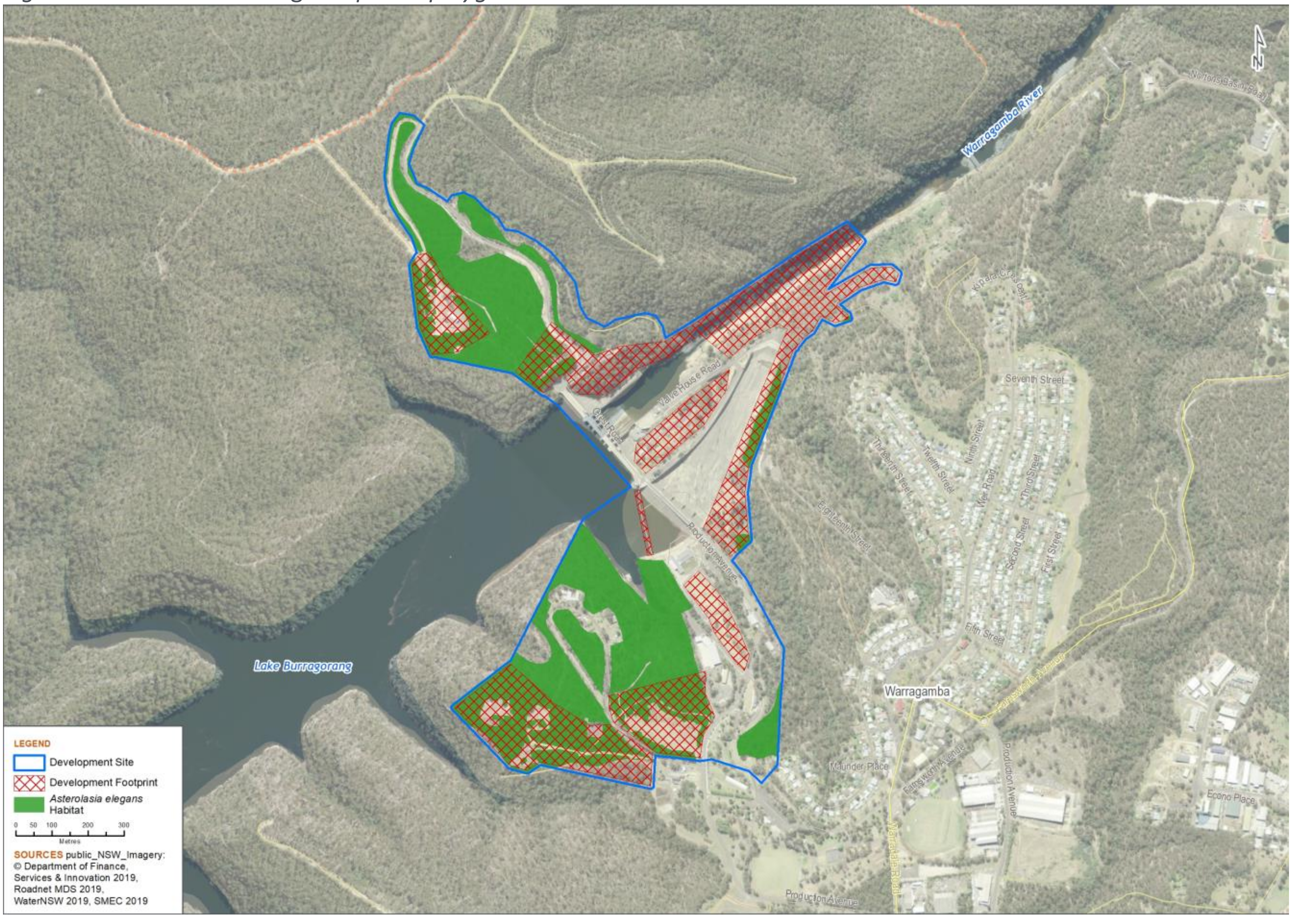


Figure B-8. Astrotricha *crassifolia species polygon*

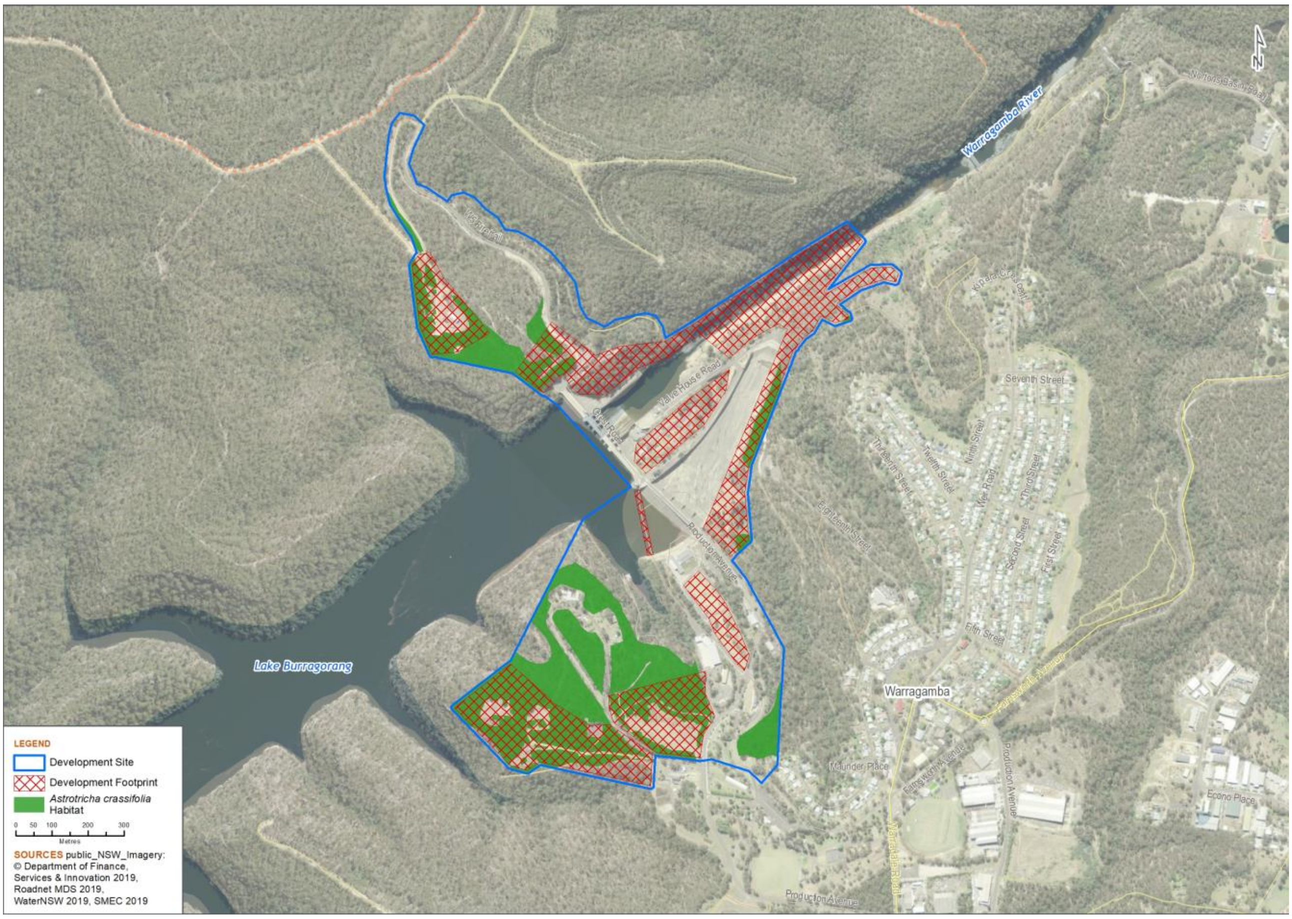


Figure B-9. Caesia parviflora subsp. parviflora *species polygon*

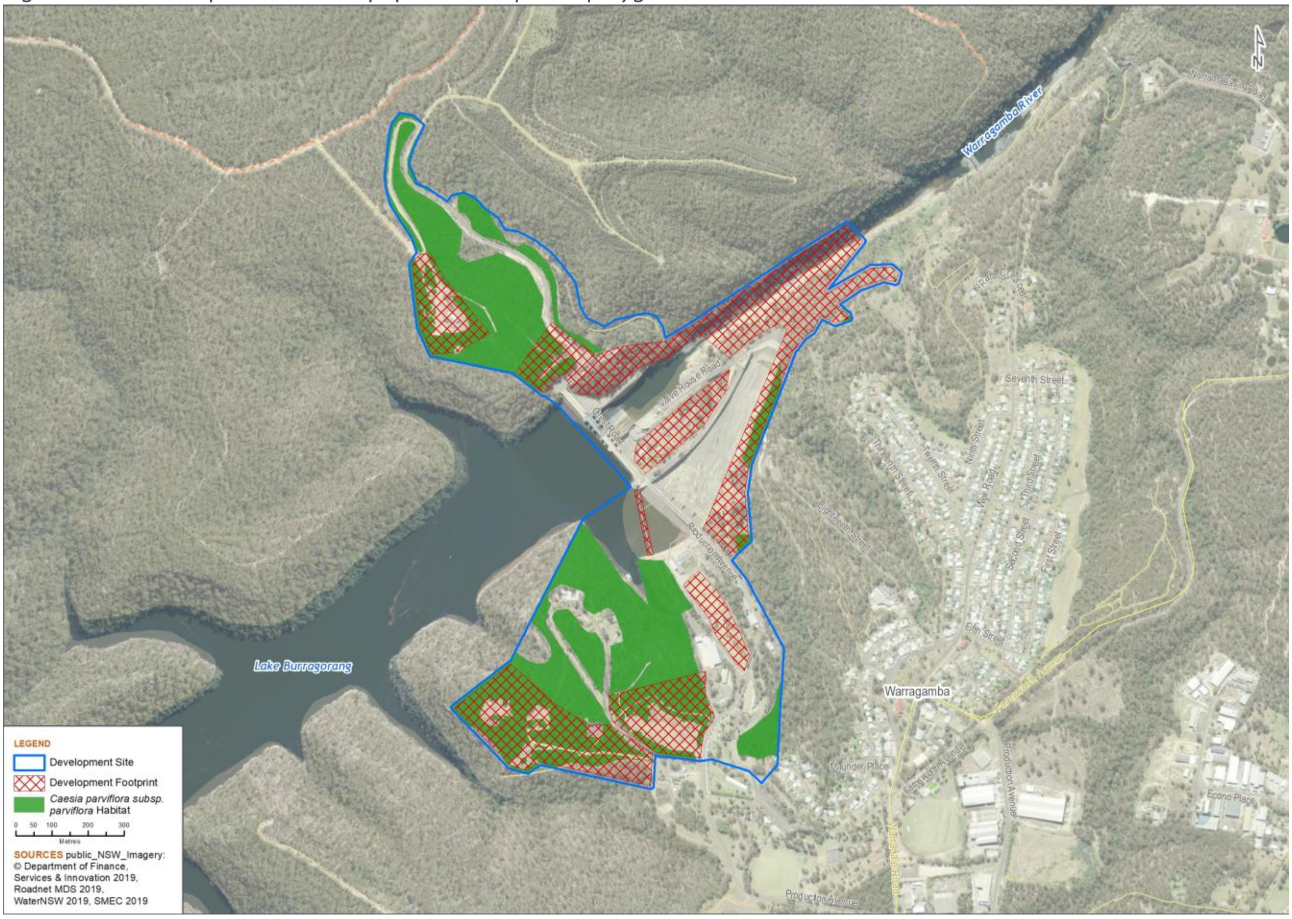


Figure B-10. Cryptostylis hunteriana *species polygon*

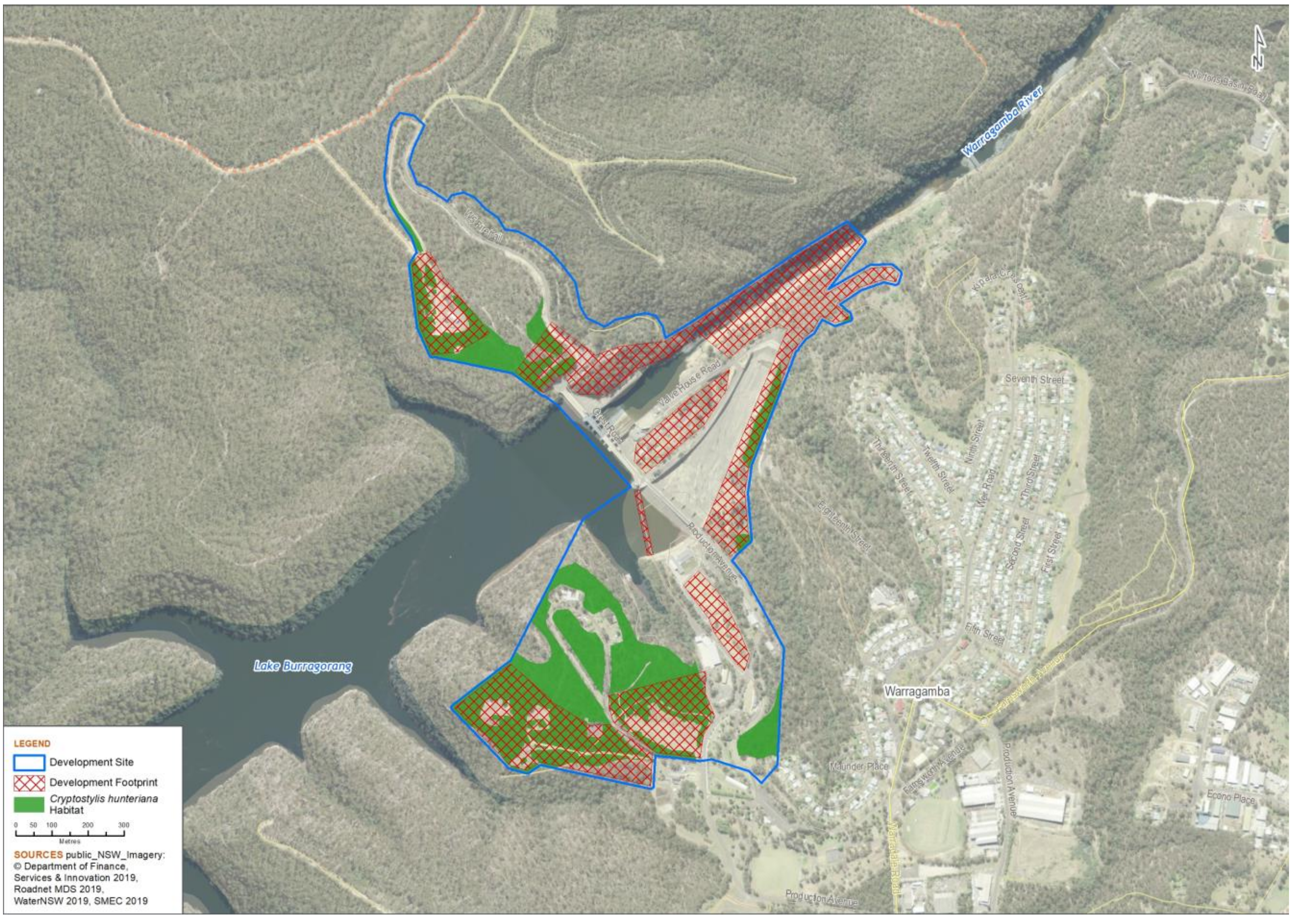


Figure B-11. Darwinia biflora *species polygon*

Figure B-12. Darwinia peduncularis *species polygon*

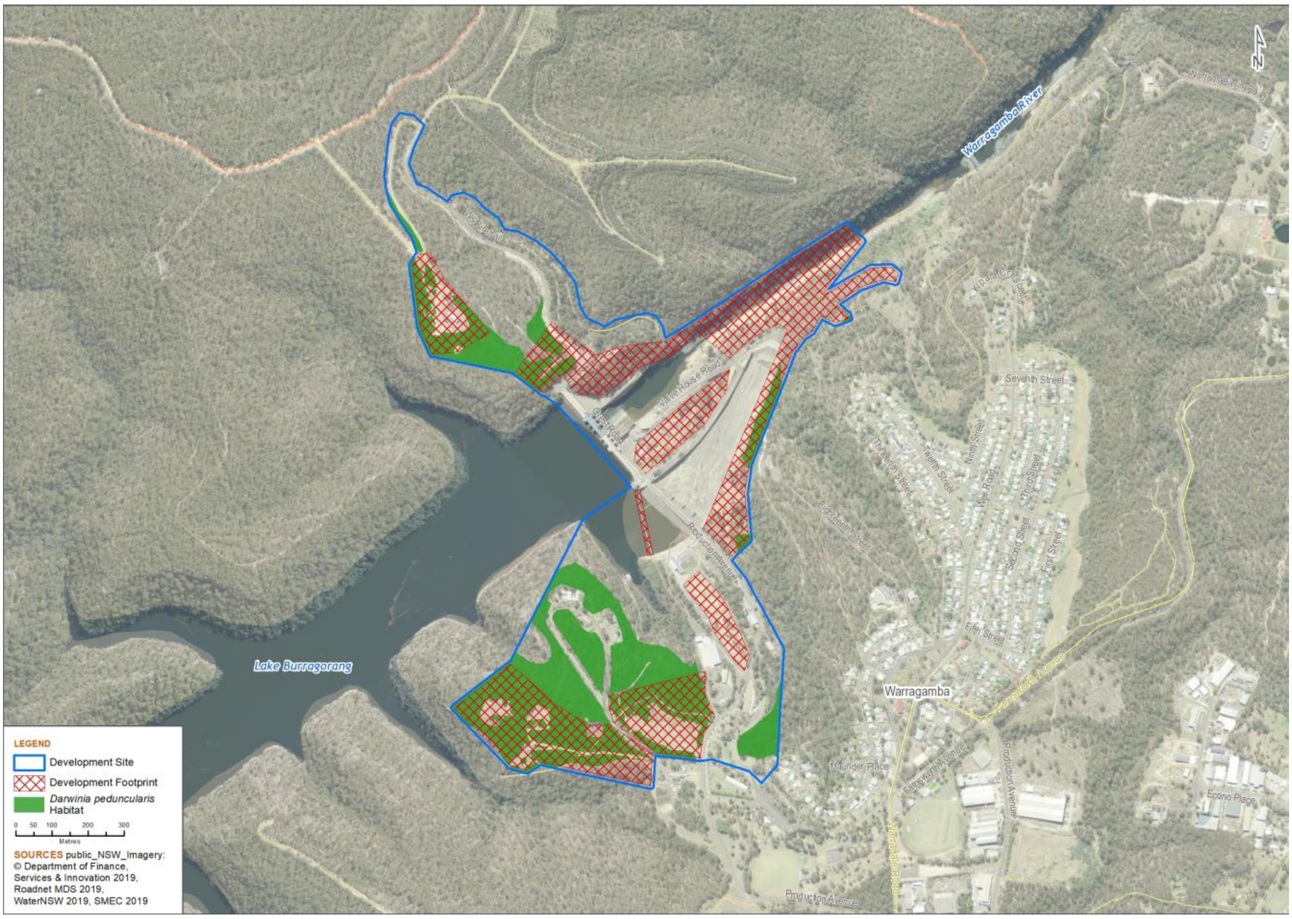


Figure B-13. Dillwynia tenuifolia *species polygon*

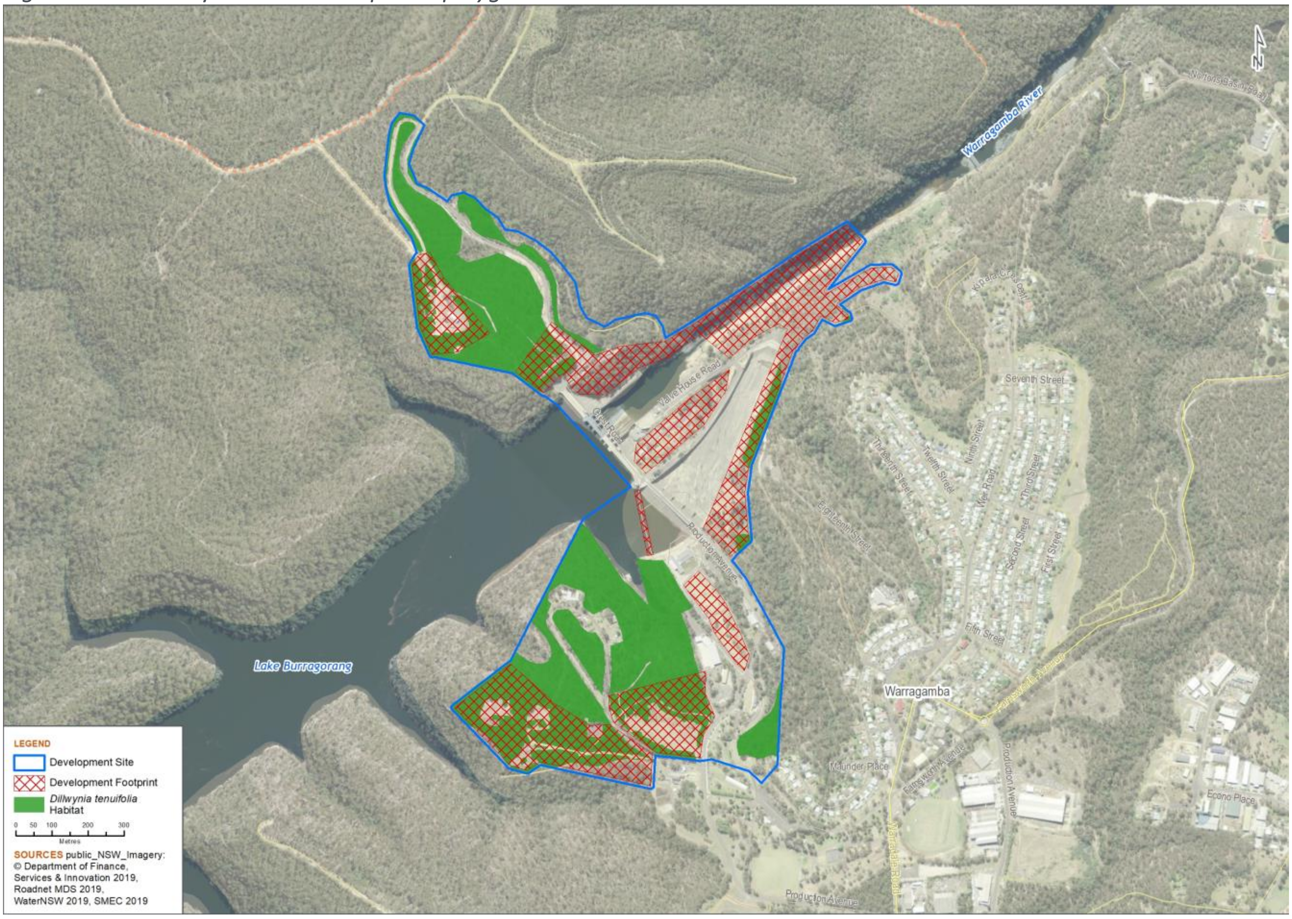


Figure B-14. Epacris purpurascens var. purpurascens *species polygon*

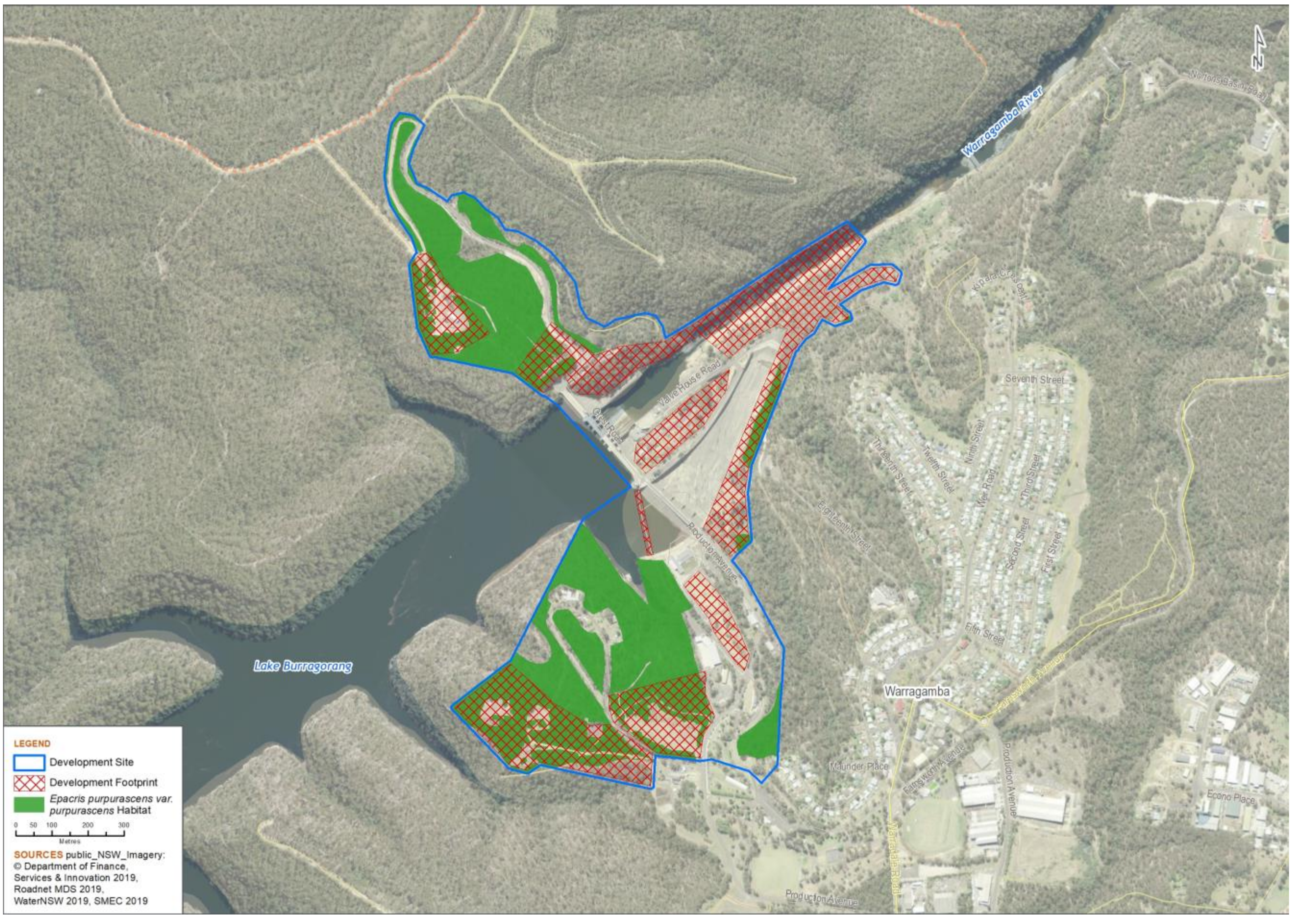


Figure B-15. Genoplesium baueri *species polygon*

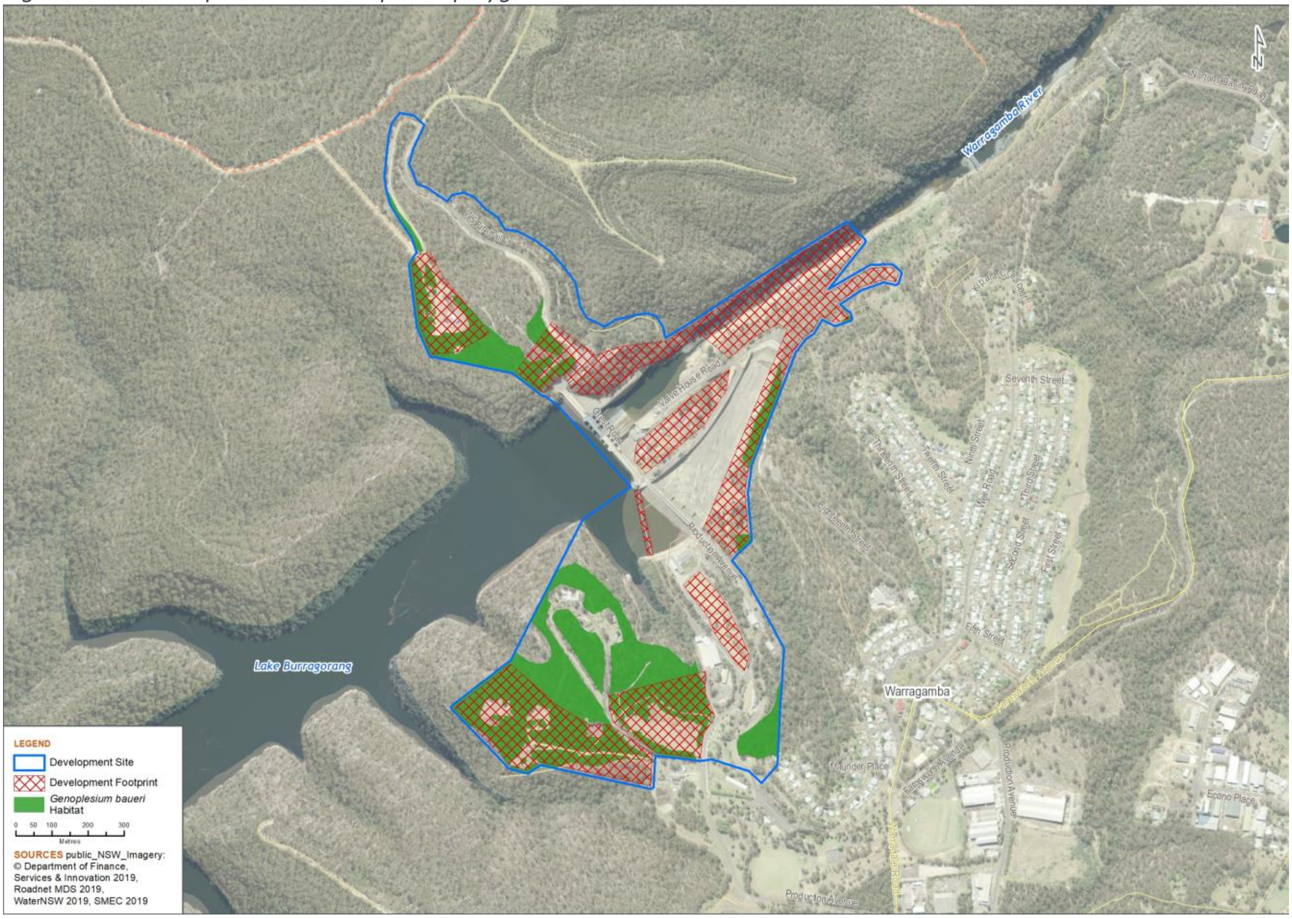


Figure B-16. Grammitis stenophylla *species polygon*

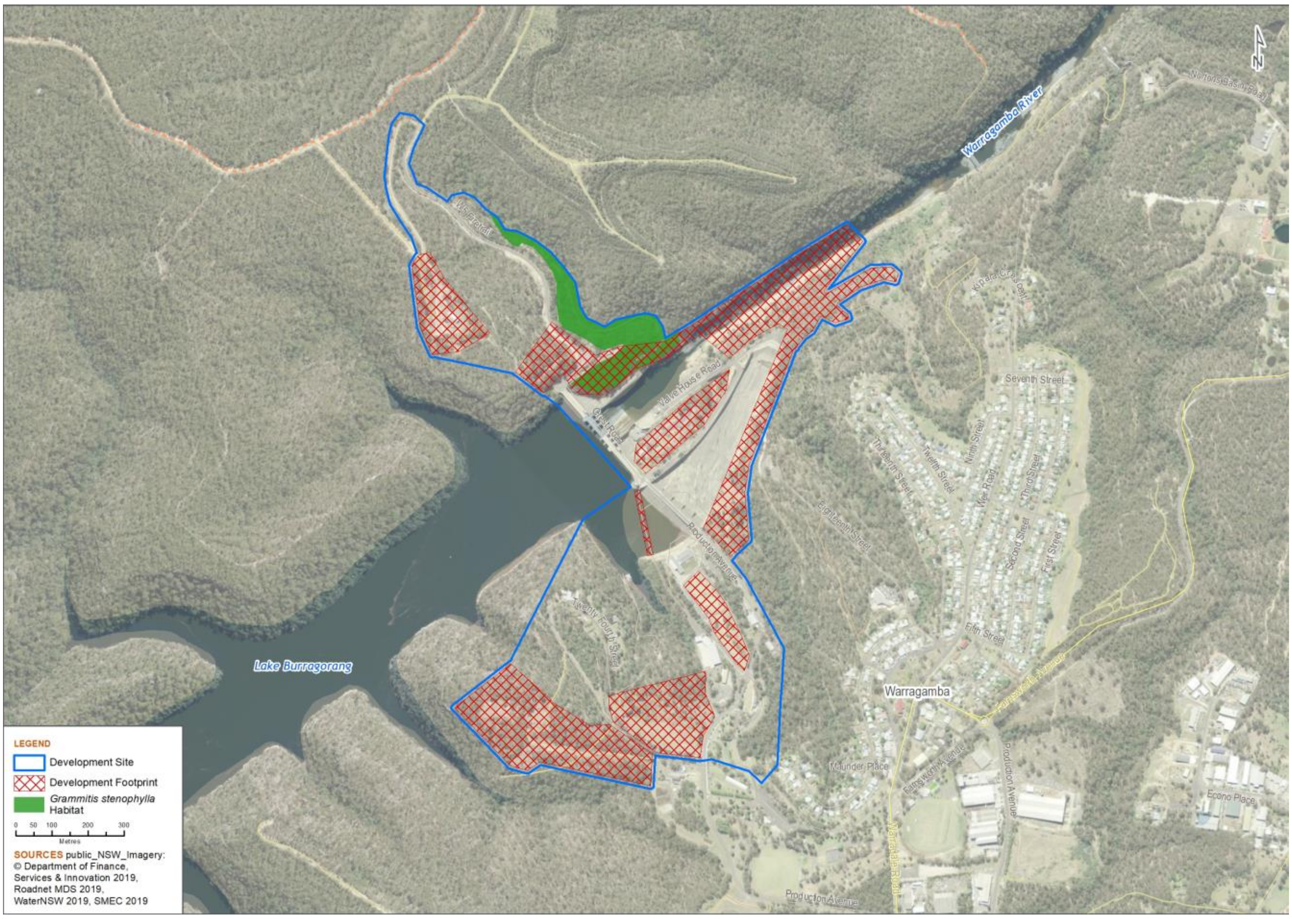


Figure B-17. Grevillea evansiana *species polygon*

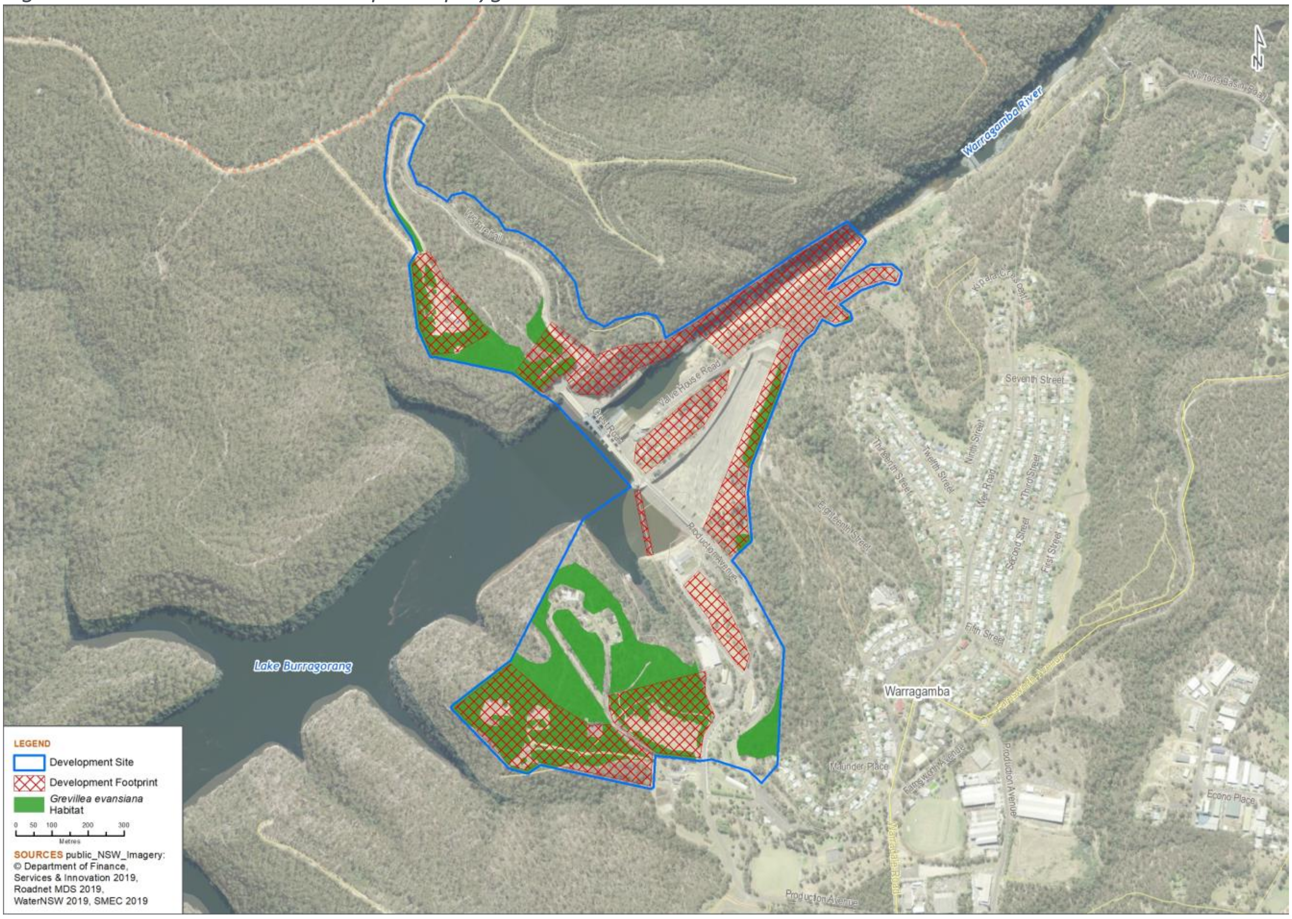


Figure B-18. Grevillea parviflora subsp. parviflora *species polygon*

Figure B-19. Gyrostemon thesioides *species polygon*

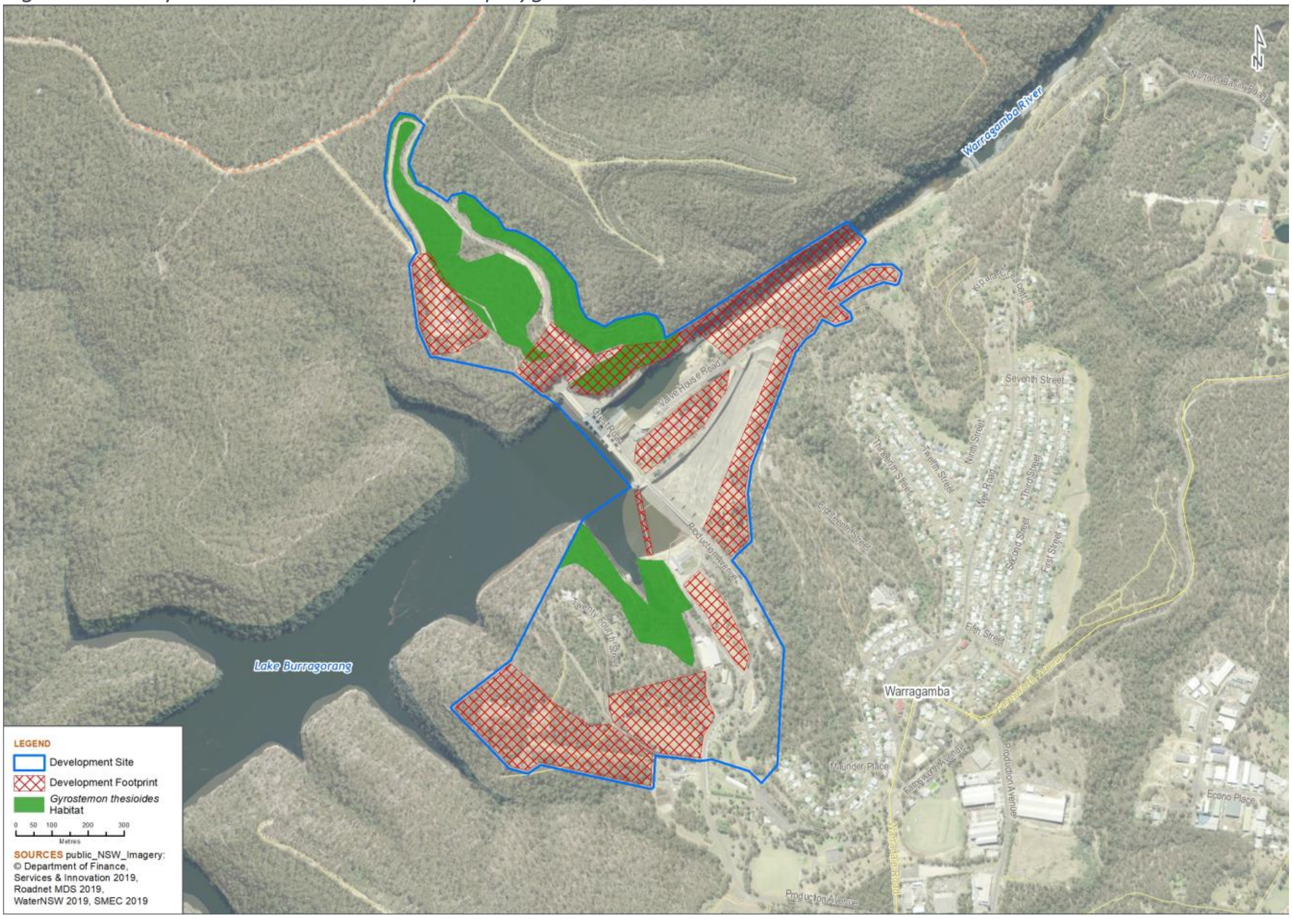


Figure B-20. Haloragodendron lucasii *species polygon*

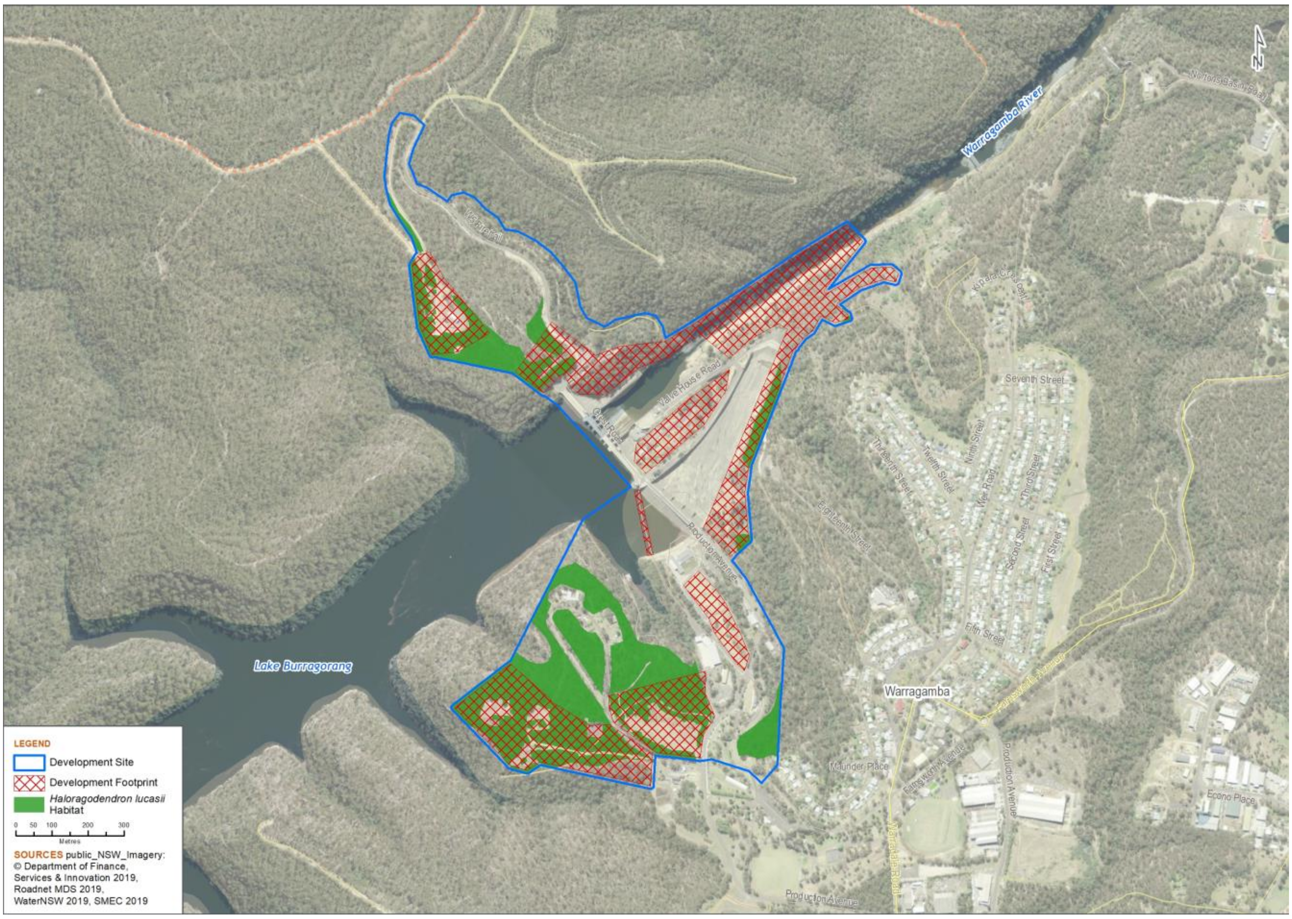


Figure B-21. Hibbertia puberula *species polygon*

Figure B-22. Hygrocybe anomala subsp. ianthinomarginata *species polygon*

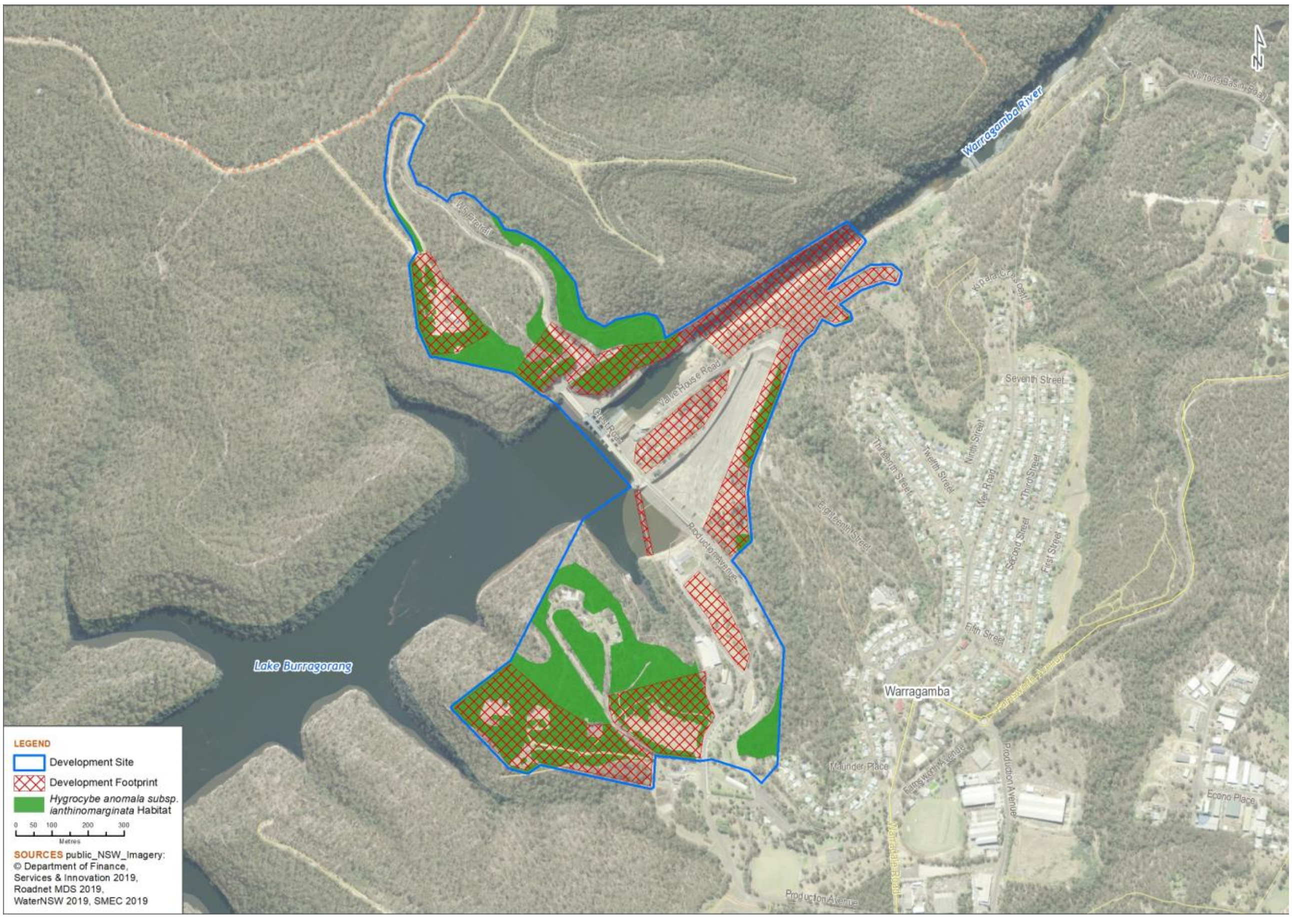


Figure B-23. Kunzea rupestris *species polygon*

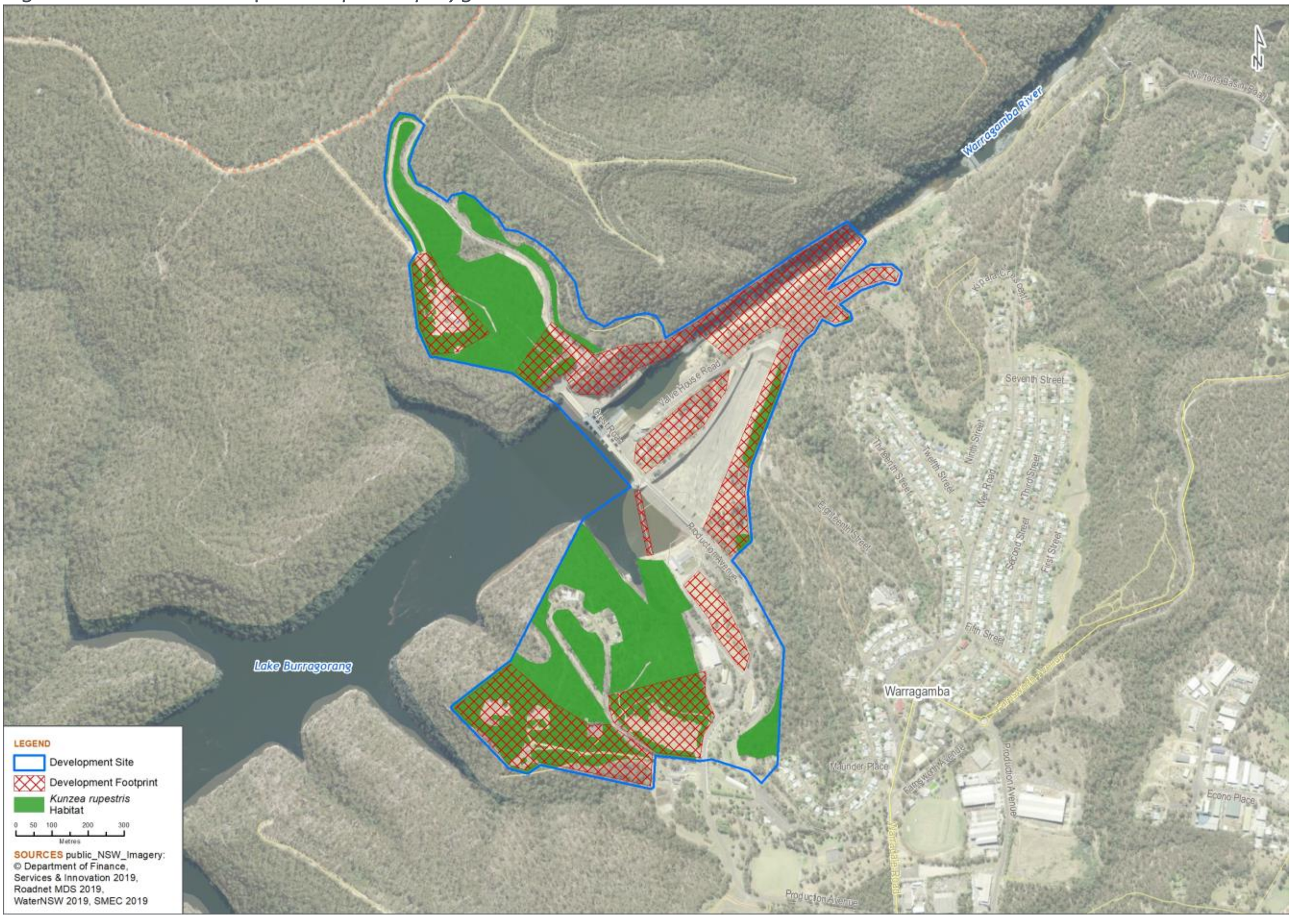


Figure B-24. Lastreopsis hispida *species polygon*

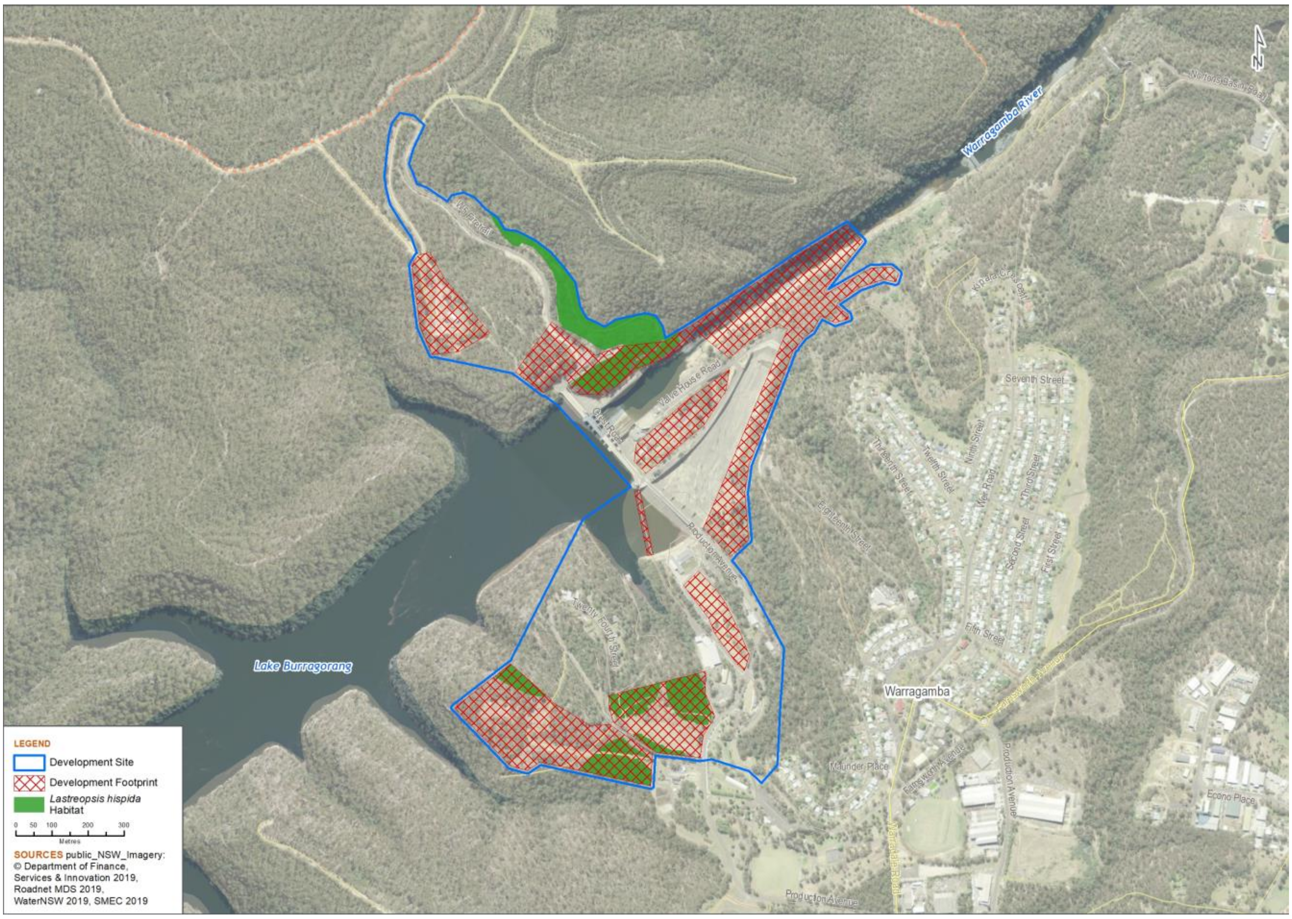


Figure B-25. Leucopogon exolasius *species polygon*

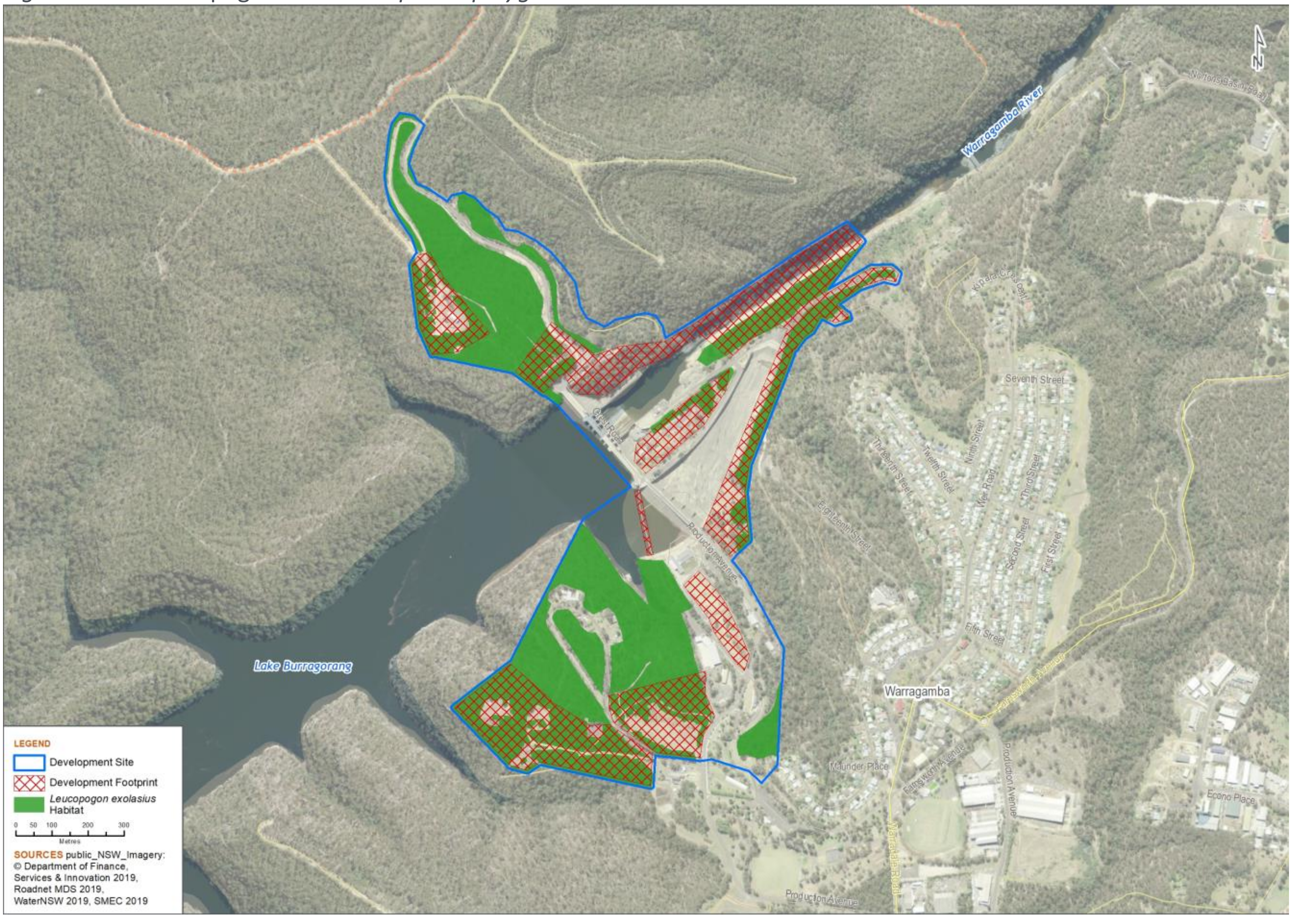


Figure B-26. Leucopogon fletcheri subsp. fletcheri *species polygon*

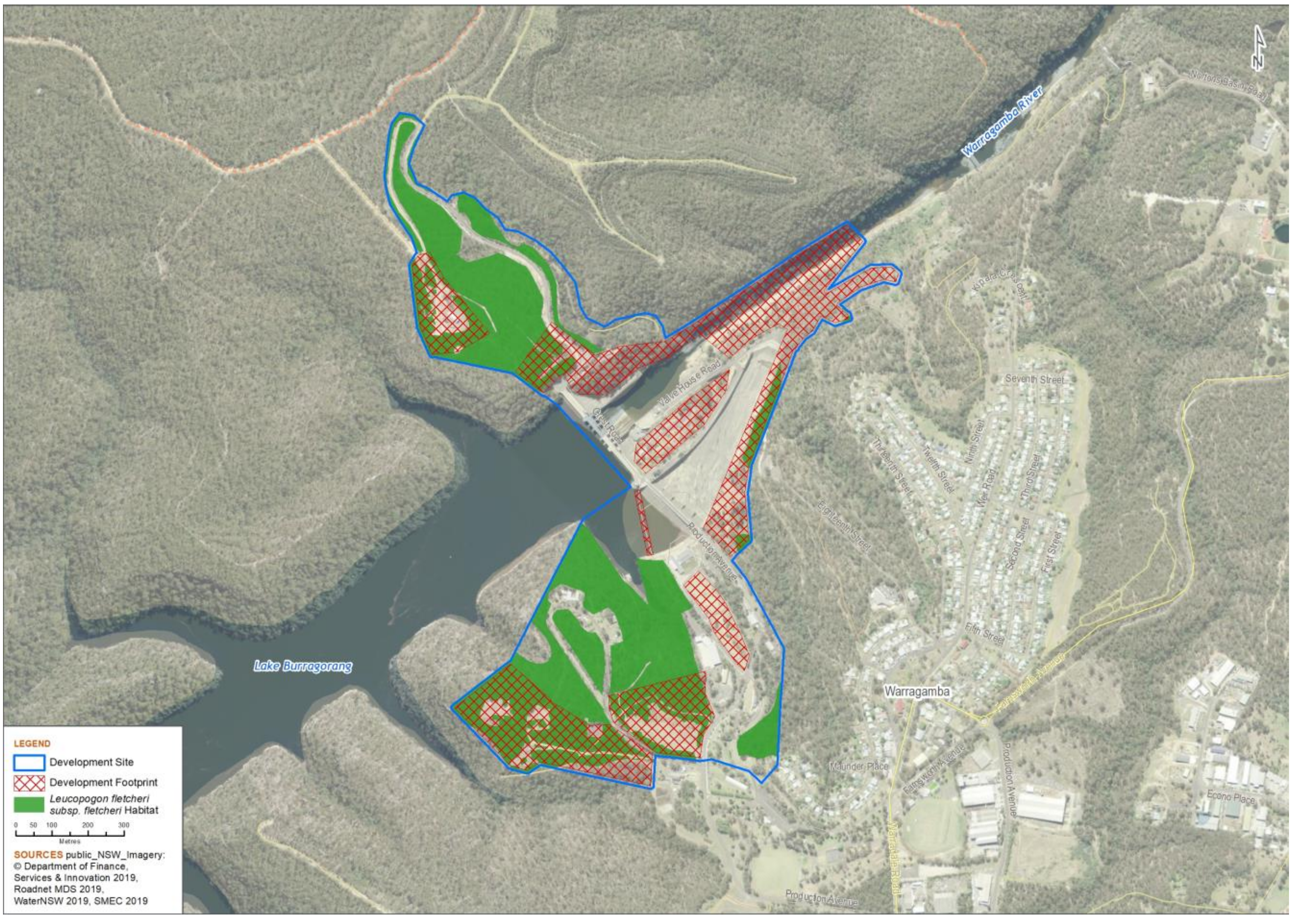


Figure B-27. Melaleuca deanei *species polygon*

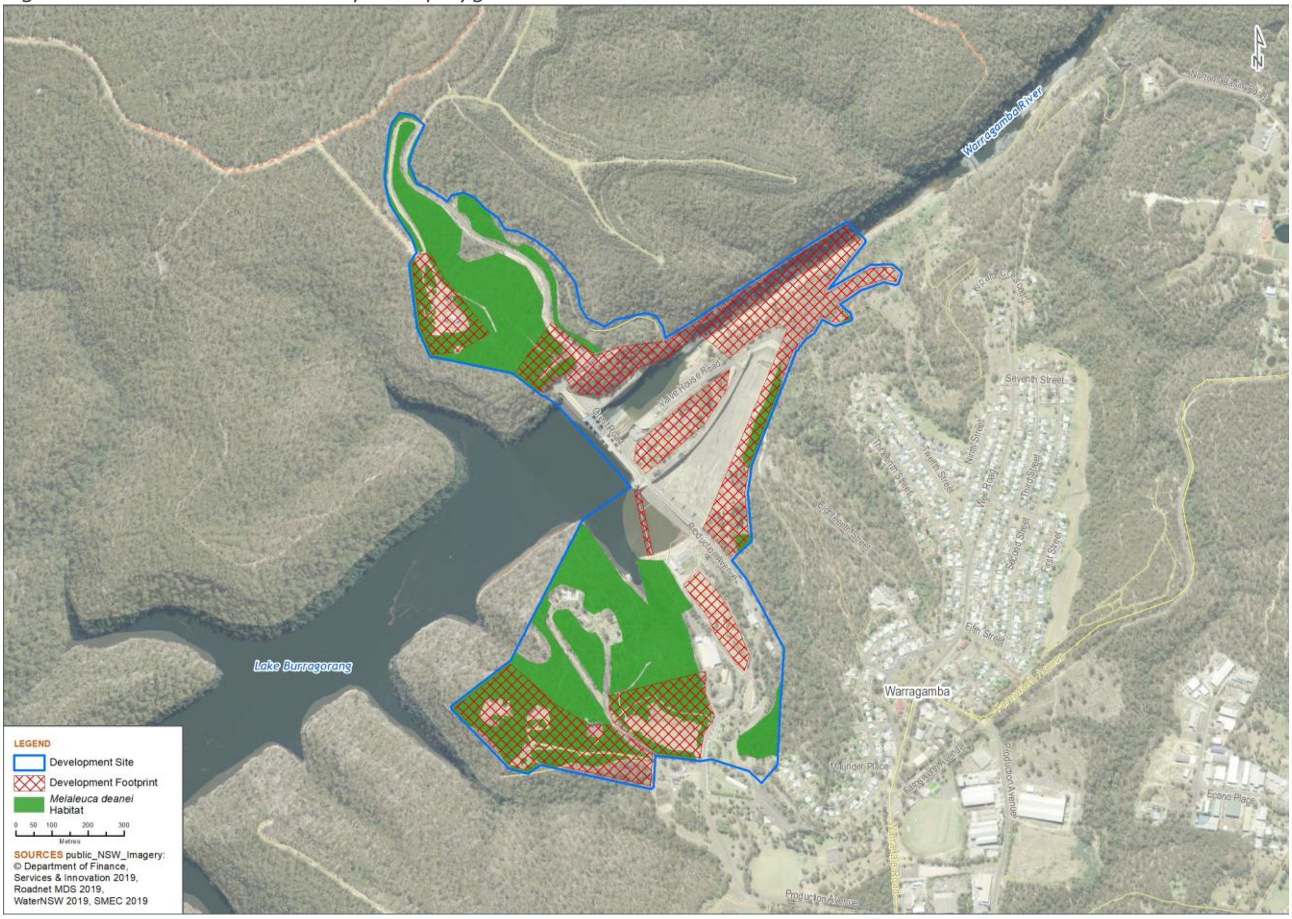


Figure B-28. Melaleuca groveana *species polygon*

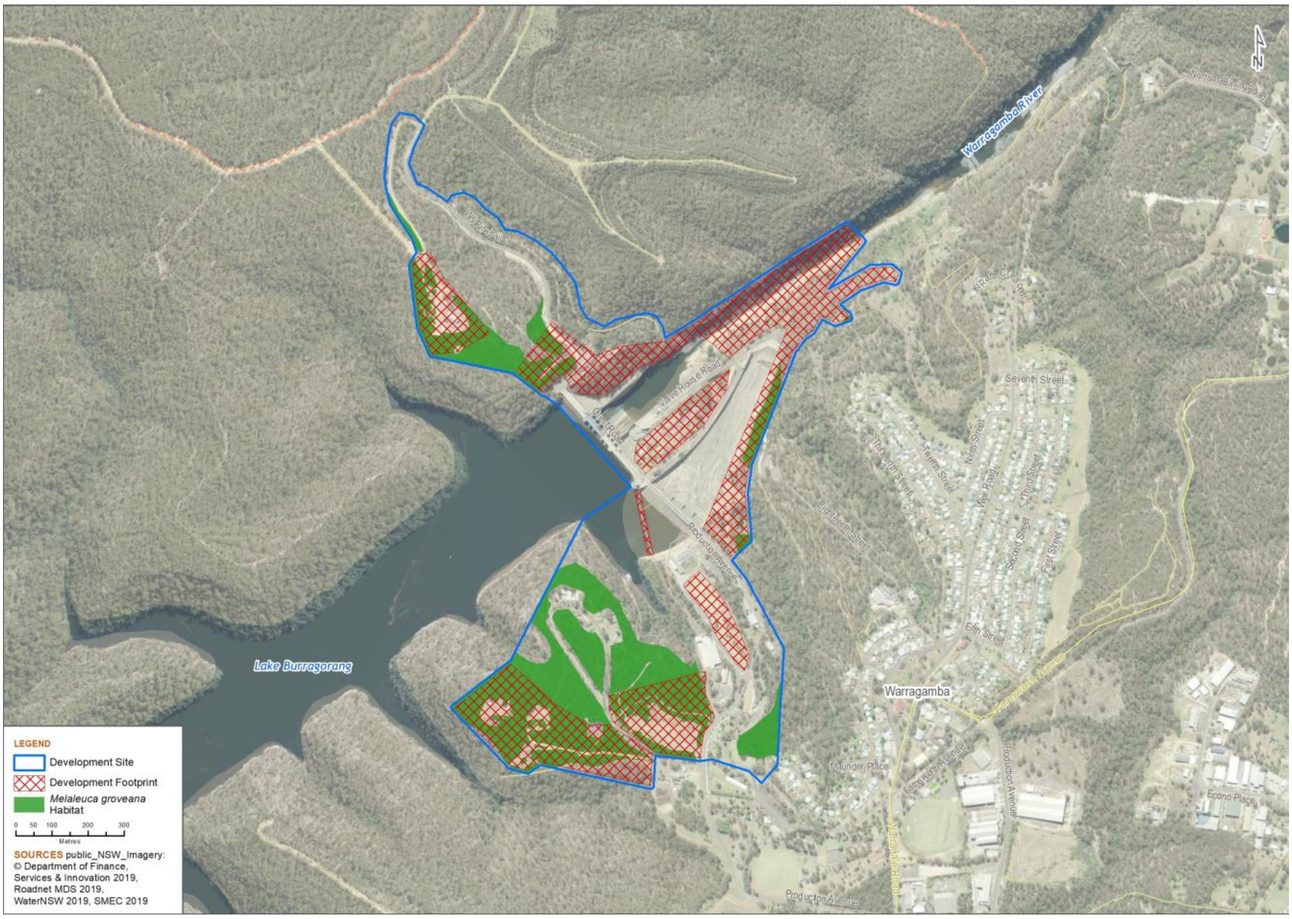


Figure B-29. Micromyrtus blakelyi *species polygon*

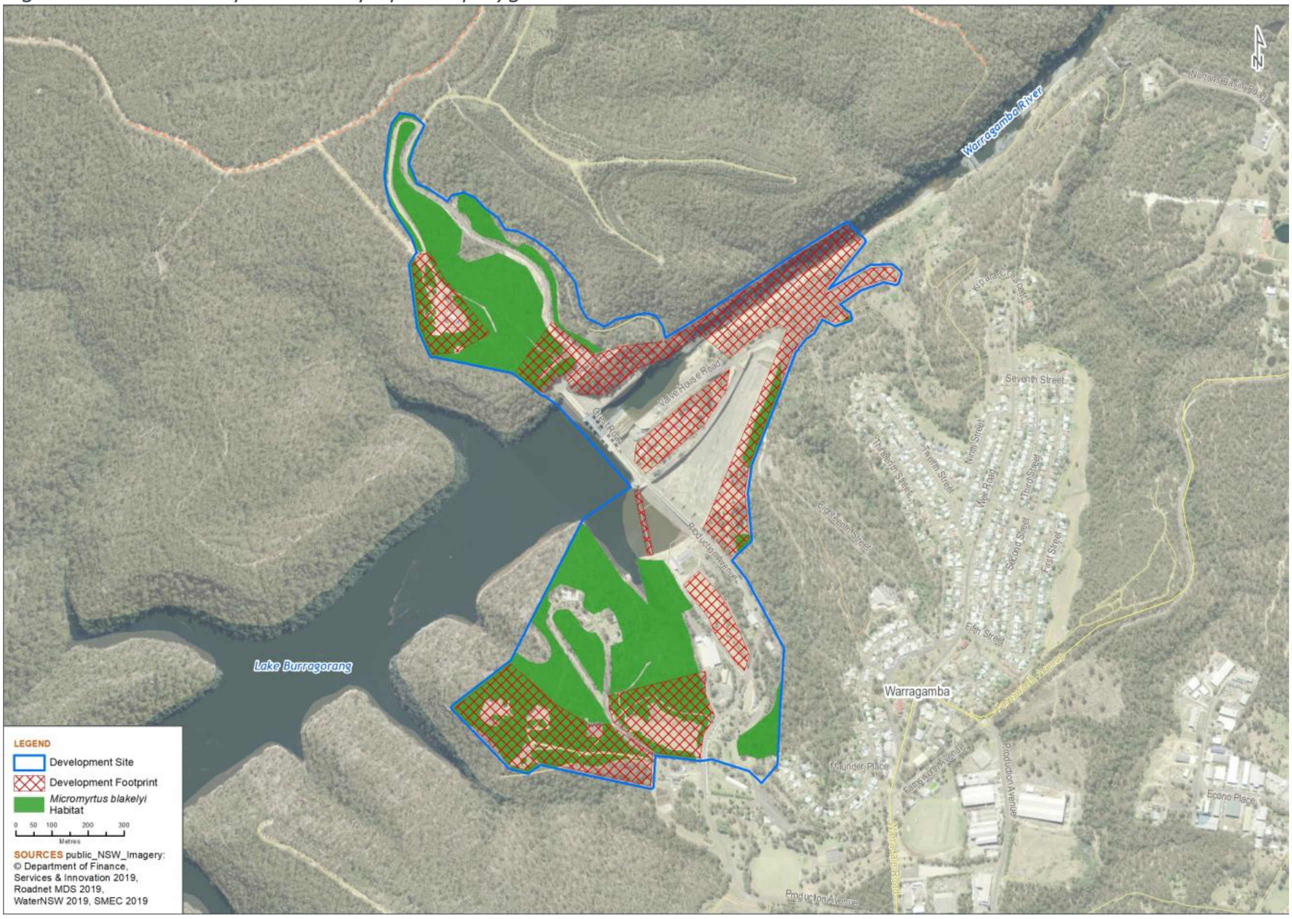


Figure B-30. Olearia cordata *species polygon*

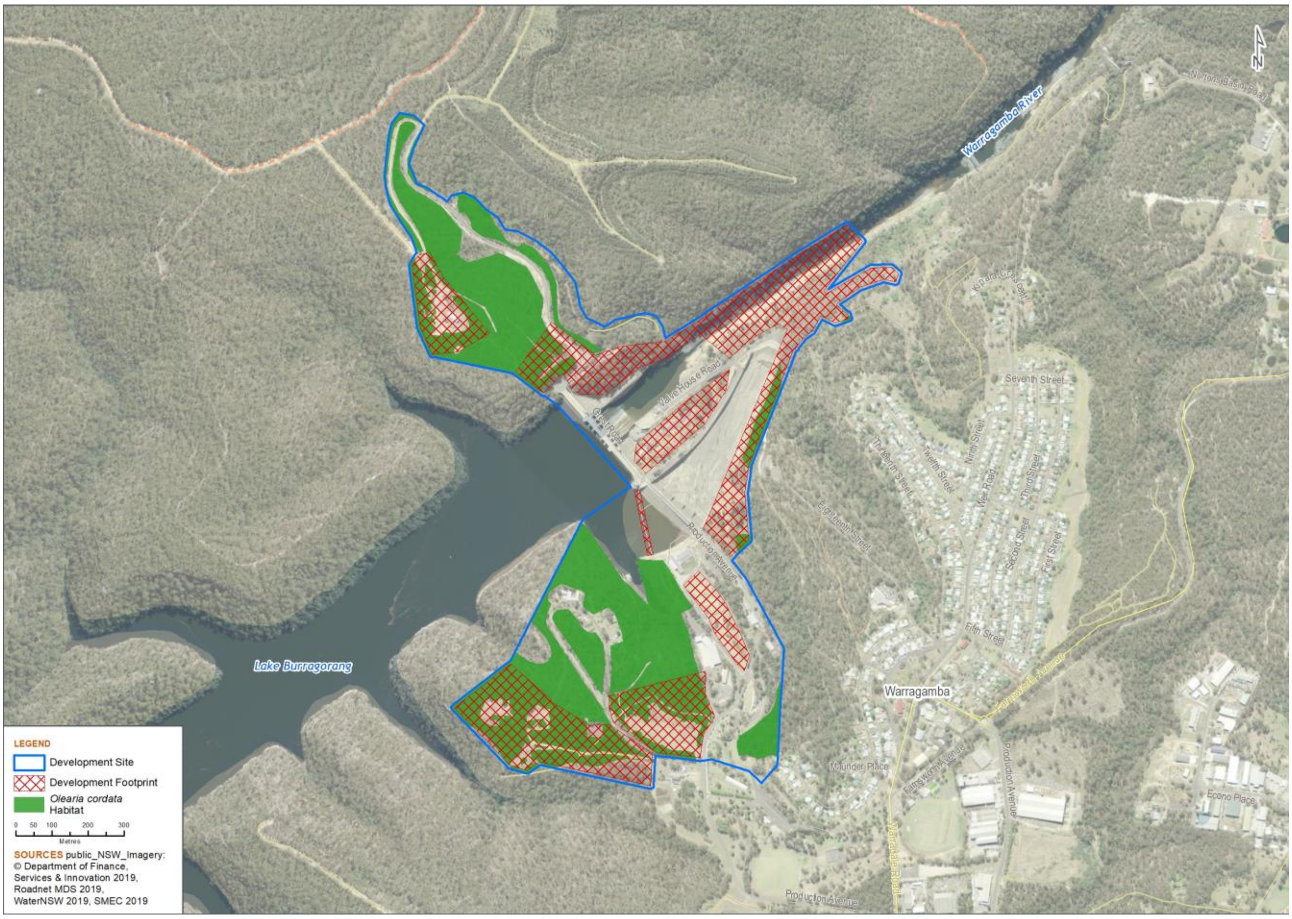


Figure B-31. Persoonia acerosa *species polygon*

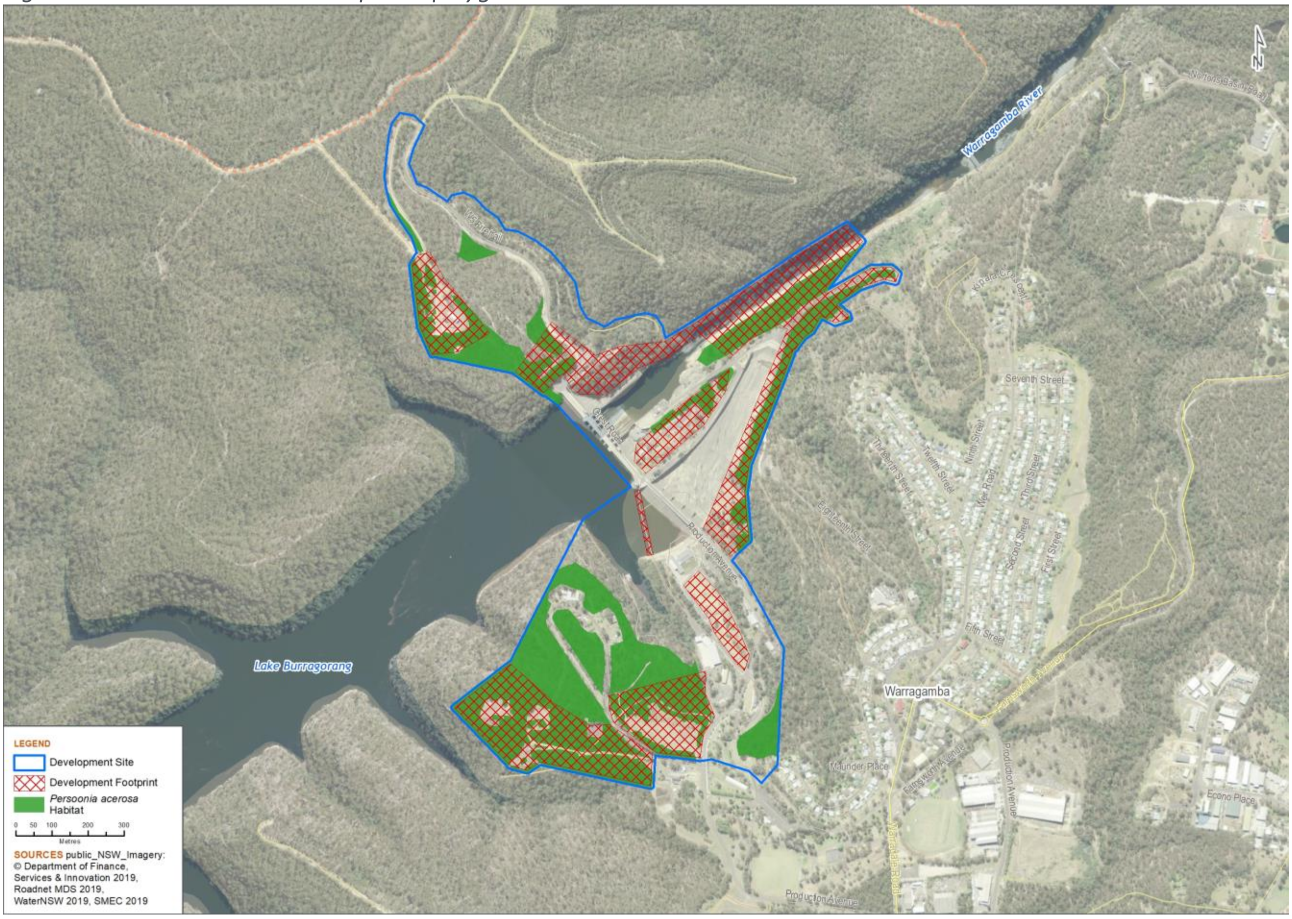


Figure B-32. Persoonia hirsuta *species polygon*

Figure B-33. Pimelea curviflora var. curviflor*a species polygon*

Figure B-34. Pomaderris brunnea *species habitat*

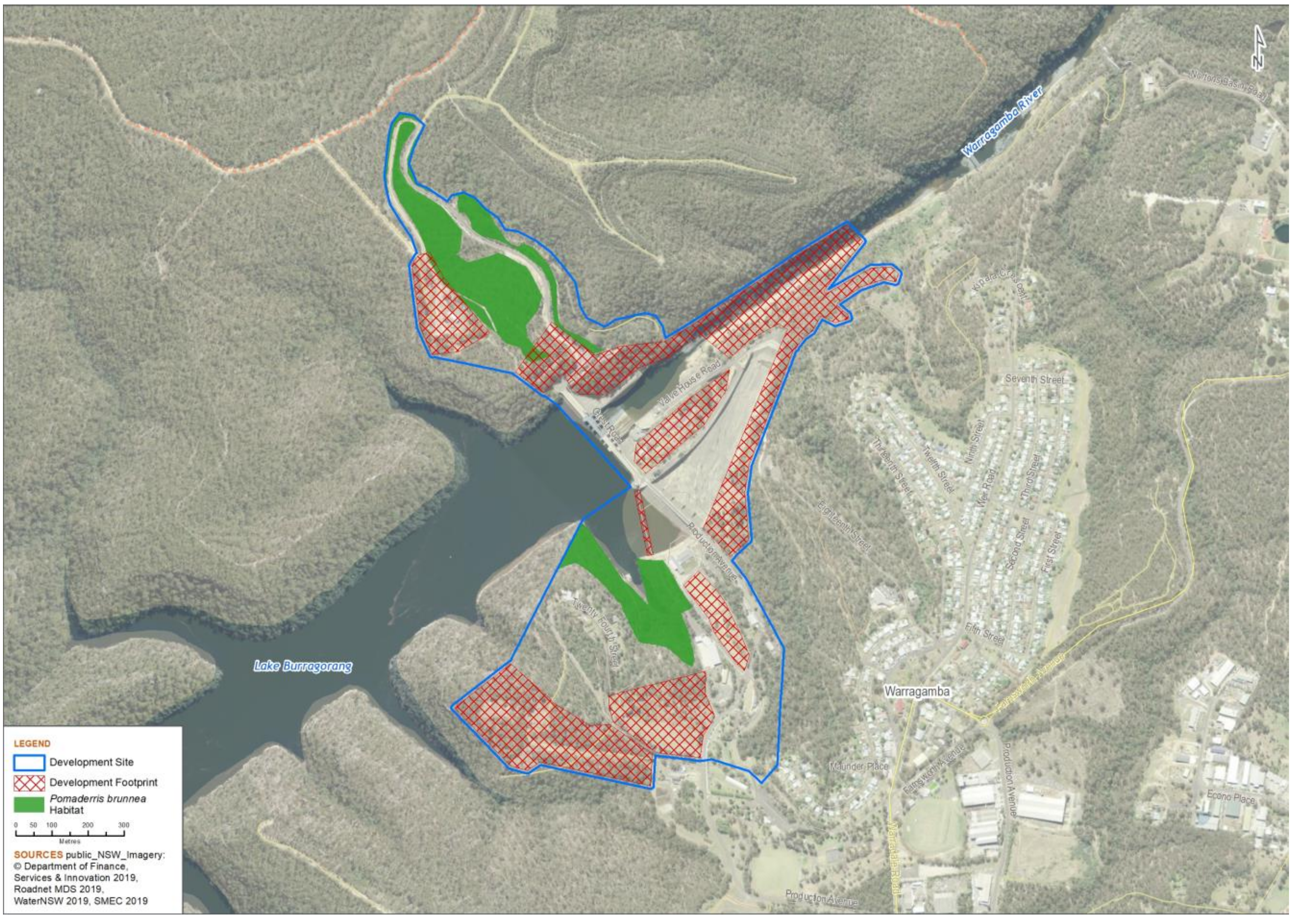


Figure B-35. Pterostylis saxicola *species polygon*

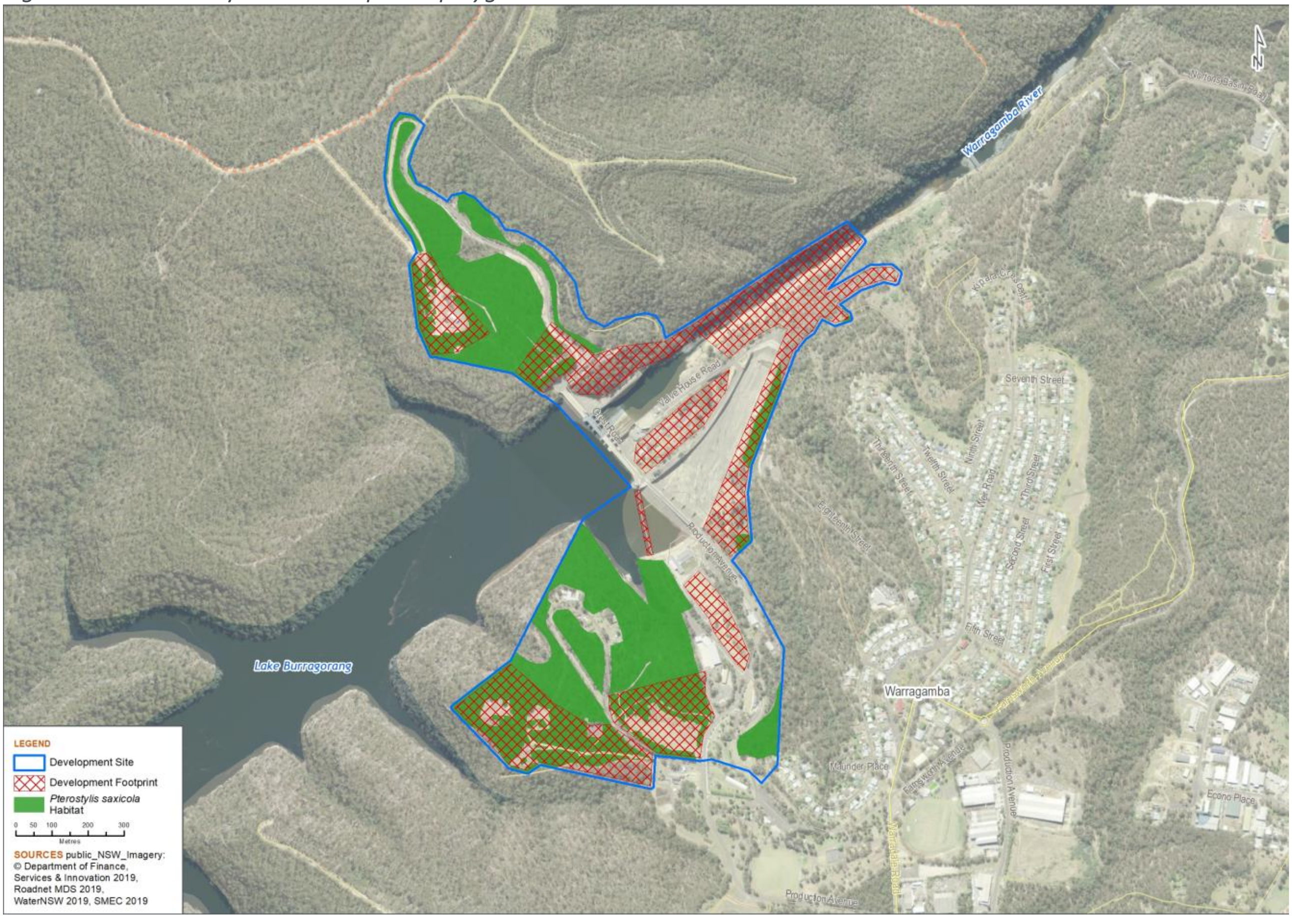


Figure B-36. Pultenaea glabra *species polygon*

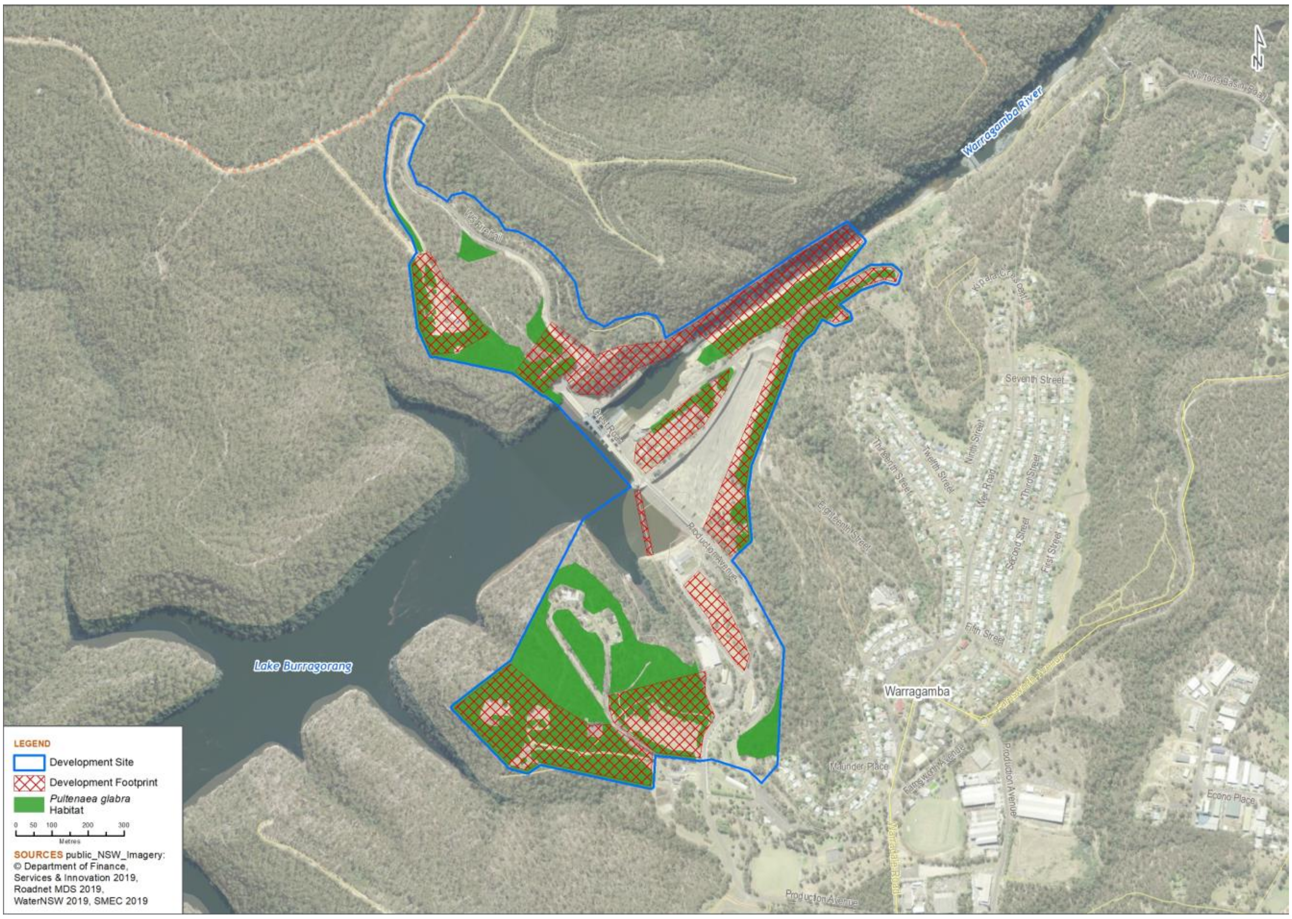


Figure B-37. Pultenaea parviflora *species polygon*

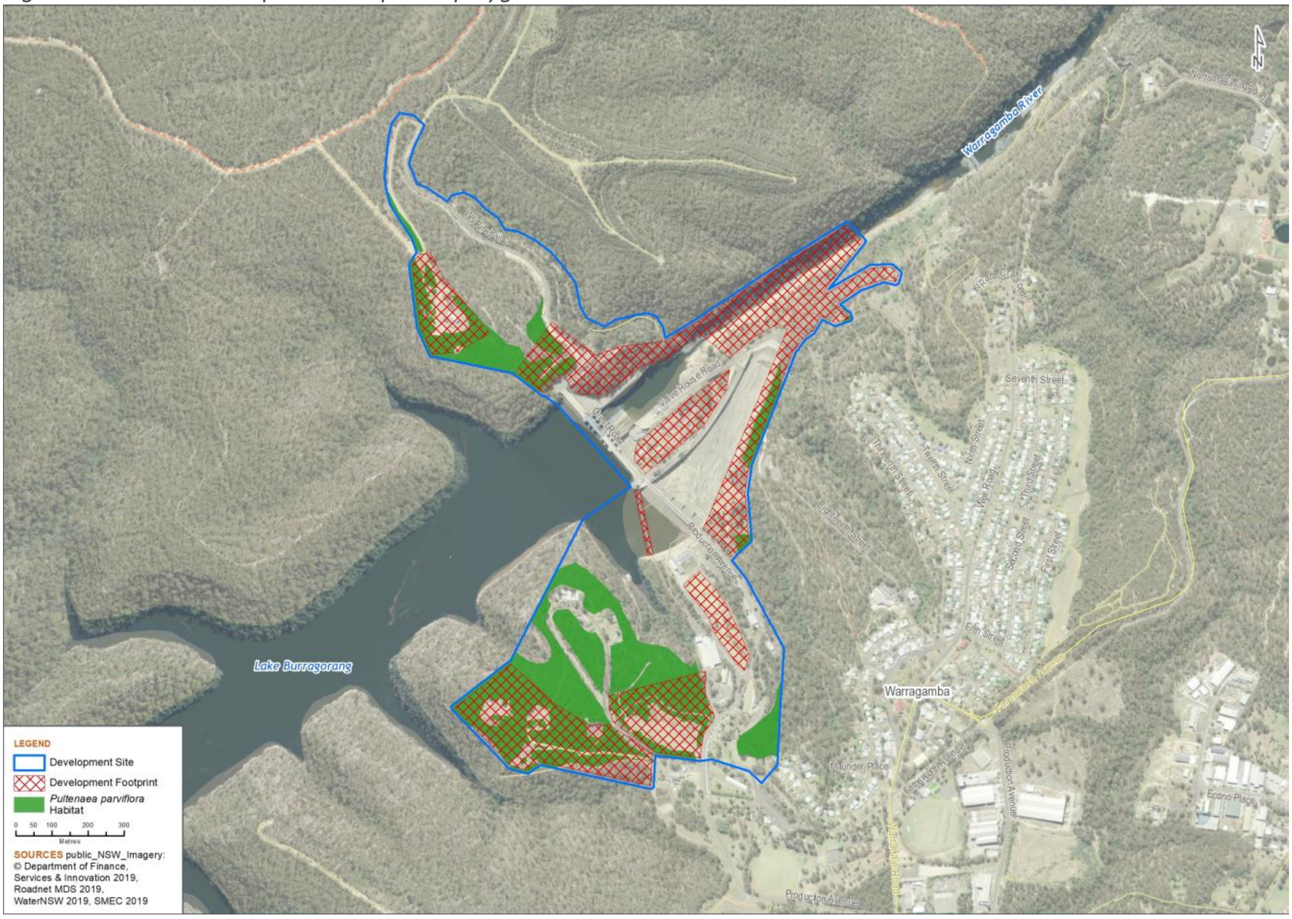


Figure B-38. Pultenaea sp. Olinda *species polygon*

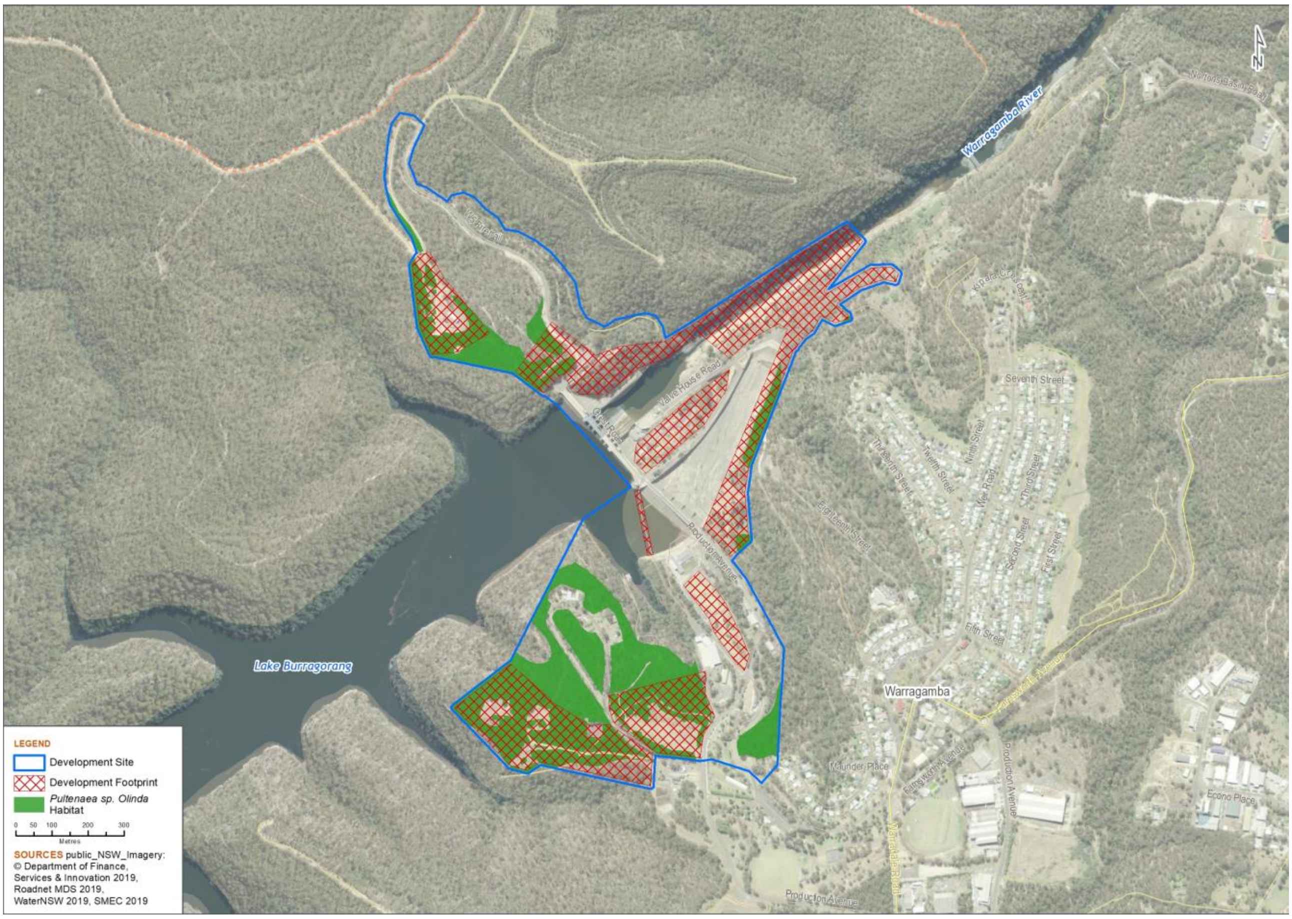


Figure B-39. Rhodamnia rubescens *species polygons*

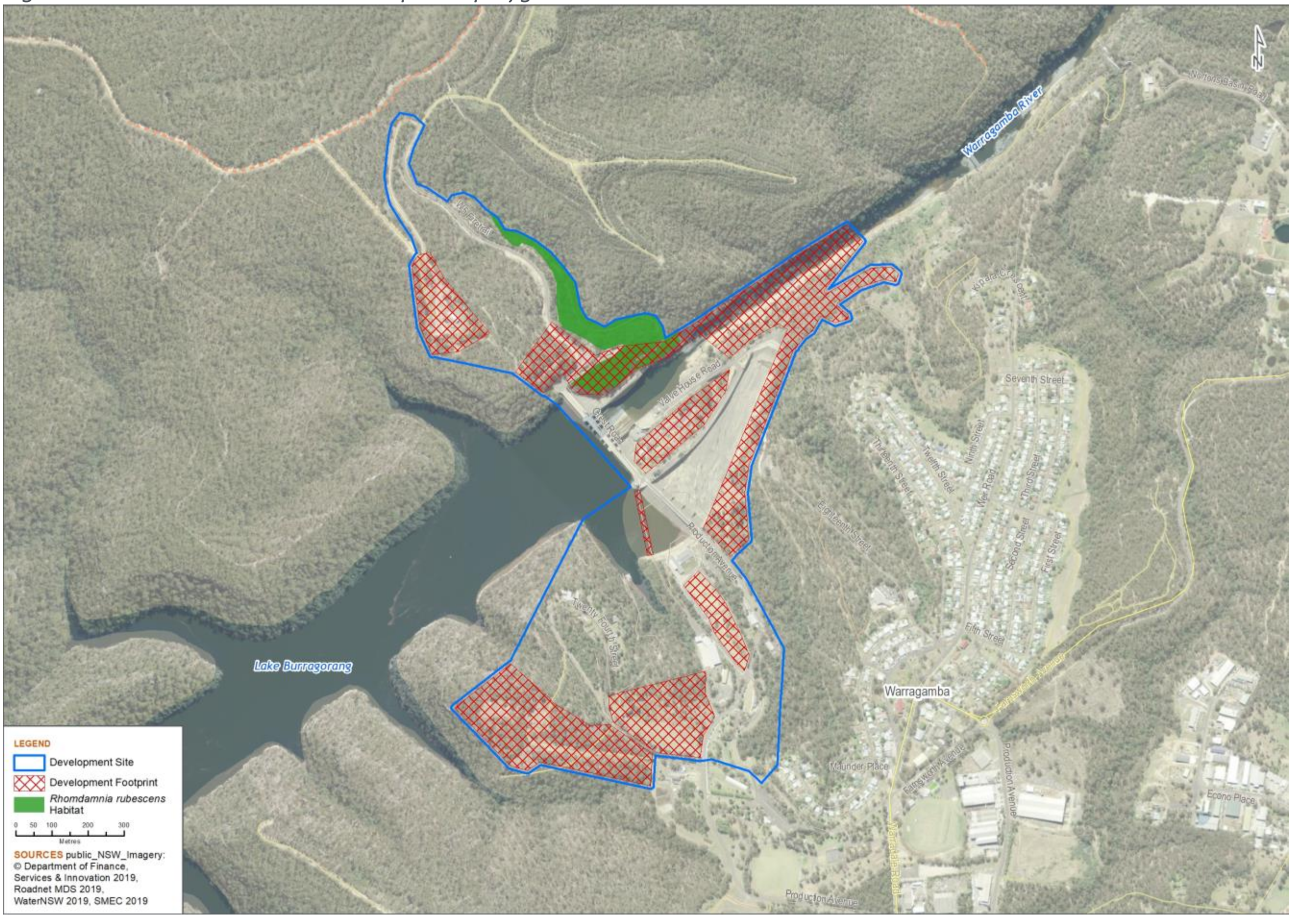


Figure B-40. Syzygium paniculatum *species polygon*

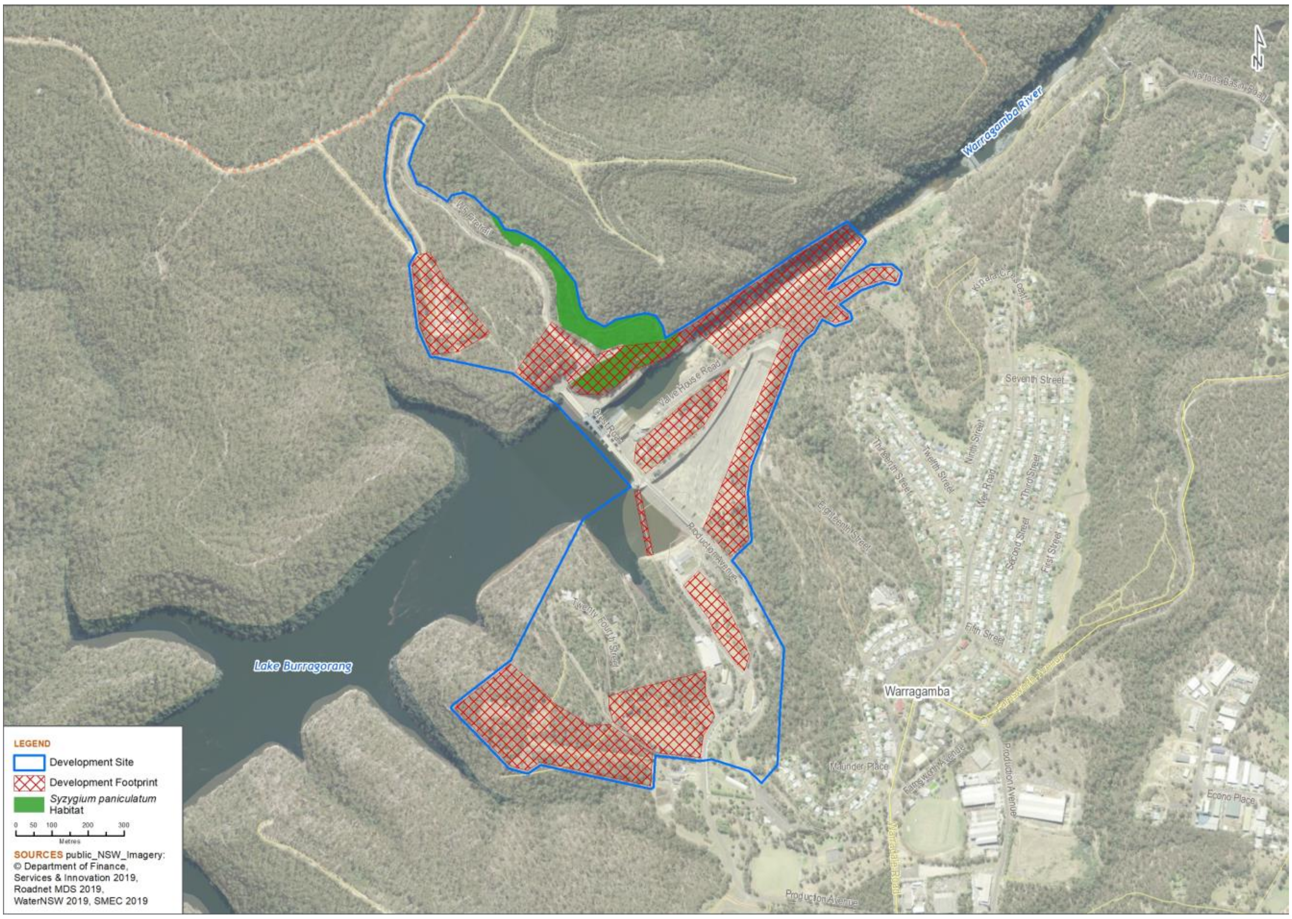


Figure B-41. Tetratheca glandulosa *species polygon*

Figure B-42. Velleia perfoliata *species polygon*

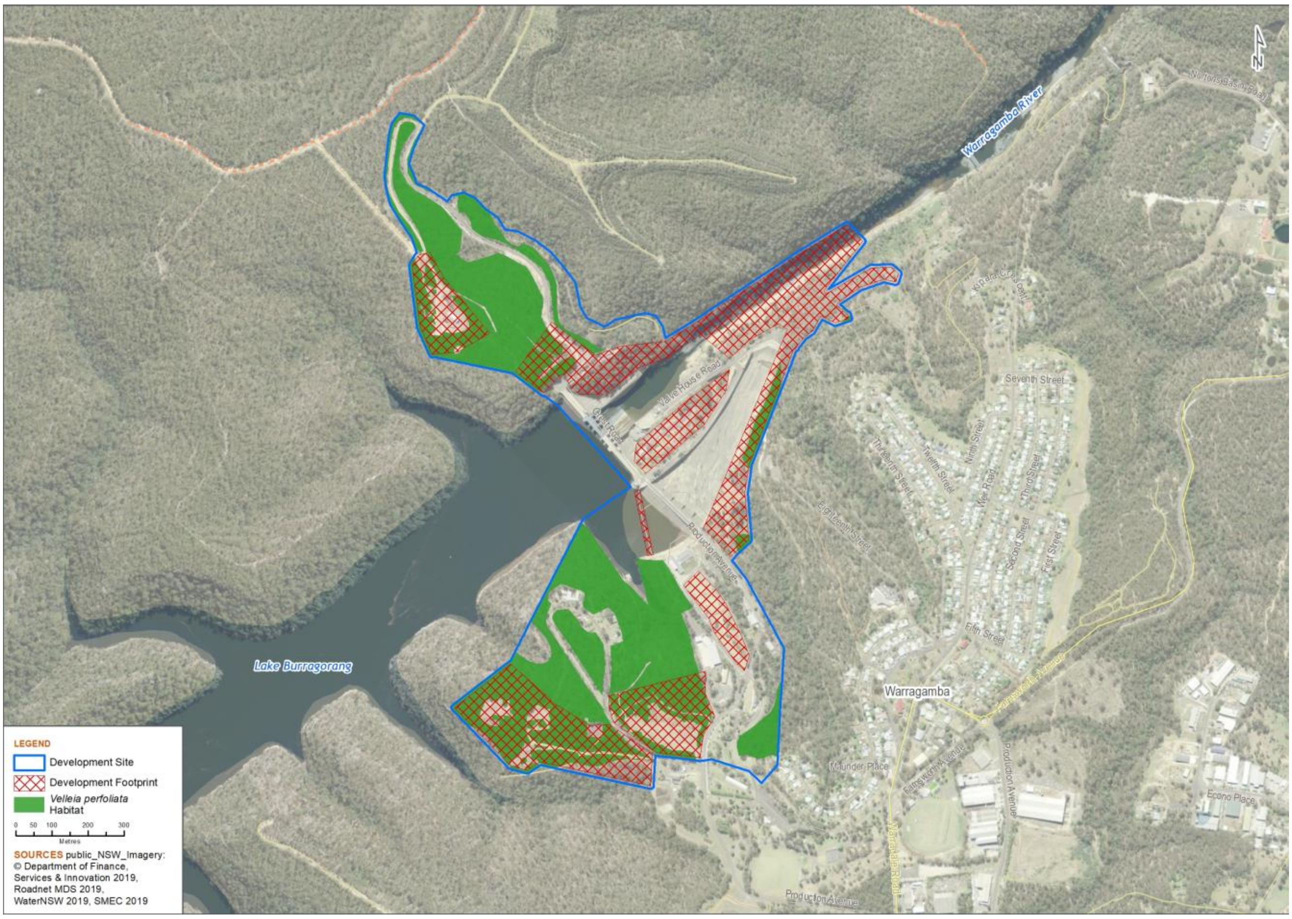


Figure B-43. Zieria involucrata *species polygon*

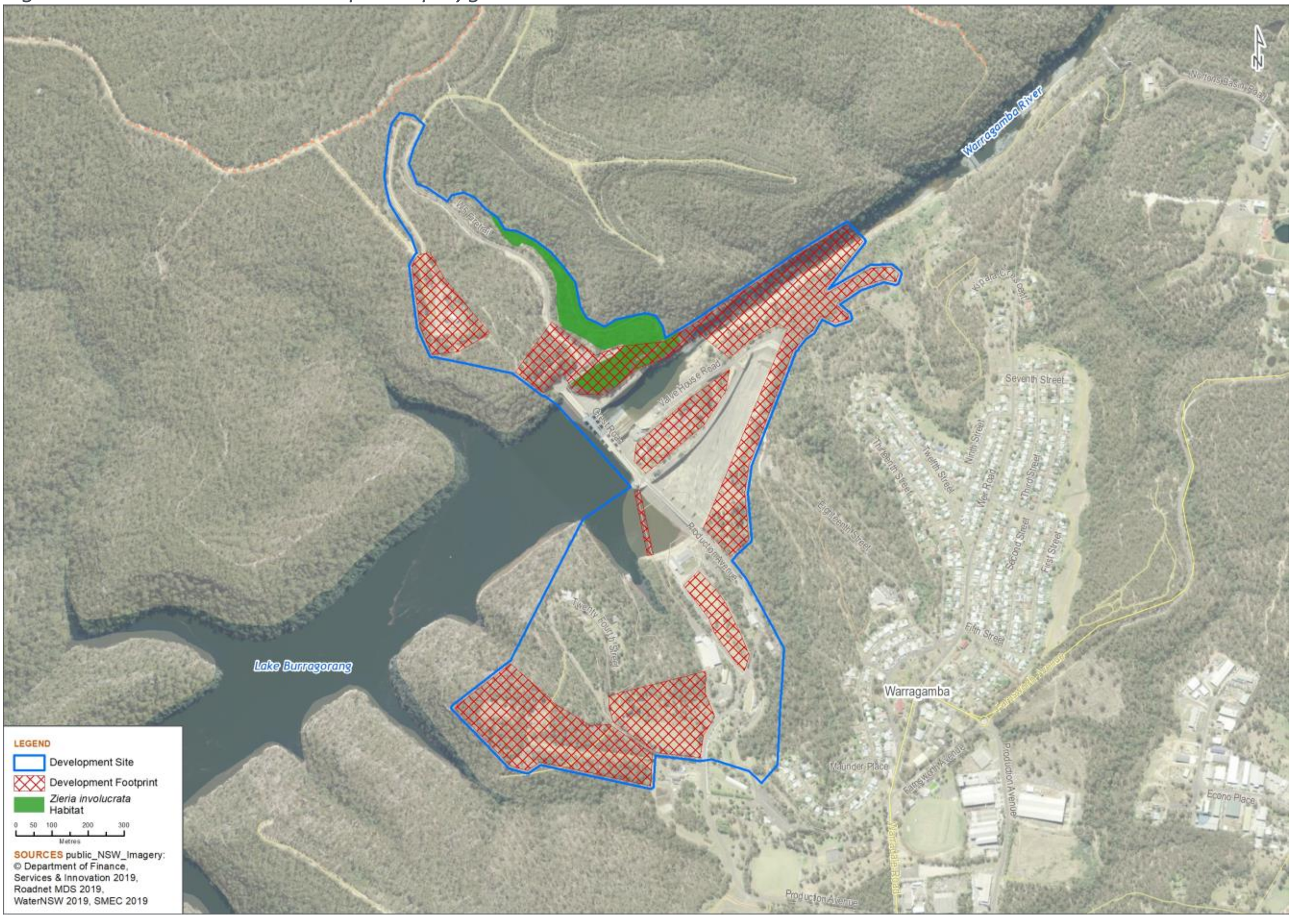


Figure B-44. Zieria murphyi *species polygon*

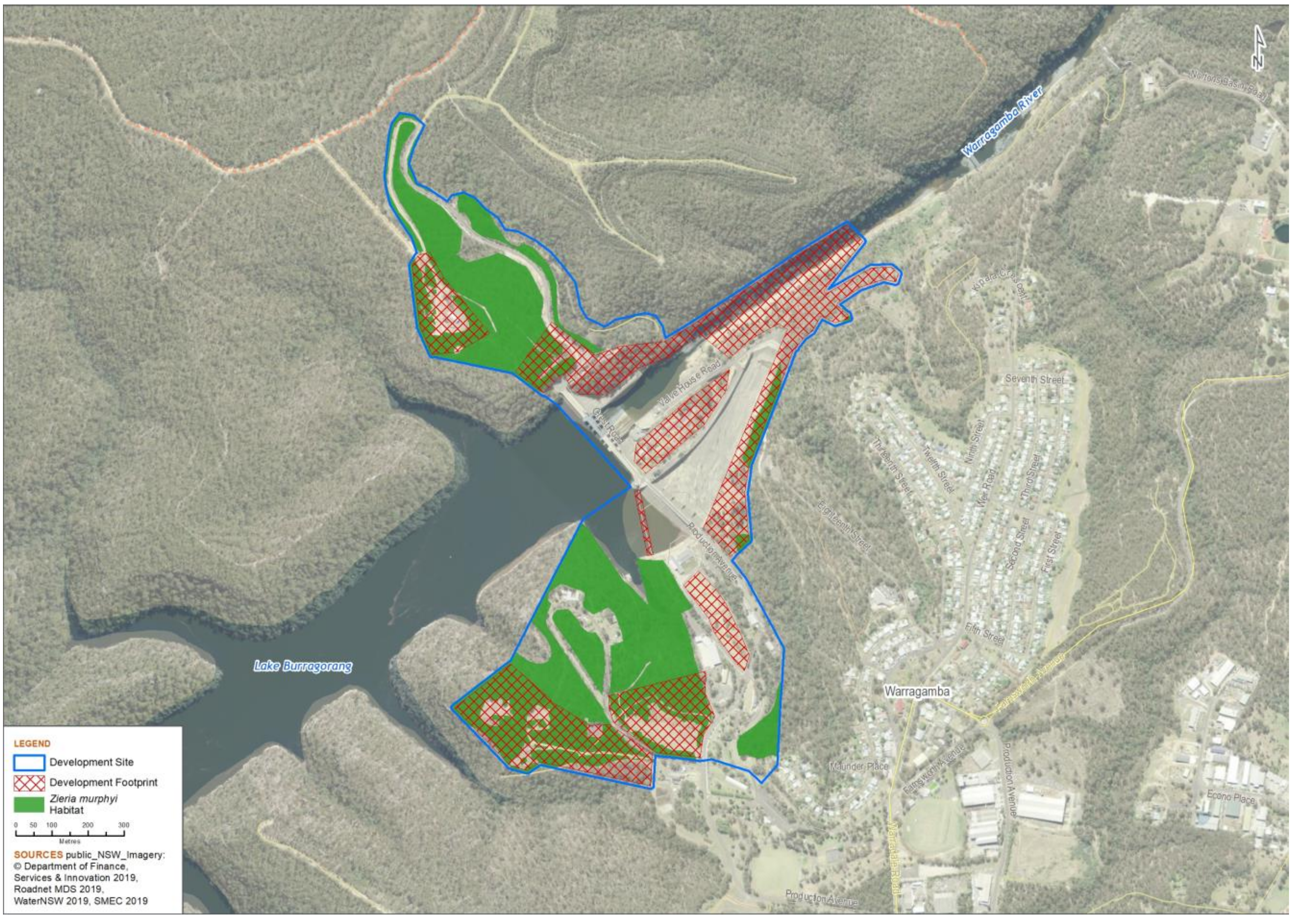


Figure B-45. Regent Honeyeater species polygon

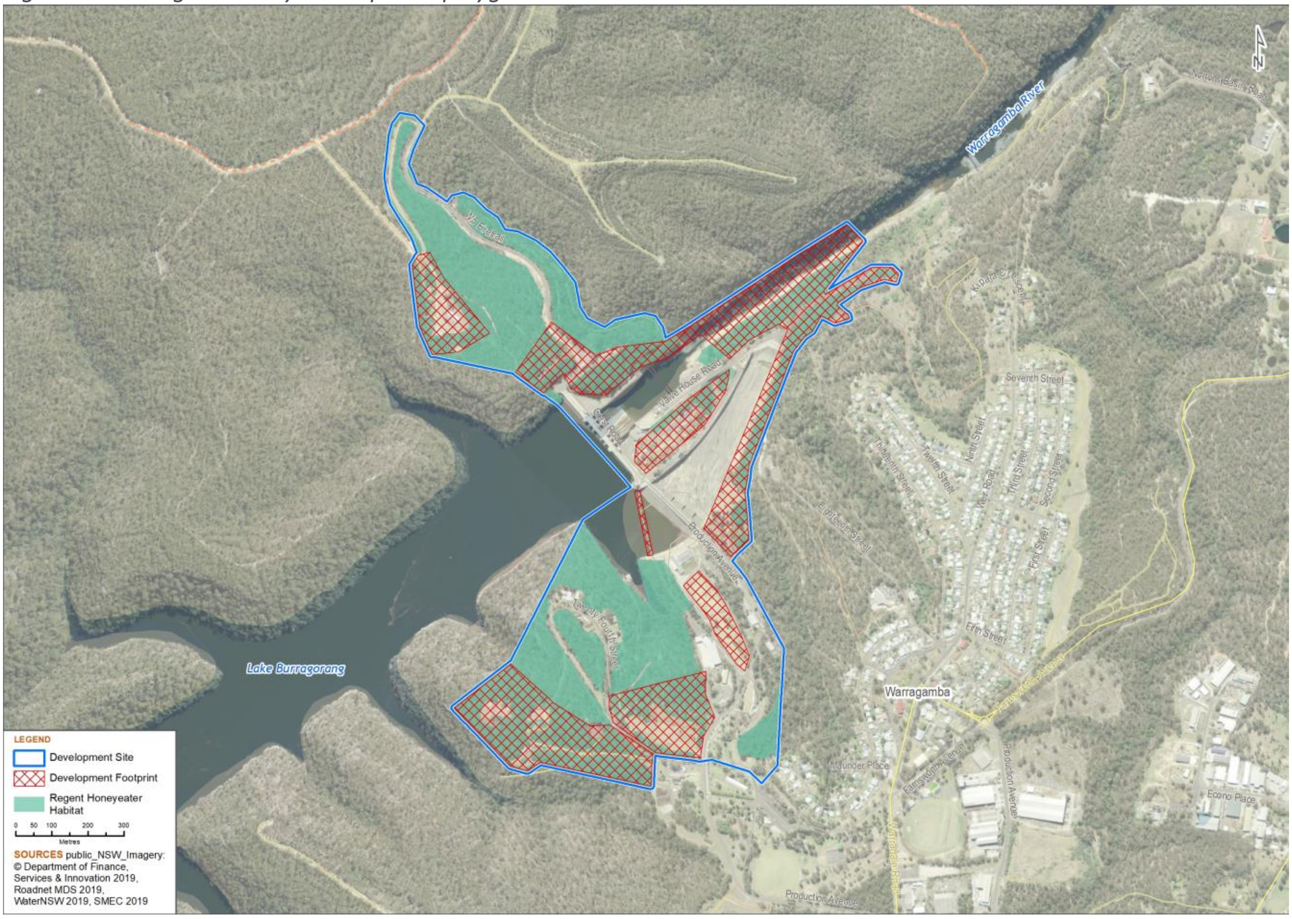


Figure B-46. Eastern Pygmy-possum species polygon

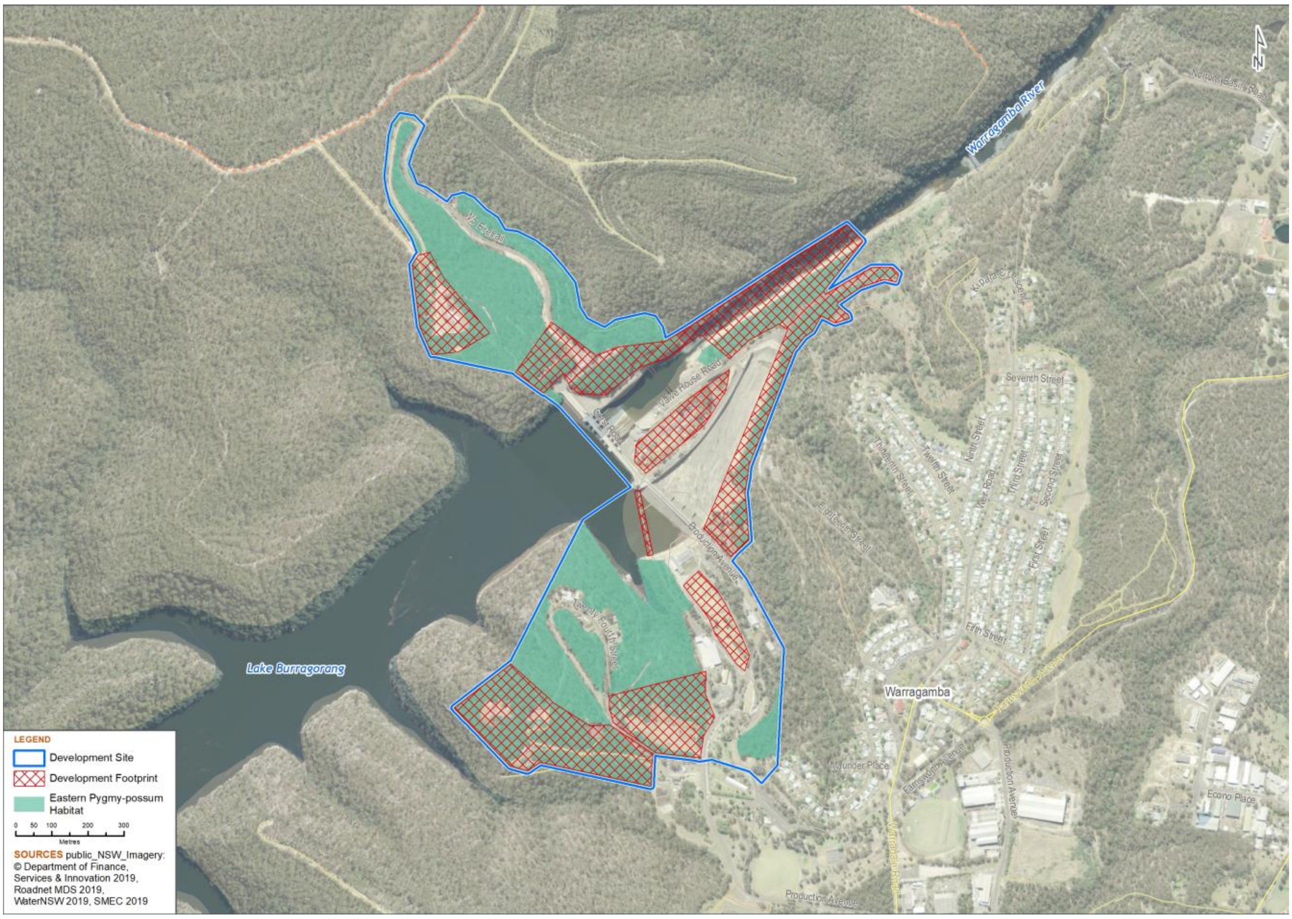


Figure B-47. Large-eared Pied Bat species polygon

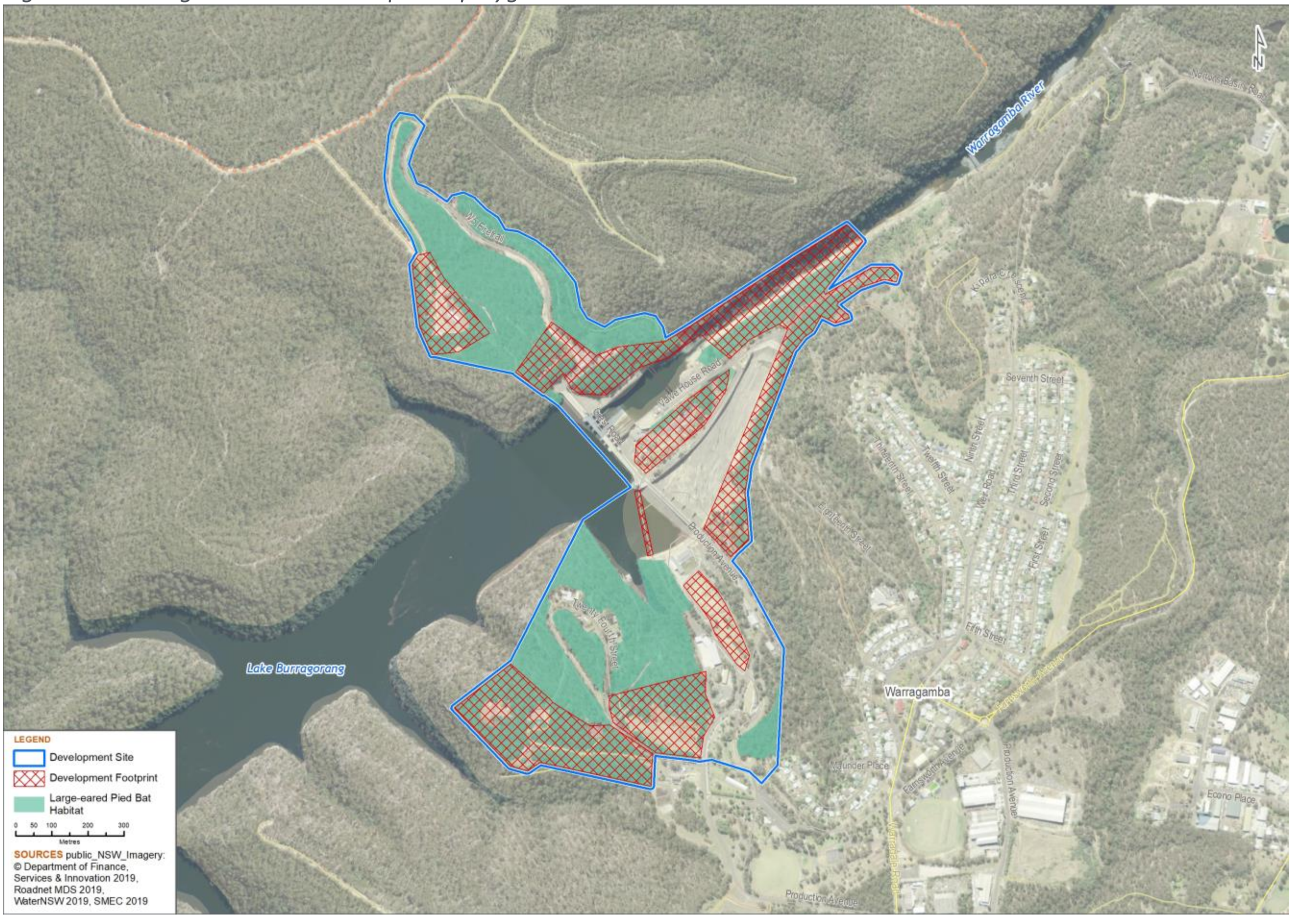


Figure B-48. Giant Burrowing Frog species polygon

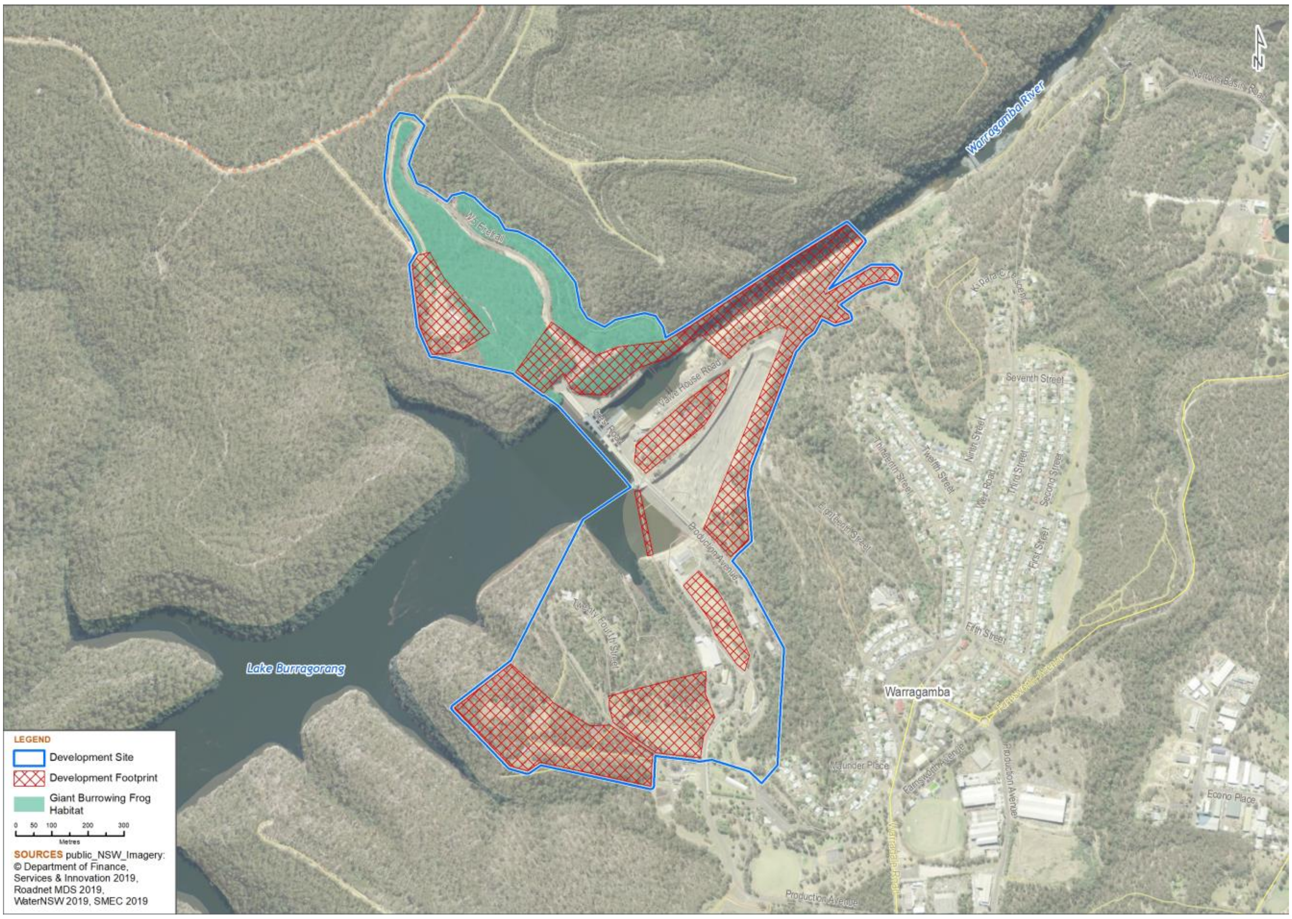


Figure B-49. Broad-headed Snake species polygon

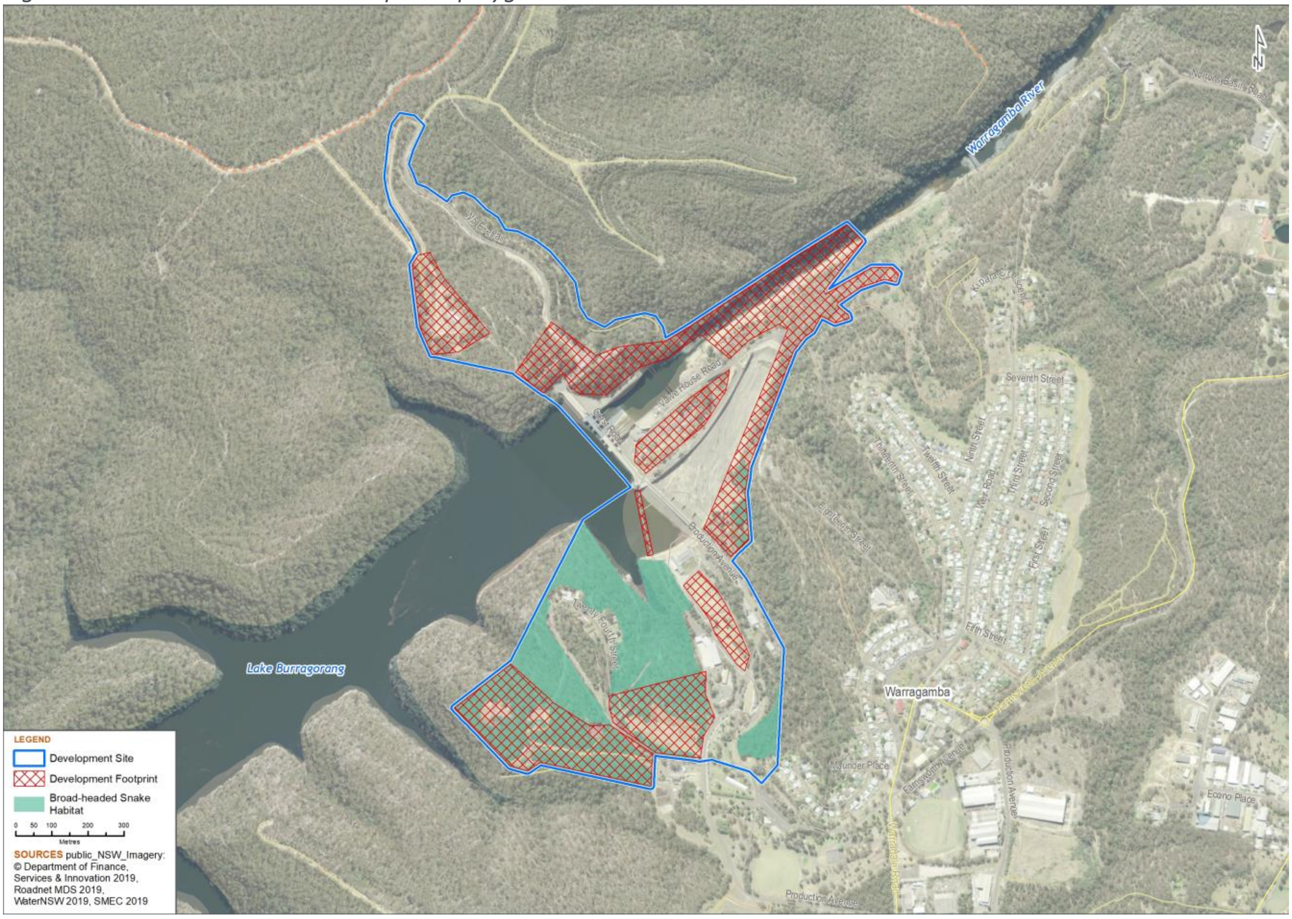


Figure B-50. Southern Brown Bandicoot species polygon

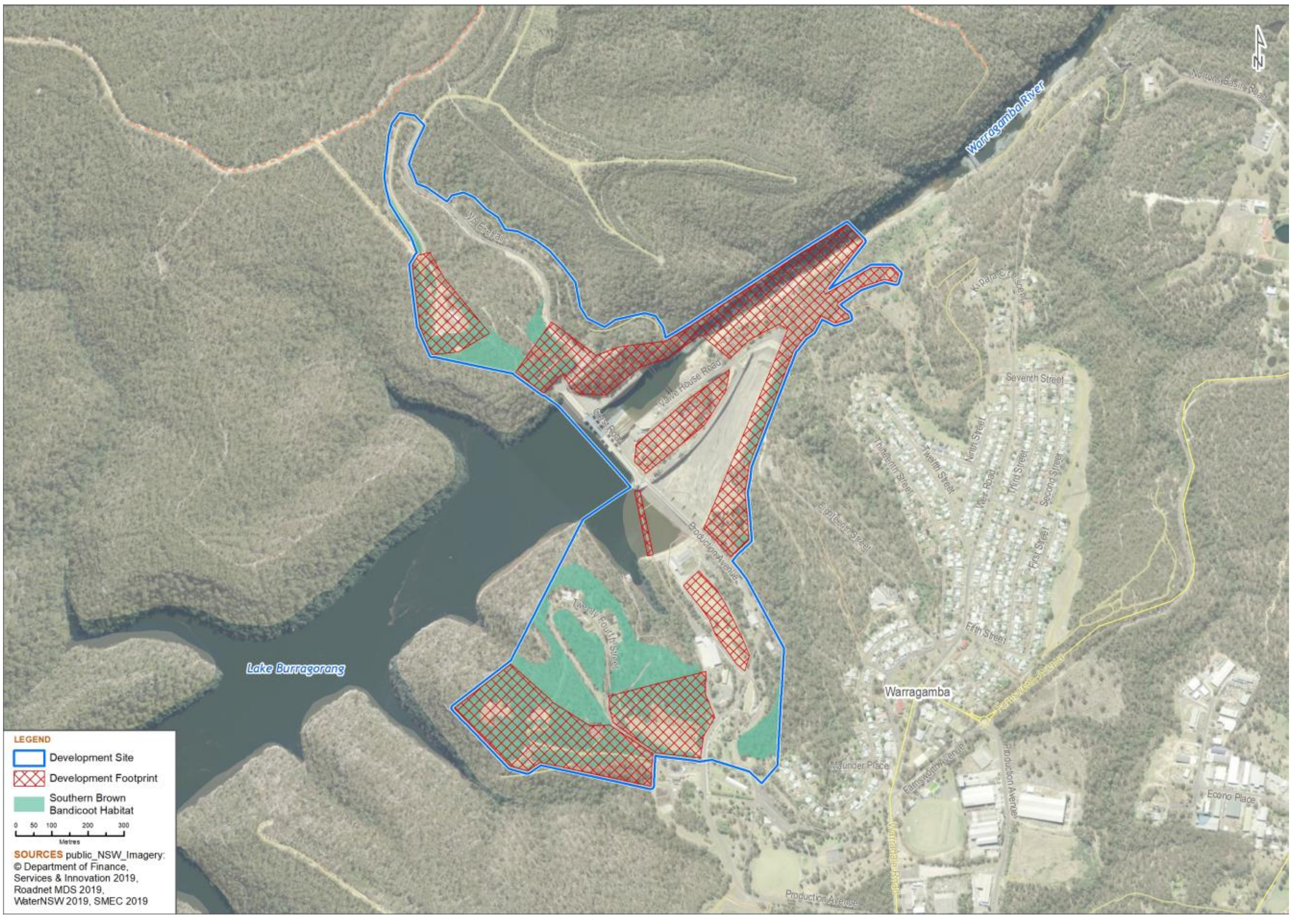


Figure B-51. Cumberland Plain Land Snail species polygon

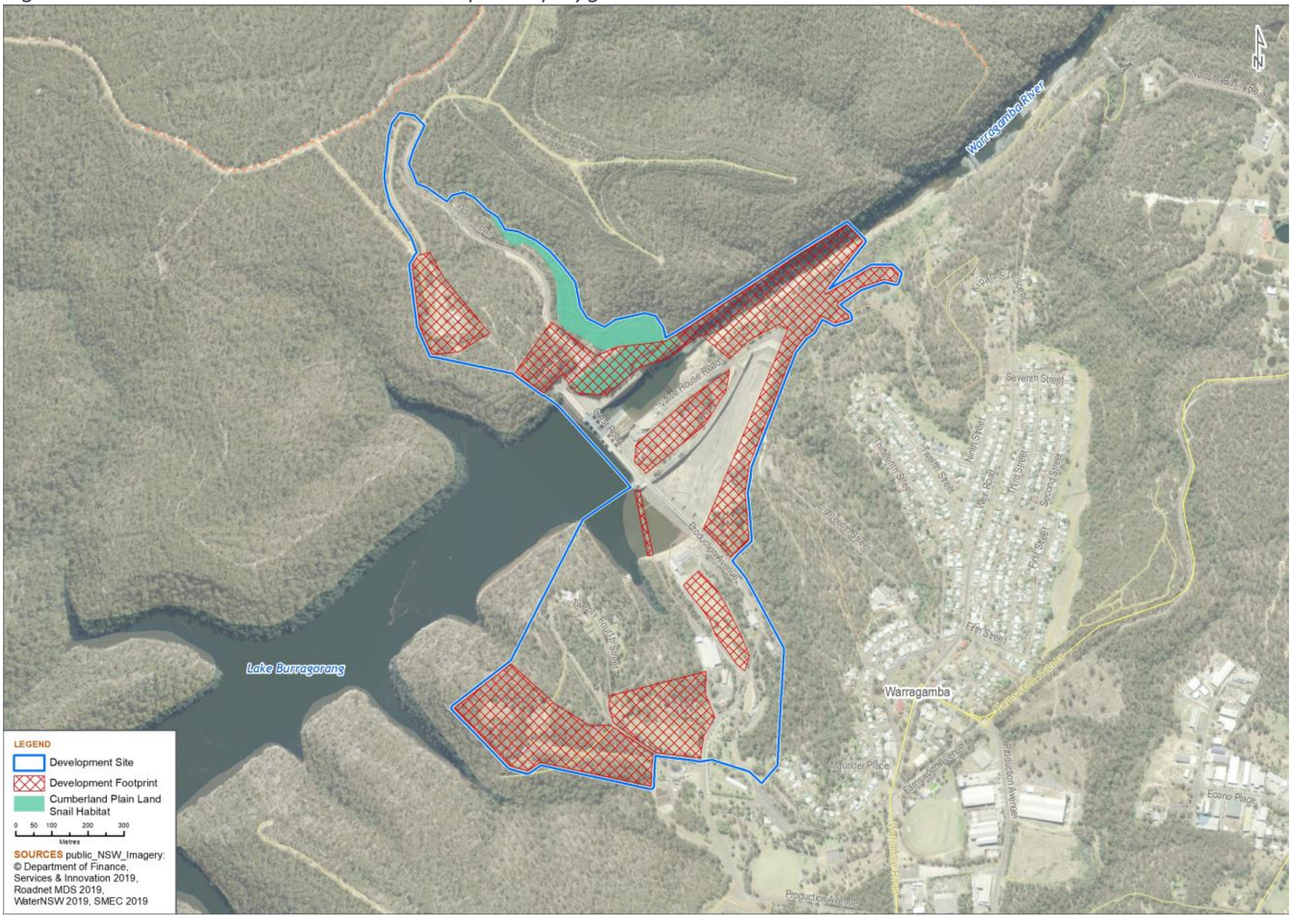


Figure B-52. Squirrel Glider species polygon

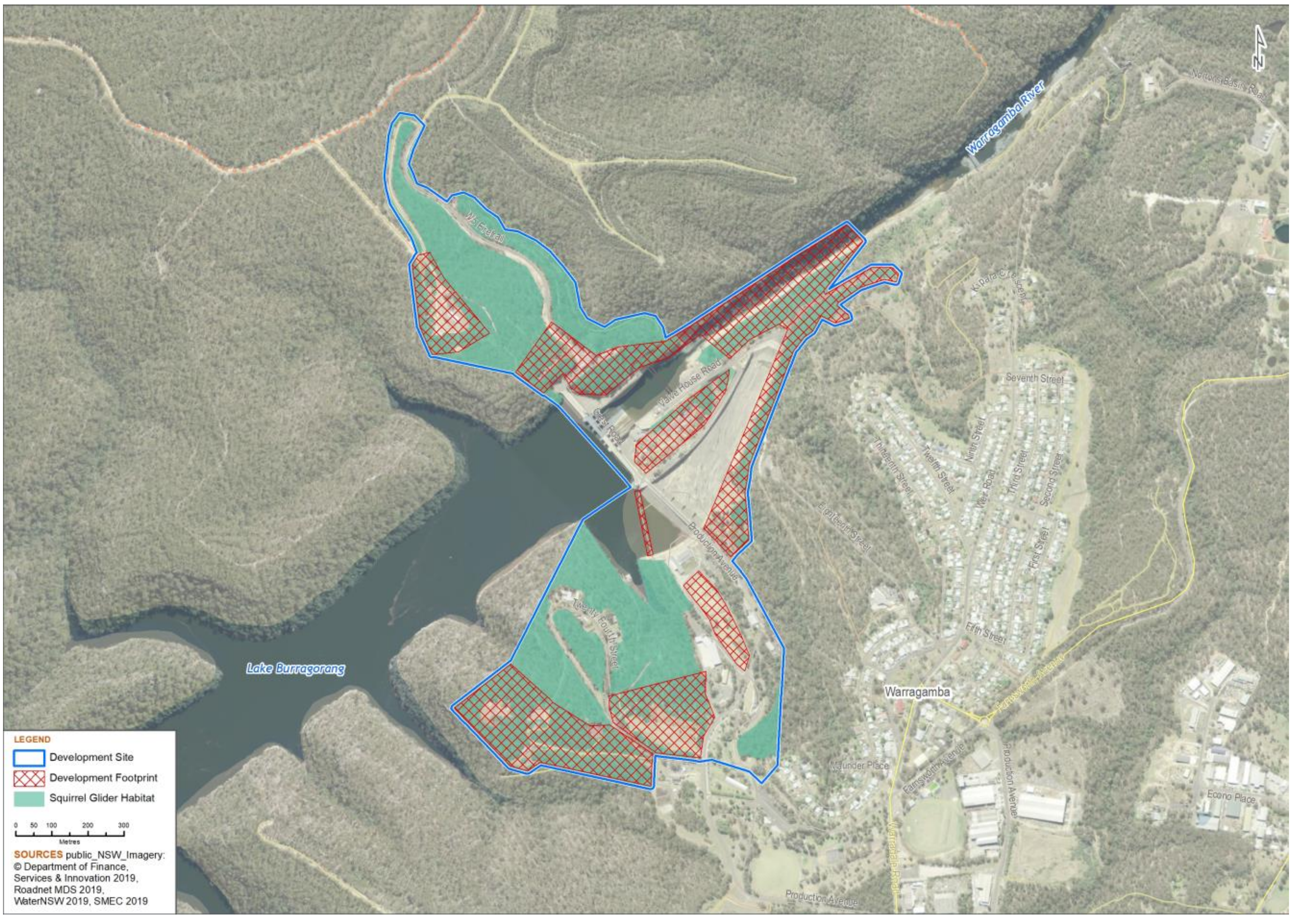


Figure B-53. Brush-tail Rock-wallaby species polygon

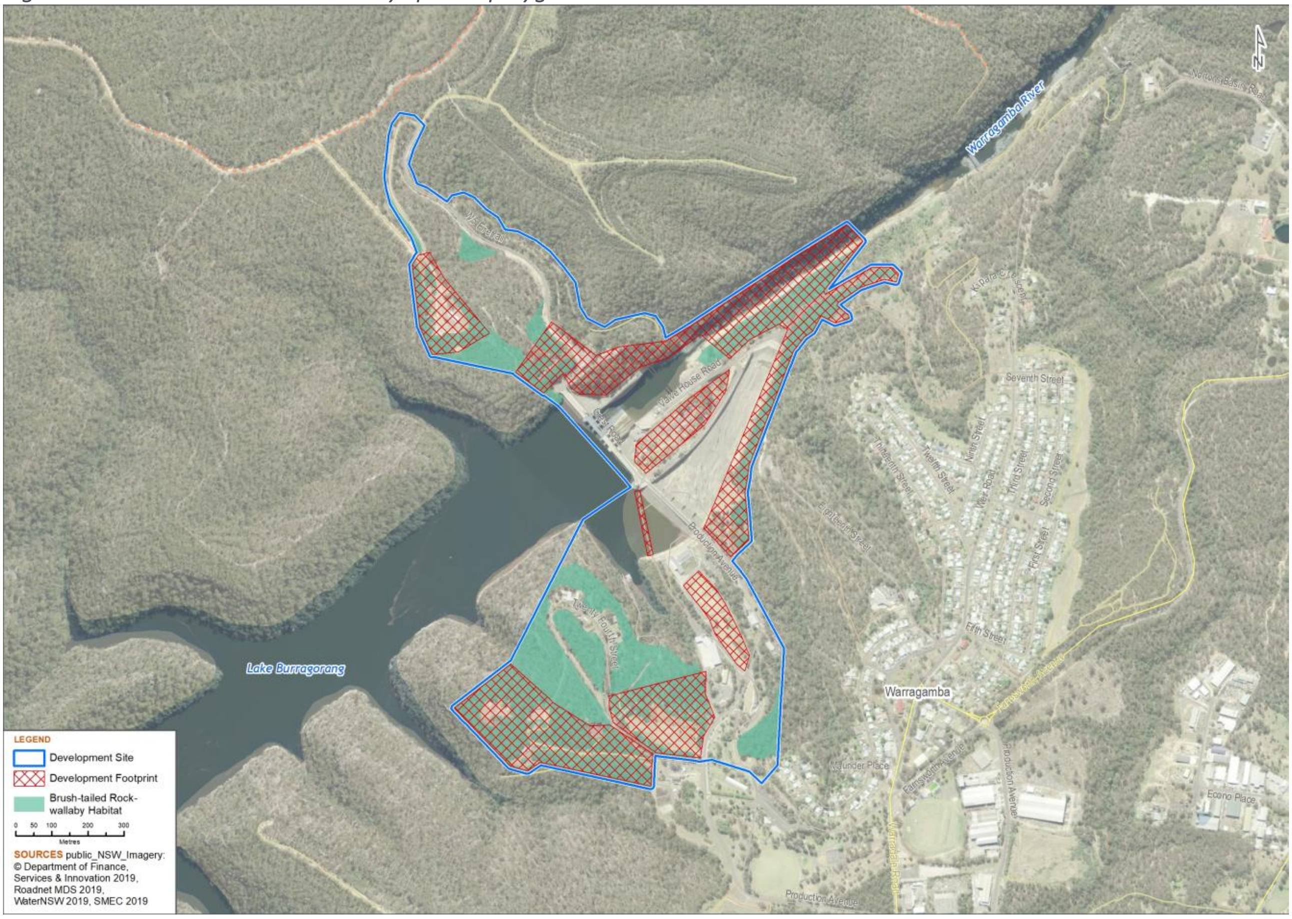


Figure B-54. Koala species polygon

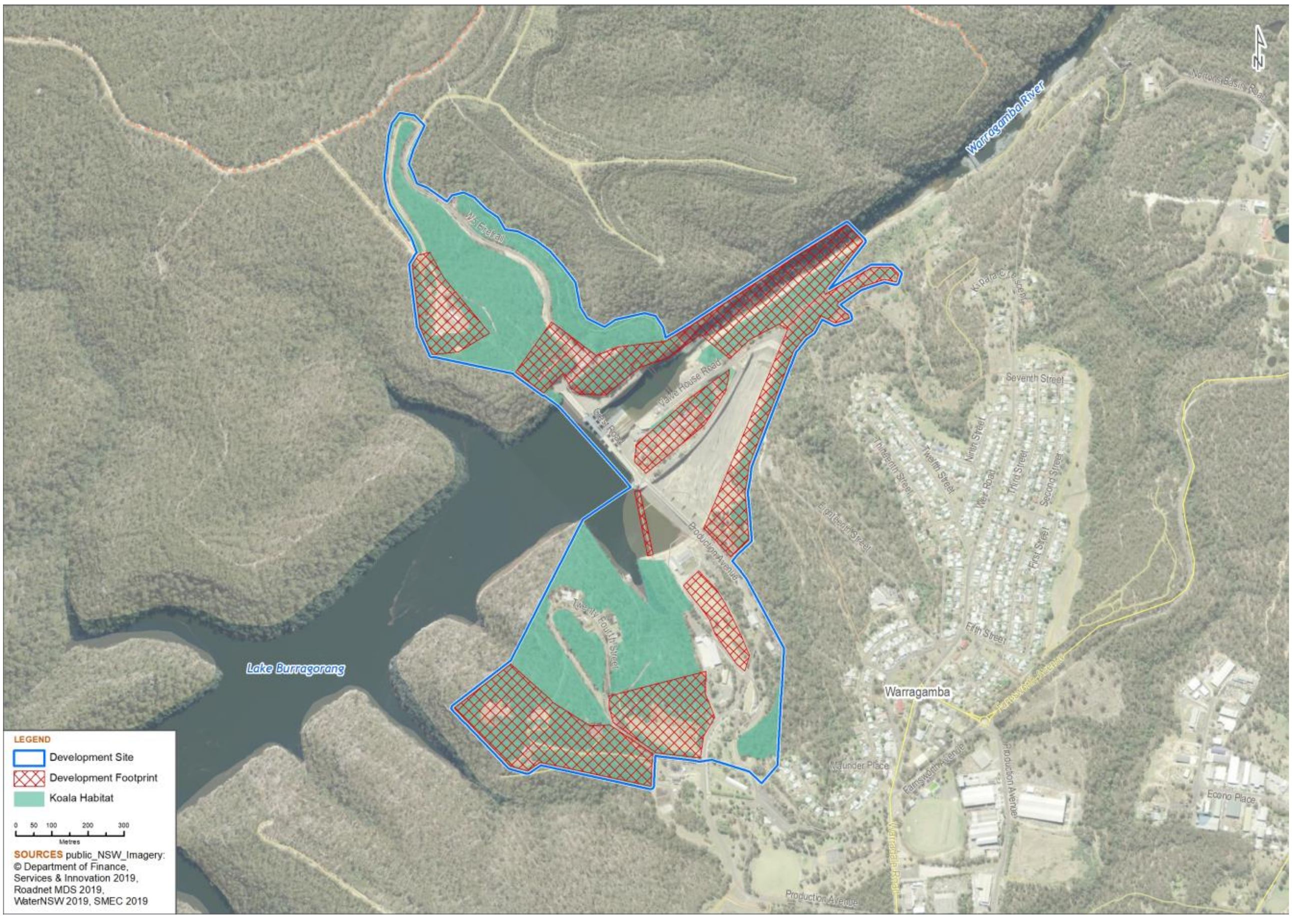


Figure B-55. Red-crowned Toadlet species polygon

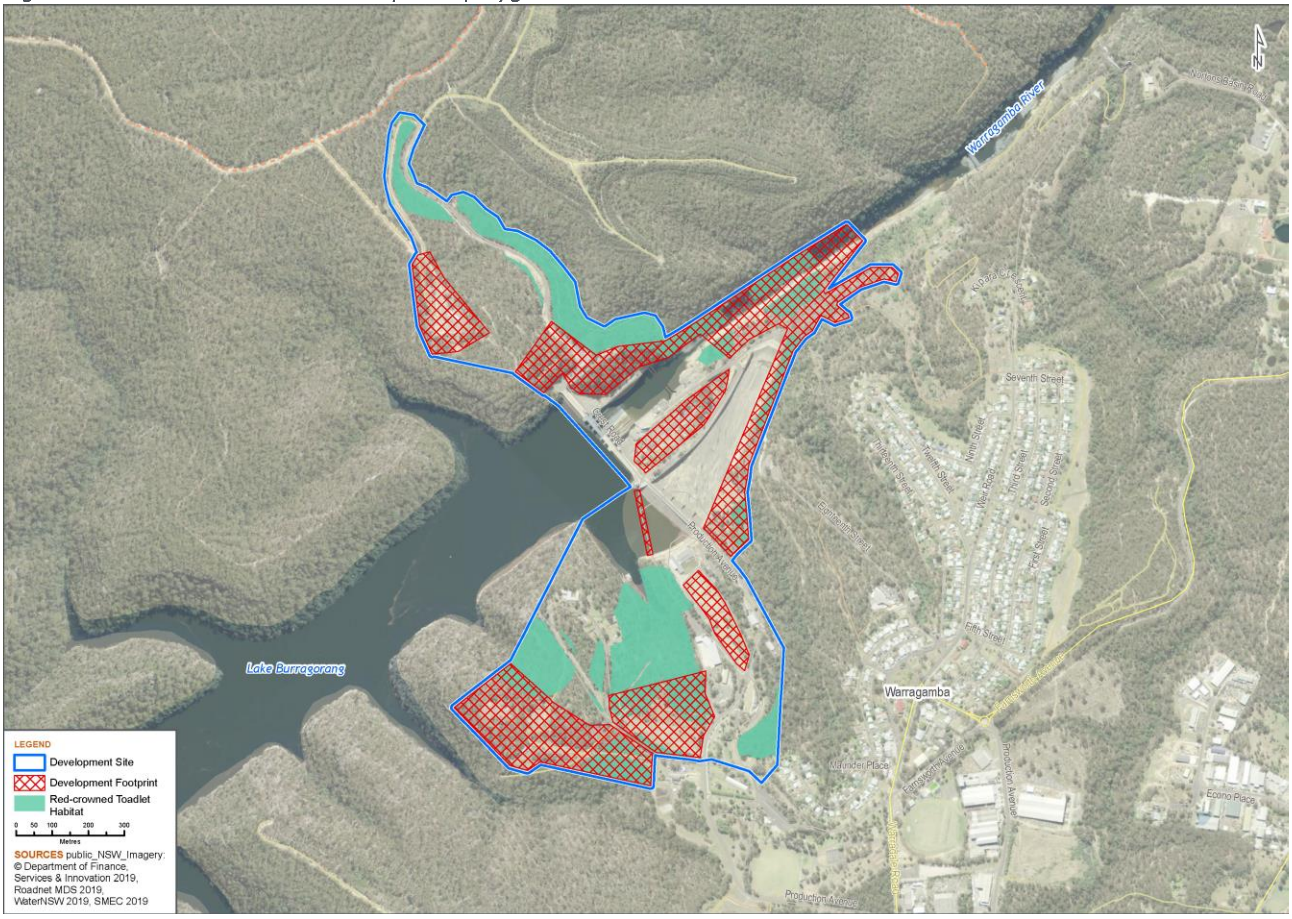
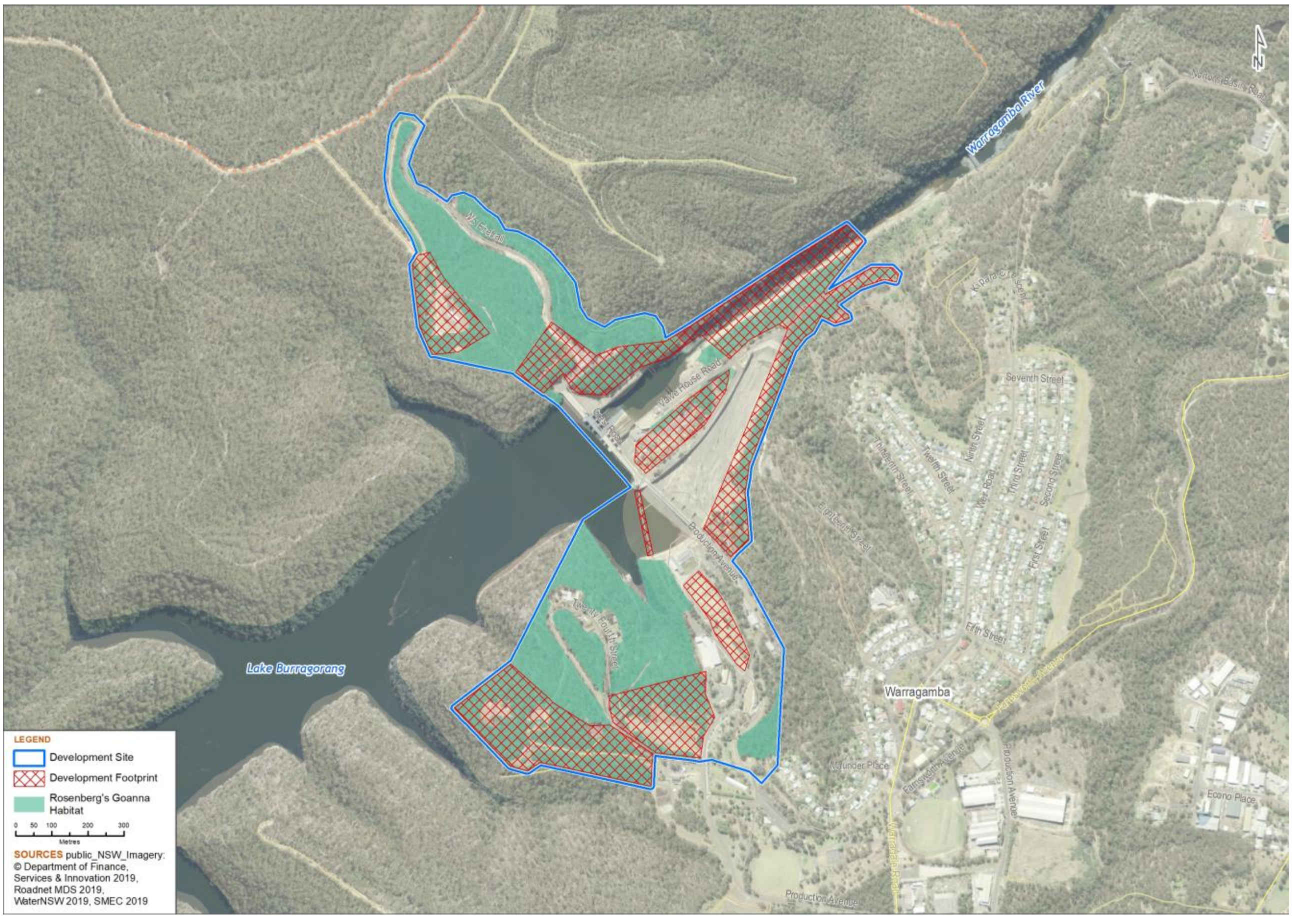


Figure B-56. Rosenberg's Goanna species polygon



Appendix C Plot and transect data

Plot and transect data

Vegetation Zone	Plot No	Date	Recorders	MU	No. Native Species	Native overstorey cover %	Native midstorey cover %	Native ground cover (grasses) %	Native ground cover (shrubs) %	Native ground cover (other) %	Exotic plant cover %	Number of trees with hollows	Regeneration	Total length of fallen logs (m)	Site Value Score	Bearing (o)	Eastings	Northings	Zone
Zone 1	US2	9/07/2018	RM JT	HN564_Moderate/Good	44	49	0	42	46	32	0	0	1	165	60.63	58	277209	6248696	56
	US7	12/12/2017	LL RM	HN564_Moderate/Good	27	38.5	0	6	2	8	0	4	1	17		94	277533	6247901	56
	US11	13/12/2017	LL RM	HN564_Moderate/Good	28	43	0	0	80	28	0	4	1	67		30	274878	6246639	56
	US12	13/12/2017	LL RM	HN564_Moderate/Good	43	44	16	2	56	18	0	9	1	42		328	274805	6246660	56
Zone 2	US1	9/07/2018	RM JT	HN566_Moderate/Good	40	24	0	20	42	24	0.67	5	1	48	86.11	328	277117	6248580	56
	US6	17/10/2018	RM MA	HN566_Moderate/Good	37	44	0	8	8	12	0	0	1	29		290	277447	6248461	56
	US8	10/07/2018	RM JT	HN566_Moderate/Good	41	28	5	6	34	14	0	3	1	53		58	277348	6247340	56
	US10	12/12/2017	LL RM	HN566_Moderate/Good	44	22	0	2	70	30	0	2	1	26		270	276545	6247022	56
Zone 3	US9	12/12/2017	LL RM	HN568_Moderate/Good	30	39	9	0	26	12	0	0	1	20	77.78	140	277058	6247536	56
	S5*	-	-	HN568_Moderate/Good	33	27.5	30	1	5.7	10.1	0	0	1	0		-	-	-	56
	S6*	-	-	HN568_Moderate/Good	33	27.5	30	1	5.7	10.1	0	0	1	0		-	-	-	56
	S7*	-	-	HN568_Moderate/Good	33	27.5	30	1	5.7	10.1	0	0	1	0		-	-	-	56
	US3	17/10/2018	RM MA	HN604_Moderate/Good	35	72	0	0	2	70	0	4	1	38		80	277248	6248882	56
	US4	17/10/2018	RM MA	HN604_Moderate/Good	45	46	0	0	2	52	0	1	1	46		140	277385	6248759	56
	US5	17/10/2018	RM MA	HN604_Moderate/Good	51	44	4	2	4	42	0	3	1	36		30	277520	6248678	56
Zone 5	S4*	-	-	HN564_Moderate/Good_Poor	20	13	17	1	4	7	50	0	0	0	30.68	-	-	-	56
	S8*	-	-	HN564_Moderate/Good_Poor	20	13	17	1	4	7	50	0	0	0		-	-	-	56

Appendix D Floristic data

Floristic data

Status	Family	*Genus species*	Common Name	US1	US1	US2	US2	US3	US3	US4	US4	US5	US5	US6	US6	US7	US7	US8	US8	US9	US9	US10	US10	US11	US11	US12	US12
				C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
lin	Adiantaceae	*Adiantum aethiopicum*	Common Maidenhair									<1	1														
lin	Apiaceae	*Platysace lanceolata*	Shrubby Platysace									<1	5														
lin	Apiaceae	*Platysace linearifolia*																<1	2	1	40	0.01	20			0.01	5
lin	Apiaceae	*Xanthosia pilosa*	Woolly Xanthosia	1	200	0.1	2					<1	25					<1	1	0.01	20	0.01	2			0.01	10
lin	Apiaceae	*Xanthosia tridentata*	Rock Xanthosia											1	20												
lin	Araliaceae	*Astrotricha latifolia*																						1	200		
lin	Araliaceae	*Astrotricha ledifolia*																		1	10	0.5	20			0.05	1
	Asteraceae	*Asteraceae sp.*										1	4														
lin	Bignoniaceae	*Pandorea pandorana*	Wonga Vine							<1	2	<1	50											0.1	2		
lin	Blechnaceae	*Blechnum cartilagineum*	Gristle Fern							<1	10	5	50														
lin	Casuarinaceae	*Allocasuarina littoralis*	Black She-Oak			5	22							1	2			7	70								
lin	Casuarinaceae	*Allocasuarina torulosa*	Forest Oak							2	20	2	20											2	150	1	10
lin	Cunoniaceae	*Ceratopetalum gummiferum*	Christmas Bush									2	3														
lin	Cyperaceae	*Caustis flexuosa*	Curly Wig	<1	25													<1	50	0.01	20	0.5	20				
lin	Cyperaceae	*Cyathochaeta diandra*		10	700	10	100	<1	1	<1	2					0.1	25	1	300	1	40						
lin	Cyperaceae	*Lepidosperma laterale*	Variable Sword-sedge					<1	50	10	500	1	200	2	250	0.1	100	<1	50			2	100	0.1	30		
lin	Cyperaceae	*Lepidosperma sp.*																<1	1								
lin	Cyperaceae????	*Cyperus sp.*																				0.01	2				
lin	Dennstaedtiaceae	*Pteridium esculentum*	Bracken			1	5	10	500	25	500																
lin	Dicksoniaceae	*Calochlaena dubia*	Rainbow Fern							25	500	30	500														
lin	Dilleniaceae	*Hibbertia aspera*	Rough Guinea Flower							<1	25							<1	1								
lin	Dilleniaceae	*Hibbertia empetrifolia*		<1	1																						
lin	Elaeocarpaceae	*Elaeocarpus reticulatus*	Blueberry Ash							1	25	10	30											1	10		
lin	Ericaceae	*?Leucopogon sp.*																				0.01	2				
lin	Ericaceae	*?Styphelia laeta*																		0.01	1	0.01	2	0.1	1		
lin	Ericaceae	*Epacris pulchella*	Wallum Heath			0.1	2			<1	3																
lin	Ericaceae	*Leucopogon lanceolatus*				0.1	1	<1	25	<1	10	1	5											0.1	5		
lin	Ericaceae	*Lissanthe sapida*	Native Cranberry			0.1	1																				
lin	Ericaceae	*Lissanthe strigosa*	Peach Heath	2	20									1	2			<1	2								
lin	Ericaceae	*Monotoca scoparia*														0.01	3									0.5	1
lin	Euphorbiaceae	*Micrantheum ericoides*																		0.01	4						
lin	Fabaceae (Faboideae)	*Bossiaea ?rhombifolia*																				20	100				
lin	Fabaceae (Faboideae)	*Bossiaea buxifolia*																3	50								
lin	Fabaceae (Faboideae)	*Bossiaea heterophylla*	Variable Bossiaea	1	15					<1	5	3	20	1	20												
lin	Fabaceae (Faboideae)	*Bossiaea obcordata*	Spiny Bossiaea	2	35													<1	50	1	10						
lin	Fabaceae (Faboideae)	*Bossiaea rhombifolia*														0	10									2	75
lin	Fabaceae (Faboideae)	*Chorizema parviflorum*	Eastern Flame Pea	<1	5													<1	2								
lin	Fabaceae (Faboideae)	*Desmodium varians*	Slender Tick-trefoil					<1	100																		
lin	Fabaceae (Faboideae)	*Dillwynia retorta*		2	500													<1	20	0.01	2	0.5	100			1	50
lin	Fabaceae (Faboideae)	*Glycine clandestina*	Twining glycine			0.5	50			<1	100																

Status	Family	Genus species	Common Name	US1	US1	US2	US2	US3	US3	US4	US4	US5	US5	US6	US6	US7	US7	US8	US8	US9	US9	US10	US10	US11	US11	US12	US12
				C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
lin	Fabaceae (Faboideae)	*Glycine microphylla*	Small-leaf Glycine											0.1	10												
lin	Fabaceae (Faboideae)	*Gompholobium glabratum*	Dainty Wedge Pea	10	100																						
lin	Fabaceae (Faboideae)	*Gompholobium grandiflorum*	Large Wedge Pea			0.1	1			2	50																
lin	Fabaceae (Faboideae)	*Hardenbergia violacea*	False Sarsaparilla							<1	2	<1	1														
lin	Fabaceae (Faboideae)	*Kennedia rubicunda*	Dusky Coral Pea									<1	2														
lin	Fabaceae (Faboideae)	*Pultenaea daphnoides*	Large-leaf Bush-pea					<1	2	<1	10	<1	15														
lin	Fabaceae (Faboideae)	*Pultenaea flexilis*																				5	20				
lin	Fabaceae (Faboideae)	*Pultenaea linophylla*																						3	250		
lin	Fabaceae (Faboideae)	*Pultenaea retusa*																								0.2	30
lin	Fabaceae (Faboideae)	*Pultenaea scabra*										<1	15													0.5	10
lin	Fabaceae (Mimosoideae)	*Acacia fimbriata*	Fringed Wattle					<1	10					1	25												
lin	Fabaceae (Mimosoideae)	*Acacia linearifolia*	Narrow-leaved Wattle																							0.1	20
lin	Fabaceae (Mimosoideae)	*Acacia linifolia*	White Wattle	10	100									1	10	1	1	<1	20			2	20				
lin	Fabaceae (Mimosoideae)	*Acacia prominens*	Gosford Wattle					5	50	<1	1	1	2	1	1	0.01	1										
lin	Fabaceae (Mimosoideae)	*Acacia sp A. clunie-rossiae or A. fimbriata?*	Wattle																					12	25		
lin	Fabaceae (Mimosoideae)	*Acacia suaveolens*	Sweet Wattle																			0.01	10				
lin	Fabaceae (Mimosoideae)	*Acacia terminalis*	Sunshine Wattle																			0.1	10				
lin	Fabaceae (Mimosoideae)	*Acacia ulicifolia*	Prickly Moses	<1	1	0.1	3					<1	1	1	10	0.1	10									0.5	10
lin	Goodeniaceae	*Dampiera purpurea*		<1	50	0.1	20	<1	10	<1	10	1	35	1	5												
lin	Goodeniaceae	*Goodenia hederacea*	Ivy Goodenia							<1	20															0.01	1
lin	Goodeniaceae	*Scaevola ramosissima*	Purple Fan-flower	<1	50									1	1											0.01	1
lin	Haloragaceae	*Gonocarpus teucrioides*	Germander Raspwort									1	50														
lin	Iridaceae	*Patersonia glabrata*	Leafy Purple-flag																	0.01	40					XX	XX
lin	Iridaceae	*Patersonia spp.*																<1	1								
lin	Lauraceae	*Cassytha pubescens*	Downy Dodder-laurel																							0.1	1
lin	Lindsaeaceae	*Lindsaea linearis*	Screw Fern							<1	1							<1	50								
lin	Lindsaeaceae	*Lindsaea microphylla*	Lacy Wedge Fern			0.1	8					1	150									0.01	5	0.1	30		
lin	Lobeliaceae	*Pratia purpurascens*	Whiteroot					<1	150	1	100																
lin	Loganiaceae	*Logania albiflora*																		0.01	4	0.5	40				
lin	Lomandraceae	*Lomandra confertifolia*	Matrush	<1	1000																						
lin	Lomandraceae	*Lomandra confertifolia subsp. rubiginosa*				0.1	40																				
lin	Lomandraceae	*Lomandra cylindrica*														0.5	50										
lin	Lomandraceae	*Lomandra filiformis*	Wattle Matt-rush					<1	50					1	250												
lin	Lomandraceae	*Lomandra longifolia*	Spiny-headed Mat-rush			5	30	<1	10			1	5	1	20									0.1	2		
lin	Lomandraceae	*Lomandra micrantha subsp. tuberculata*	Small-flowered Mat-rush													0.5	50										
lin	Lomandraceae	*Lomandra multiflora*	Many-flowered Mat-rush	<1	100															0.01	5	0.01	5	0.1	15		
lin	Lomandraceae	*Lomandra obliqua*		<1	1000	5	50							1	500			1	300							0.1	20
lin	Lomandraceae	*Lomandra sp.*																				0.01	1				
lin	Lomandraceae	*Lomandra sp.*																				0.1	1				
lin	Loranthaceae	*Dendrophthoe vitellina*														0.01	1										

Status	Family	Genus species	Common Name	US1	US1	US2	US2	US3	US3	US4	US4	US5	US5	US6	US6	US7	US7	US8	US8	US9	US9	US10	US10	US11	US11	US12	US12
				C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
lin	Myrtaceae	*Angophora costata*	Sydney Red Gum	11	2	20	2	30	3	10	2	10	1	1	1			<1	5			5	3	2	20	10	4
lin	Myrtaceae	*Corymbia eximia*	Yellow Bloodwood							10	2	2	5	1	2	15	5	5	46	40	10	5	3				
lin	Myrtaceae	*Corymbia gummifera*	Red Bloodwood	40	28	20	2	20	4							15	5	30	10	10	5	15	5	5	40	15	20
lin	Myrtaceae	*Eucalyptus resinifera*				1	2																				
lin	Myrtaceae	*Eucalyptus agglomerata*	Blue-leaved Stringybark																	5	1			12	25		
lin	Myrtaceae	*Eucalyptus eugenioides*	Thin-leaved Stringybark	12	9																						
lin	Myrtaceae	*Eucalyptus globoidea*	White Stringybark															1	1								
lin	Myrtaceae	*Eucalyptus pilularis*	Blackbutt					30	2	5	2	10	1	30	6	20	4										
lin	Myrtaceae	*Eucalyptus piperita*	Sydney Peppermint															3	2			20	12	5	10	5	10
lin	Myrtaceae	*Eucalyptus punctata*	Grey Gum											1	1											5	3
lin	Myrtaceae	*Eucalyptus resinifera*	Red Mahogany	2	2							5	1														
lin	Myrtaceae	*Eucalyptus sieberi*	Silvertop Ash							10	5																
lin	Myrtaceae	*Eucalyptus sparsifolia*	Narrow-leaved Stringybark	14	2	0.5	1																				
lin	Myrtaceae	*Kunzea ambigua*	Tick Bush			0.1	3																				
lin	Myrtaceae	*Leptospermum polygalifolium*	Tantoon			0.1	3					<1	10	1	17												
lin	Myrtaceae	*Leptospermum trinervium*	Slender Tea-tree	10	60	10	7			<1	10			1	10	1	5	<1	25	15	40	2	15			0.5	20
lin	Myrtaceae	*Syncarpia glomulifera*	Turpentine	2	10	15	6	10	4	1	4	15	7	2	1	1	1	82	5			5	3	15	50	15	9
lin	Oleaceae	*Notelaea longifolia*	Large Mock-olive									1	20														
lin	Orchidaceae	*Acianthus fornicatus*	Pixie Caps					<1	150	<1	25	1	150					<1	50								
lin	Phormiaceae	*Dianella caerulea*	Blue Flax-lily			5	25											<1	2			0.01	2	1	50		
lin	Phormiaceae	*Dianella longifolia*	Blueberry Lily					<1	25	<1	30																
lin	Phormiaceae	*Dianella revoluta*	Blueberry Lily											1	25												
lin	Phormiaceae	*Stypandra glauca*	Nodding Blue Lily									1	150														
lin	Phyllanthaceae	*Breynia oblongifolia*	Coffee Bush					<1	1																		
lin	Phyllanthaceae	*Phyllanthus hirtellus*	Thyme Spurge	1	500	0.1	40	<1	50	<1	250	1	100	1	50	0.5	50	<1	50	0.05	50			1	500	0.05	75
lin	Pittosporaceae	*Billardiera scandens*	Hairy Apple Berry	<1	100	1	50	<1	1	<1	50	<1	100					1	20					0.1	80	0.1	40
lin	Pittosporaceae	*Pittosporum revolutum*	Rough Fruit Pittosporum							<1	2	1	3														
lin	Poaceae	*Anisopogon avenaceus*	Oat Speargrass	<1	20									1	25												
lin	Poaceae	*Aristida vagans*	Threeawn Speargrass											1	100												
lin	Poaceae	*Cymbopogon refractus*	Barbed Wire Grass													0.5	50										
lin	Poaceae	*Entolasia marginata*	Bordered Panic	2	1,600	0.5	50											<1	800								
lin	Poaceae	*Entolasia stricta*	Wiry Panic	3	600	1	100	<1	200	1	100	1	500	1	500	0.1	100	<1	800	0.01	100	0.01	40	1	300	0.01	5
lin	Poaceae	*Eragrostis Brownii*	Brown's Lovegrass											1	1												
lin	Poaceae	*Imperata cylindrica*	Blady Grass			1	100	<1	50	<1	100			1	300												
lin	Poaceae	*Microlaena stipoides*	Weeping Grass			0.5	50	<1	500	<1	500	1	500	1	175												
lin	Poaceae	*Oplismenus aemulus*						<1	100																		
lin	Poaceae	*Panicum simile*	Two-colour Panic	<1	100	0.1	1																				
lin	Poaceae	*Themeda triandra*												1	25												
lin	Primulaceae	*Myrsine variabilis*						<1	50	<1	15	1	10														
lin	Proteaceae	*Banksia serrata*	Old-man Banksia	<1	1							<1	3														
lin	Proteaceae	*Banksia spinulosa*	Hairpin Banksia	3	15	5	30	1	25			<1	2	1	3	1	6	<1	14	10	15	2	20			0.5	7

Status	Family	*Genus species*	Common Name	US1	US1	US2	US2	US3	US3	US4	US4	US5	US5	US6	US6	US7	US7	US8	US8	US9	US9	US10	US10	US11	US11	US12	US12
				C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A	C	A
lin	Proteaceae	*Grevillea buxifolia*	Grey Spider Flower																	0.1	15	1	20				
lin	Proteaceae	*Grevillea mucronulata*		10	70	20	100	3	200	3	15	<1	10	1	20	0.1	10	<1	2					0.1	1	0.5	15
lin	Proteaceae	*Grevillea parviflora subsp. parviflora*	Small-flower Grevillea	13	3	1	30											<1	1								
lin	Proteaceae	*Grevillea sphacelata*	Grey Spider Flower															<1	1								
lin	Proteaceae	*Hakea dactyloides*	Finger Hakea			0.5	3											<1	2			1	5				
lin	Proteaceae	*Hakea sericea*	Needlebush			0.1	1																				
lin	Proteaceae	*Lambertia formosa*	Mountain Devil															<1	4	15	25	1	5				
lin	Proteaceae	*Lomatia silaifolia*	Crinkle Bush			0.1	3			<1	5											0.01	2			0.01	2
lin	Proteaceae	*Persoonia levis*	Broad-leaved Geebung	<1	1	2	6									0.01	1	<1	2	2	7					0.1	2
lin	Proteaceae	*Persoonia linearis*	Narrow-leaved Geebung	2	30			10	200	1	25	1	25	1	10	1	5			0.5	10	0.5	30	1	40	0.1	2
lin	Proteaceae	*Persoonia mollis*	Soft Geebung	<1	1																						
lin	Proteaceae	*Persoonia mollis subsp. revoluta*				0.1	1							1	1												
lin	Proteaceae	*Petrophile pedunculata*																<1	7			0.01	2				
lin	Proteaceae	*Xylomelum pyriforme*	Woody Pear					<1	30									<1	1	0.01	3	0.1	5				
lin	Ranunculaceae	*Clematis sp*						<1	50																		
lin	Rhamnaceae	*Pomaderris aspera*	Hazel Pomaderris																	0.01	4	0.01	6	1	25		
lin	Rhamnaceae	*Pomaderris sp.*																						25	500		
lin	Rubiaceae	*Galium binifolium*										<1	150														
lin	Rubiaceae	*Pomax umbellata*	Pomax	<1	100			<1	25					1	20	0.5	100									0.01	30
lin	Rutaceae	*Asterolasia correifolia*										<1	1														
lin	Rutaceae	*Boronia ledifolia*	Sydney Boronia																	0.01	3	0.01	5			0.5	10
lin	Rutaceae	*Correa reflexa*	Native Fuchsia			0.1	4	5	100			<1	10													0.1	10
lin	Rutaceae	*Eriostemon australasius*		2	40															0.01	4					0.1	7
lin	Rutaceae	*Zieria pilosa*	Pilose-leafed Zieria									<1	50														
lin	Santalaceae	*Exocarpos strictus*	Dwarf Cherry																					0.1	1	0.01	2
lin	Sapindaceae	*Dodonaea triquetra*	Large-leaf Hop-bush			0.1	1			<1	5					0.1	10							5	500	1	15
lin	Smilacaceae	*Smilax glyciphylla*	Sweet Sarsaparilla			0.01	1			<1	10	<1	5													0.01	1
lin	Stylidiaceae	*Stylidium laricifolium*	Tree Triggerplant									4	2														
lin	Stylidiaceae	*Stylidium lineare*	Narrow-leaved Triggerplant							<1	1																
lin	Stylidiaceae	*Stylidium productum*																				0.01	1			0.05	1
lin	Thymelaeaceae	*Pimelea latifolia*										1	1	1	2			<1	2								
lin	Uvulariaceae	*Schelhammera undulata*						<1	50	<1	100	2	500														
lin	Xanthorrhoeaceae	*Xanthorrhoea arborea*						25	50	4	10	1	15							0.1	15	2	9	5	30		
lin	Xanthorrhoeaceae	*Xanthorrhoea media*														0.01	5	<1	3							1	3
lin	Xanthorrhoeaceae	*Xanthorrhoea Spp.*		<1	1																						

Appendix E Fauna species list

Fauna species list

Common name	Scientific name	BC Act status	EPBC Act status
Amphibians			
Red-crowned Toadlet	*Pseudophryne australis*	V	
Birds			
Brown Thornbill	*Acanthiza pusilla*		
Eastern Spinebill	*Acanthorhynchus tenuirostris*		
Australian King Parrot	*Alisterus scapularis*		
Red Wattlebird	*Anthochaera carunculata*		
Sulphur-crested Cockatoo	*Cacatua galerita*		
Grey Shrike-thrush	*Colluricincla harmonica*		
Australian Magpie	*Cracticus tibicen*		
Laughing Kookaburra	*Dacelo novaeguineae*		
Eastern Yellow Robin	*Eopsaltria australis*		
White-bellied Sea-eagle	*Haliaeetus leucogaster*	V	
Wonga Pigeon	*Leucosarcia melanoleuca*		
Yellow-faced Honeyeater	*Lichenostomus chrysops*		
Scarlet Honeyeater	*Myzomela sanguinolenta*		
Rufous Whistler	*Pachycephala rufiventris*		
Common Bronzewing	*Phaps chalcoptera*		
Noisy Friarbird	*Philemon corniculatus*		
Grey Fantail	*Rhipidura albiscapa*		
Rufous Fantail	*Rhipidura rufifrons*		M
Rainbow Lorikeet	*Trichoglossus moluccanus*		
Mammals			
Brown Antechinus	*Antechinus stuartii*		
Large-eared Pied Bat	*Chalinolobus dwyeri*	V	V
Gould's Wattled Bat	*Chalinolobus gouldii*		
Chocolate Wattled Bat	*Chalinolobus morio*		
Eastern False Pipistrelle	*Falsistrellus tasmaniensis*	V	
Common Wallaroo	*Macropus robustus*		
Little Bent-winged Bat	*Miniopterus australis*	V	
Large Bent-winged Bat	*Miniopterus orianae oceanensis*	V	
Southern Free-tailed Bat	*Mormopterus planiceps*		
Eastern Free-tailed Bat	*Mormopterus ridei*		
Unidentified long-eared bat	*Nyctophilus* sp.		
Eastern Horseshoe-bat	*Rhinolophus megaphyllus*		
Eastern Broad-nosed Bat	*Scotorepens orion*		
White-striped Freetail-bat	*Tadarida australis*		

Common name	Scientific name	BC Act status	EPBC Act status
Large Forest Bat	*Vespadelus darlingtoni*		
Little Forest Bat	*Vespadelus vulturnus*		
Common Wombat	*Vombatus ursinus*		
Fox	*Vulpes vulpes**		
Swamp Wallaby	*Wallabia bicolor*		

* introduced species

Appendix F Likelihood of occurrence table

Likelihood of Occurrence Table

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
FAUNA												
Amphibians												
Heleioporus australiacus	Giant Burrowing Frog	V	V	✓	✓	✓	✓	HN564 HN566 HN568 HN604	Distributed through the Sydney Basin sandstone country in woodland, open woodland and heath vegetation. Breeding habitat is comprised of soaks or pools within first or second order streams, but also 'hanging swamp' seepage lines and where small pools form from collected water. Spends the majority of time in non-breeding habitat up to 300 m away and burrows in soil surface or leaf litter.	5	16/4/2006	High - Sydney Sandstone areas and suitable creeks present in the development site and study area.
Litoria aurea	Green and Golden Bell Frog	E	V	✓	✓	✓	-	HN604	Large populations in NSW are located around coastal and near coastal areas of the metropolitan areas of Sydney, Shoalhaven and the Mid North Coast. The species inhabits marshes, dams and stream-sides with emergent vegetation, particularly those containing bullrushes (*Typha* spp.) or spikerushes (*Eleocharis* spp.).	1	28/8/1999	Nil – no suitable habitat present within the development site or study area.
Litoria booroolongensis	Booroolong Frog	E	E	-	-	-	-	HN564 HN566 HN568	The Booroolong Frog is restricted to NSW and north-eastern Victoria, predominantly along the western-flowing streams of the Great Dividing Range. Lives along permanent streams with some fringing vegetation cover such as ferns, sedges or grasses. Shelter under rocks or amongst vegetation near the ground on the stream edge. Adults occur on or near cobble banks and other rock structures within stream margins.	-	-	Nil - no suitable rocky western flowing streams present. No suitable rocky flowing stream habitat in general.
Litoria littlejohni	Littlejohn's Tree Frog	V	V	-	✓	✓	-	HN566	Restricted to sandstone woodland and heath communities at mid to high altitude. It forages both in the tree canopy and on the ground, and it has been observed sheltering under rocks, leaf litter and low vegetation in heath-based forests and woodland. It is not known from coastal habitats.	-	-	Low - permanent flowing streams absent from construction area.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Mixophyes balbus	Stuttering Frog	E	V	-	✓	✓	-	HN564 HN568	Found in rainforest and wet, tall open forest in the foothills and escarpment on the eastern side of the Great Dividing Range. Spends the majority of time in non-breeding habitat up to 300 m away and burrows in soil surface or leaf litter.	-	-	Nil: permanent flowing streams with wet gullies absent from construction area.
Mixophyes iteratus	Giant Barred Frog	E	E	-	-	-	✓	-	Freshwater streams with permanent or semi-permanent slow flowing water at lower elevations within moist riparian habitats such as rainforest and wet sclerophyll forest with deep leaf litter and open perching sites on forest floor.	-	-	Nil - no known extant populations south of the Hunter River. No suitable rainforest habitat present within the development site and study area.
Pseudophryne australis	Red-crowned Toadlet	V	-	✓	-	-	✓	HN564 HN566 HN568	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. Shelters under rocks and amongst masses of dense vegetation or thick piles of leaf litter. Breeding congregations occur in dense vegetation and debris beside ephemeral creeks and gutters. Red-crowned Toadlets have not been recorded breeding in waters that are even mildly polluted or with a pH outside the range 5.5 to 6.5.	15	7/12/2015	Known: suitable habitat of open forest and periodic drainage lines present in the development site and study area.
Birds												
Actitis hypoleucos	Common Sandpiper	-	M, Ma	-	✓	-	-	-	Utilises a wide range of coastal wetlands and some inland wetlands, with varying levels of salinity, and is mostly found around muddy margins or rocky shores and rarely on mudflats. Roost sites are typically on rocks or in roots or branches of vegetation, especially mangroves.	-	-	Low: no saline environments in the development site or in study area.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Anthochaera phrygia	Regent Honeyeater	CE	CE	✓	✓	✓	✓	HN564 HN566 HN568 HN604	Inhabits temperate woodlands and open forests of the inland slopes of south-east Australia. NSW the distribution is very patchy and mainly confined to the two main breeding areas at Capertee Valley and the Bundarra-Barraba region and surrounding fragmented woodlands. Birds are also found in drier coastal woodlands and forests. The species inhabits dry open forest and woodland, particularly Box-Ironbark woodland, and riparian forests of River She-oak. These habitats have significantly large numbers of mature trees, high canopy cover and abundance of mistletoes. Key eucalypt species include Mugga Ironbark, Yellow Box, Blakely's Red Gum, White Box and Swamp Mahogany. Nectar and fruit from the mistletoes are also eaten during the breeding season.	4	17/12/2009	Moderate: dry open forests in area and so suitable habitat present, although probably not breeding habitat. Records from upstream development site and study area.
Apus pacificus	Fork-tailed Swift	-	M, Ma	-	✓	-	-	-	Aerial space over a variety of habitat types; feeds on insects; breeds in Asia.	-	-	Moderate
Ardea alba	Great Egret	-	Ma	-	✓	-	-	-	Freshwater wetlands and swamps.	-	-	Low: limited wetland and swamps in the construction area.
Ardea ibis	Cattle Egret	-	Ma	-	✓	-	-	-	South-eastern, south-western and northern mainland Australia and Tasmania. Typically associated with wetlands or open grassy areas, often seen with stock.	-	-	Low - maybe moderate. Species well known for using terrestrial habitats used by stock.
Artamus cyanopterus cyanopterus	Dusky Woodswallow	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Often reported in woodlands and dry open sclerophyll forests, usually dominated by eucalypts, including mallee associations. Has also been recorded in shrublands and heathlands and various modified habitats, including regenerating forests; very occasionally in moist forests or rainforests. Understorey is typically open with sparse eucalypt saplings, acacias and other shrubs, including heath. The ground cover may consist of grasses, sedges or open ground, often with coarse woody debris.	12	29/10/2017	High: found in Eucalyptus dominated open forests and woodlands. Recorded in many locations around Lake Burragorang.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Botaurus poiciloptilus	Australasian Bittern	E	E	-	✓	✓	-	-	Inhabits temperate freshwater wetlands and occasionally estuarine reedbeds, with a preference for permanent waterbodies with tall dense vegetation. The species prefers wetlands with dense vegetation, including sedges, rushes and reeds. Freshwater is generally preferred, although dense saltmarsh vegetation in estuaries and flooded grasslands are also used by the species.	-	-	Nil: no suitable habitat within the development site or study area.
Calidris acuminata	Sharp-tailed Sandpiper	-	M, Ma	-	✓	-	-	-	Sharp-tailed Sandpiper prefers muddy edges of shallow fresh or brackish wetlands, with inundated or emergent sedges, grass, saltmarsh or other low vegetation.	-	-	Nil: no suitable habitat within the development site or study area.
Calidris ferruginea	Curlew Sandpiper	E	CE, M, Ma	-	✓	-	-	-	Coastal migratory species with a NSW distribution from Hastings Point to Shoalhaven Heads. Found in open, sandy beaches with exposed sand bars and rocky outcrops. Rare use of near-coastal wetlands.	-	-	Nil: no suitable habitat within the development site or study area.
Calidris melanotos	Pectoral Sandpiper	-	M, Ma	-	✓	-	-	-	Shallow freshwater ponds/pools with low vegetation, flooded pasture, swamp margins, sewage ponds; occasionally mudflats and saltmarsh.	-	-	Nil: no suitable habitat within the development site or study area.
Callocephalon fimbriatum	Gang-gang Cockatoo	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Occupies tall montane forests and woodlands, particularly in heavily timbered and mature wet sclerophyll forests in winter and open eucalypt forests and woodlands, particularly in box-ironbark assemblages, or in dry forest in coastal areas in summer. Nests in tree hollows.	12	29/12/2015	High: open eucalypt forests and woodlands and tree hollows present, representing suitable habitat. Records present from locality.
Calyptorhynchus lathami	Glossy Black-cockatoo	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Occupy coastal woodlands and drier forest areas, open inland woodlands, or timbered watercourses where Casuarina and Allocasuarina species are present. This species is dependent on large hollow-bearing eucalypts for nesting.	29	11/8/2016	High: open eucalypt forests and woodlands with tree hollows present and so suitable habitat present. Good number of records from locality.

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				NSW Atlas	PMST	SEARs	BBCC					
Chrysococcyx osculans	Black-eared Cuckoo	-	Ma	-	✓	-	-	-	Dry open forests, scrublands, mallee, mulga, lignum, saltbush and riverside thickets.	-	-	Moderate: suitable habitat is present in the form of open dry forests. Within range.
Chthonicola sagittata	Speckled Warbler	V	-	✓	-	-	-	HN604	Lives in a wide range of Eucalyptus dominated communities that have a grassy understorey, often on rocky ridges or in gullies. Typical habitat would include scattered native tussock grasses, a sparse shrub layer, some eucalypt regrowth, and an open canopy. Large, relatively undisturbed remnants are required for the species to persist in an area.	1	26/11/1993	Moderate: suitable woodland habitat present.
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	V	-	-	-	-	-	HN564 HN568	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; also found in mallee and River Red Gum (*Eucalyptus camaldulensis*).	-	-	Moderate: suitable woodlands with hollows present.
Cuculus opatus	Oriental Cuckoo	-	M	-	✓	-	-	-	Inhabits rainforest margins, monsoon forest, vine scrub, riverine thickets, dense eucalypt forest, paperbark swamp and mangroves.	-	-	Low: suitable habitat in the former of denser vegetation not clearly present.
Daphoenositta chrysoptera	Varied Sittella	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	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 gums with dead branches, mallee and Acacia woodland.	20	31/8/2017	High: suitable woodlands and forest habitat present and a number of records from the locality.

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				NSW Atlas	PMST	SEARs	BBCC					
Dasyornis brachypterus	Eastern Bristlebird	E	E	-	✓	✓	-	HN566	Habitat for central and southern populations is characterised by dense, low vegetation including heath and open woodland with a heathy understorey. In northern NSW the habitat occurs in open forest with dense tussocky grass understorey and sparse mid-storey near rainforest ecotone; all of these vegetation types are fire prone. Shy and cryptic and rarely flies, although can be seen scampering over the ground; when approached, may move to a lookout perch 1 m or more above the ground, then retreat into dense vegetation.	-	-	Low: suitable dense vegetation lacking in the development site or study area. No records from locality.
Ephippiorhynchus asiaticus	Black-necked Stork	E	-	✓	-	-	-	-	Restricted to coastal and near-coastal habitat. Inhabits wetlands, floodplains and deeper permanent water bodies. Occurs in shallow, permanent freshwater terrestrial wetlands and surrounding marginal vegetation. Nest in tall, isolated paddock trees near freshwater swamps and construct large nesting platform.	1	29/12/1994	Nil: suitable wetlands not present in the development site or study area.
Epthianura albifrons	White-fronted Chat	V	-	-	-	✓	-	-	Open damp ground, grass clumps, fencelines, heath, samphire saltmarsh, mangroves, dunes, saltbush plains.	-	-	Nil: suitable damp and swampy habitat absent from the development site and study area. No records from locality.
Gallinago hardwickii	Latham's Snipe	-	M, Ma	-	✓	-	-	-	Soft wet ground, shallow water with tussocks, inundated parts of paddocks, seepage below dams, saltmarsh and mangrove fringes.	-	-	Nil: suitable wet habitat absent from the development site and study area. No records from locality.
Glossopsitta pusilla	Little Lorikeet	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Mostly occur in dry, open eucalypt forests and woodlands. They have been recorded from both old-growth and logged forests in the eastern part of their range, and in remnant woodland patches and roadside vegetation on the western slopes. Nest in small hollows (entrance approx. 3 cm) of Eucalyptus spp. between 2 - 15 m above the ground.	1	12/1/2005	Moderate: suitable woodlands with hollows and feed trees present. Only one record from locality.

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Grantiella picta	Painted Honeyeater	V	V	-	✓	✓	-	HN564 HN604	Occurs in Eucalyptus woodland and forests, with a preference for mistletoe (Amyema spp.). Can also occur along watercourses and in farmland. Nests from spring to autumn in outer canopy of eucalypts, she-oak, paperbark and mistletoe branches.	-	-	Moderate: suitable woodland habitat present. More likely to use area during dry years when populations move towards coastal areas.
Haliaeetus leucogaster	White-bellied Sea-eagle	V	M, Ma	✓	✓	-	-	HN566	Coastlines, estuaries, large rivers and lakes; occasionally over adjacent habitats; builds a large stick nest in a tall tree, rarely on artificial structures	16	31/8/2017	High: breeds near water bodies and has been identified nearby. Nesting trees of greatest importance
Hieraaetus morphnoides	Little Eagle	V	-	-	-	-	-	HN564 HN566 HN568 HN604	Occupies habitats rich in prey (birds, reptiles and mammals) within open eucalypt forest, woodland or open woodland. Requires tall living trees for building a large stick nest and preys on birds, reptiles and mammals and occasionally carrion.	-	-	Moderate: suitable woodlands present.
Hirundapus caudacutus	White-throated Needletail	-	M, Ma	-	✓	-	-	-	Aerial space over a variety of habitat types but prefers to forage over treed habitats as these would provide a greater abundance of insect prey; often forage on the edge of low pressure systems and may follow these systems ; breeds in Asia.	-	-	Moderate: suitable wooded habitat present for foraging.
Ixobrychus flavicollis	Black Bittern	V	-	✓	-	-	-	-	Rarely occurs above 200m in altitude and inhabits both terrestrial and estuarine wetlands, with a preference for permanent water bodies and dense vegetation. Roosts in trees or amongst dense reeds.	1	29/1/1995	Nil: suitable wetland habitat absent from the development site and study area.
Lathamus discolor	Swift Parrot	E	CE, M, Ma	✓	✓	✓	-	HN564 HN566 HN568 HN604	In NSW mostly occurs on the coast and south west slopes, occurring in areas where eucalypts are flowering profusely or where there are abundant lerp (from sap-sucking insects) infestations. Favoured feed trees include winter flowering species such as Swamp Mahogany (*Eucalyptus robusta*), Spotted Gum (*Corymbia maculata*), Red Bloodwood (*C. gummifera*), Mugga Ironbark (*E. sideroxylon*), and White Box (*E. albens*). Nests in Tasmania.	5	5/8/2015	Moderate: suitable woodland habitat with winter flowering trees present.

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Limosa limosa	Black-tailed Godwit	V	-	✓	-	-	-	-	Estuaries and lagoons with large intertidal sandflats or mudflats.	1	30/10/1982	Nil: estuaries and mudflats absent from the development site and study area
Lophoictinia isura	Square-tailed Kite	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Found in a variety of timbered habitats including dry woodlands and open forests. Shows a particular preference for timbered watercourses. Builds a large stick nest in a tall tree.	3	12/1/2005	Moderate: suitable wooded environments present including woodlands around the Warragamba River
Melanodryas cucullata	Hooded Robin (south-eastern form)	V	-	✓	-	-	-	HN568	Prefers lightly wooded country, usually open eucalypt woodland, acacia scrub and mallee, often in or near clearings or open areas. Requires structurally diverse habitats featuring mature eucalypts, saplings, some small shrubs and a ground layer of moderately tall native grasses.	3	9/11/2004	Moderate: some open woodlands present and records from locality
Melithreptus gularis	Black-chinned Honeyeater (eastern subspecies)	V	-	-	-	-	-	HN564 HN604	Occupies mostly upper levels of drier open forests or woodlands dominated by box and ironbark eucalypts, especially Mugga Ironbark (*Eucalyptus sideroxylon*), White Box (*E. albens*), Inland Grey Box (*E. microcarpa*), Yellow Box (*E. melliodora*), Blakely's Red Gum (*E. blakelyi*) and Forest Red Gum (*E. tereticornis*). Also inhabits open forests of smooth-barked gums, stringybarks, ironbarks, river she oaks (nesting habitat) and tea-trees.	-	-	Moderate: box-ironbark forest not present within the development site and study area, but other woodlands are present. No records from locality
Merops ornatus	Rainbow Bee-eater	-	Ma	-	✓	-	-	-	Found in open woodlands, beaches, dunes, cliffs, mangroves, woodlands.	-	-	Moderate: open areas around dam provide suitable habitat
Monarcha melanopsis	Black-faced Monarch	-	M, Ma	-	✓	-	-	-	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.	-	-	Low: suitable rainforest habitat absent from the development site and study area

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Monarcha trivirgatus (Symposiarchus trivirgatus)	Spectacled Monarch	-	M, Ma	-	✓	-	-	-	Usually found in rainforest, mangroves and moist gullies of dense eucalypt forest.	-	-	Low: suitable rainforest and mangrove habitat absent from the development site and study area.
Motacilla flava	Yellow Wagtail	-	M, Ma	-	✓	-	-	-	Occurs in a variety of damp or wet habitats with low vegetation. Outside of the breeding season it is also found in cultivated areas. Typically forages in damp grassland and on relatively bare open ground at edges of waterbodies, but also feeds in dry grassland and in fields of cereal crops.	-	-	Low: suitable vegetation types not clearly present.
Myiagra cyanoleuca	Satin Flycatcher	-	M, Ma	-	✓	-	-	-	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.	-	-	Low: could occur in the development site and study area occasionally, but only as part of migration. Suitable habitat generally not present.
Neophema pulchella	Turquoise Parrot	V	-	-	-	-	-	HN564 HN568 HN604	Lives on the edges of eucalypt woodland adjoining clearings, timbered ridges and creeks in farmland. Nests in tree hollows.	-	-	Moderate: woodlands present and species recorded during current investigations around Joorilands
Ninox connivens	Barking Owl	V	-	✓	-	-	-	HN564 HN568 HN604	Occurs throughout NSW, where it inhabits dry open sclerophyll forests and woodlands. Favours dense riparian stands of eucalypts or casuarinas that occur along watercourses or around wetlands where there are many large trees suitable for roosting or breeding. Nests in tree hollows. Consumes a variety of prey items, including smaller gliders.	2	30/10/2017	Moderate: suitable woodland habitats present for foraging habitat and large hollow bearing trees present that can be used for nesting.

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Ninox strenua	Powerful Owl	V	-	✓	-	-	-	HN564 HN568 HN604	Inhabits a range of vegetation types, from woodland and open sclerophyll forest to tall open wet forest and rainforest. They require large tracts of forest or woodland habitat but can occur in fragmented landscapes as well. Powerful Owls nest in large tree hollows (at least 0.5m deep), in large eucalypts (diameter at breast height of 80-240 cm) that are at least 150 years old. Forages mainly on medium-sized arboreal mammals (greater glider, common ringtail possum), though sometimes takes roosting birds and other prey.	29	23/5/2017	High: suitable foraging habitat present, suitable hollows for breeding present, and large number of records from locality.
Numenius madagascariensis	Eastern Curlew	-	CE, M, Ma	-	✓	-	-	-	It generally occupies coastal lakes, inlets, bays and estuarine habitats, and in New South Wales is mainly found in intertidal mudflats and sometimes saltmarsh of sheltered coasts. It forages in or at the edge of shallow water, occasionally on exposed algal mats or waterweed, or on banks of beach-cast seagrass or seaweed.	-	-	Nil: suitable coastal wetlands not present in the development site and study area.
Pandion haliaetus	Osprey	-	M, Ma	-	✓	-	-	-	Requires clear estuarine and inshore marine waters and coastal rivers for foraging, and nests in tall (usually dead or dead-topped) trees in coastal habitats from open woodland to open forest, within 1-2 km of water.	-	-	Low: Warragamba Dam provides a water body that the species could forage on, but it prefers marine environments and no records from locality.
Petroica boodang	Scarlet Robin	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	The Scarlet Robin lives in dry eucalypt forests and woodlands. The understorey is usually open and grassy with few scattered shrubs. It lives in both mature and regrowth vegetation, occasionally occurring in mallee or wet forest communities, or in wetlands and tea-tree swamps. Scarlet Robin habitat usually contains abundant logs and fallen timber, which are important habitat components. Known from coastal NSW to tablelands area	2	9/6/2006	High: suitable woodlands present and a couple of records from locality.

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				NSW Atlas	PMST	SEARs	BBCC					
Rhipidura rufifrons	Rufous Fantail	-	M, Ma	-	✓	-	-	-	In east and south-east Australia, the Rufous Fantail mainly inhabits wet sclerophyll forests, often in gullies dominated by eucalypts such as Tallow-wood (*Eucalyptus microcorys*), Mountain Grey Gum (*E. cypellocarpa*), Narrow-leaved Peppermint (*E. radiata*), Mountain Ash (*E. regnans*), Alpine Ash (*E. delegatensis*), Blackbutt (*E. pilularis*) or Red Mahogany (*E. resinifera*); usually with a dense shrubby understorey often including ferns.	-	-	Low: gullies with dense vegetation not present within the development site and study area and no records from locality.
Rostratula australis	Australian Painted Snipe	E	E, Ma	-	✓	✓	-	-	Inhabits shallow inland wetlands, either freshwater or brackish water bodies. Nests on the ground amongst tall reed-like vegetation near water, and feeds near the water's edge and on mudflats.	-	-	Nil: suitable shallow wetlands not present in the development site and study area.
Stagonopleura guttata	Diamond Firetail	V	-	✓	-	-	-	HN564 HN568	Found in grassy eucalypt woodlands, open forest, mallee, grassland and riparian areas.	1	2/6/1990	Moderate: suitable woodland areas present in development site and study area.
Tringa nebularia	Common Greenshank	-	M	-	✓	-	-	-	Found in mudflats, estuaries, saltmarshes, and the margins of wetlands.	-	-	Nil: suitable coastal habitats absent from the development site and study area.
Tyto novaehollandiae	Masked Owl	V	-	✓	-	-	-	HN564 HN568 HN604	Occurs throughout NSW, roosting and nesting in heavy forest. Hunts over open woodland and farmland, with a home range of 500 - 1000 ha. The main requirements are tall trees with suitable large hollows for nesting and roosting and adjacent areas for foraging. Feeds on small mammals.	3	13/6/2017	Moderate: dense vegetation for nesting not really present, but woodlands suitable for foraging are present.
Tyto tenebricosa	Sooty Owl	V	-	✓	-	-	-	HN568 HN604	Inhabits subtropical and warm temperate rainforest, and moist or dry eucalypt forest with a well-developed mid-storey of trees or shrubs. Roost and nest sites for the species occur in gullies. Utilise large hollows for nesting and prey on other hollow dependent species. Roost in hollows or dense vegetation.	5	31/8/2017	Moderate: dense vegetation for nesting not really present, but woodlands suitable for foraging are present.

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Fish												
Maccullochella peelii	Murray Cod	-	V	-	-	-	-	-	Murray Cod generally prefer slow flowing, turbid water in streams and rivers, favouring deeper water around boulders, undercut banks, overhanging vegetation and logs. Small numbers are still present in the Nepean River and Yarra River.	-	-	Nil – suitable habitat not present within the development site.
Macquaria australasica	Macquarie Perch	-	E	-	✓	✓	-	-	Found in both river and lake habitats, especially the upper reaches of rivers and their tributaries.	-	-	Nil – suitable habitat not present within the development site.
Prototroctes maraena	Australian Grayling	E	V	-	✓	✓	-	-	The Australian Grayling is endemic to south-eastern Australia, including Victoria, Tasmania and New South Wales. Rare fish are likely in South Australia.	-	-	Nil – suitable habitat not present within the development site.
Invertebrates												
Meridolum corneovirens	Cumberland Plain Land Snail	E	-	✓	-	-	✓	HN604	Primarily inhabits Cumberland Plain Woodland. Lives under litter of bark, leaves and logs, or shelters in loose soil around grass clumps. Occasionally shelters under rubbish. Can dig several centimetres into soil to escape drought.	67	19/9/2018	Moderate: vegetation types associated with this species present within the development site.
Pommerhelix duralensis	Dural Land Snail	E	E	-	✓	✓	-	HN564 HN604	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.	-	-	Moderate: habitat is suitable being a sandstone area with potential grading to shales.
Synemon plana	Golden Sun Moth	E	CE	-	✓	-	-	-	Species found in the area between Queanbeyan, Gunning, Young and Tumut. It occurs in Natural Temperate Grasslands and grassy Box-Gum Woodlands in which ground layer is dominated by wallaby grasses *Austrodanthonia* spp.	-	-	Nil – suitable habitat not present within the development site.

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Mammals												
Cercartetus nanus	Eastern Pygmy-possum	V	-	-	-	-	✓	HN564 HN566 HN568 HN604	In New South Wales the species is found in coastal areas and at higher elevation. Inhabit shrubby vegetation in a wide variety of habitats, from open heathland or shrubland to sclerophyll or rain forest. Require flowering plants and shrubs for foraging and access to hollows/nesting vegetation.	-	-	Moderate: suitable habitat is present in the form of woodlands, although there are no records from the development site or study area.
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	✓	✓	✓	✓	HN564 HN566 HN568 HN604	Roosts in disused mine shafts, caves, overhangs and disused Fairy Martin (*Petrochelidon ariel*) nests for shelter and to raise young. Also potentially roost in tree hollows. Occurs in low to mid-elevation dry open forest and woodlands, preferably with extensive cliffs, caves or gullies. Pied Bat is largely restricted to the interface of sandstone escarpment (for roost habitat) and relatively fertile valleys (for foraging habitat).	8	9/5/2018	Recorded: suitable sandstone cliffs present that may provide roosting sites.
Dasyurus maculatus maculatus	Spotted-tailed Quoll	V	E	✓	✓	✓	-	HN564 HN566 HN568 HN604	Utilises 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 crevices, boulder fields and rocky-cliff faces as den sites.	2	13/7/2004	Moderate: this species is known to range widely and use a very broad variety of landscapes. Prefers locations with high productivity and s food abundance.
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	-	-	-	-	-	HN564 HN566 HN568 HN604	This species occupies tall, mature, wet forest and the species have been recorded roosting in stem holes in Eucalyptus and in buildings. Prefers moist habitats, with trees taller than 20 m. Generally roosts in eucalypt hollows, but has also been found under loose bark on trees or in buildings.	-	-	Recorded.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Isoodon obesulus obesulus	Southern Brown Bandicoot (eastern)	E	E	-	-	✓	✓	HN566	Generally, only found in heath or open forest with a heathy understorey on sandy or friable soils. Feeds on a variety of ground-dwelling invertebrates and the fruit-bodies of hypogeous (underground-fruiting) fungi. Their searches for food often create distinctive conical holes in the soil. Males have a home range of approximately 5-20 hectares whilst females forage over smaller areas of about 2-3 hectares. 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.	-	-	Low: suitable heathy understorey not present in the development site and study area.
Miniopterus australis	Little Bent-winged Bat	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	This species occurs in moist eucalypt forest, rainforest or dense coastal banksia scrub. Little Bent-winged Bats roost in caves, tunnels and sometimes tree hollows during the day, and at night forage for small insects beneath the canopy of densely vegetated habitats.	1	13/3/2012	Moderate: roost sites potentially present and species may forage over the development site and study area. But at edge of range and few records this far south.
Miniopterus orianae oceanensis	Large Bent-winged Bat	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Caves are the primary roosting habitat, but 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. This species tends to hunt in forested areas.	15	9/5/2018	High: roost sites potentially present and species is likely to forage over the development site and study area. Large number of records in locality.
Micronomus norfolkensis	Eastern Coastal Free-tailed Bat	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Habitats preference includes dry eucalypt forest and coastal woodlands but also include riparian zones in rainforest and wet sclerophyll forest. Forages above forest canopy or forest edge and requires roosts including tree hollows.	19	29/10/2017	Recorded.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Myotis macropus	Southern Myotis	V	-	✓	-	-	-	HN564 HN568 HN604	This species 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.	8	9/5/2018	High: suitable foraging habitat present in the form of dam and river. Suitable cave roosts likely to be present.
Petauroides volans	Greater Glider	-	V	-	✓	✓	-	-	The Greater Glider is restricted to eastern Australia, occurring from the Windsor Tableland in north Queensland through to central Victoria. It is typically found in highest abundance in taller, montane, moist eucalypt forests. Requires large tree hollows for denning.	-	-	Low: suitable taller forests absent from the development site and study area.
Petaurus australis	Yellow-bellied Glider	V	-	✓	-	-	-	HN568	Typically occurs in tall, mature eucalypt forest in regions of high rainfall, but is also known to occur in drier areas. Preference for resource rich forests where mature trees provide nesting hollows and tree species composition with adequate food resources, including winter-flowering Eucalypts and sap-rich trees.	9	12/10/2004	Moderate: habitat present not high quality, but species will use woodlands and was recorded within multiple locations around Lake Burragorang during current investigations.
Petaurus norfolcensis	Squirrel Glider	V	-	-	-	-	✓	HN568 HN604	The Squirrel Glider inhabits dry sclerophyll forest and woodland. In NSW, potential habitat includes Box-Ironbark forests and woodlands in the west, the River Red Gum forests of the Murray Valley and the eucalypt forests of the northeast. Individuals have also been recorded in a diverse range of vegetation communities, including Blackbutt, Forest Red Gum and Red Bloodwood forests, Coastal Banksia heathland and Grey Gum/Spotted Gum/Grey Ironbark dry hardwood forests of the Central NSW Coast. The Squirrel Glider is nocturnal and shelters in tree hollows. This species is capable of gliding up to 50 m.	-	-	Moderate: suitable woodlands with hollows and feed trees present. But no records from locality.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	✓	✓	✓	✓	HN566 HN568	This species prefers rocky habitats, including loose boulder-piles, rocky outcrops, steep rocky slopes, cliffs, gorges, isolated rock stacks and tree limbs. Preference for north-facing slopes and cliff lines. A range of vegetation types are associated with Brush-tailed Rock-wallaby habitat, including dense rainforest, wet sclerophyll forest, vine thicket, dry sclerophyll forest, and open forest.	3	1/7/1996	High: suitable rocky cliffs present. A few records from locality.
Phascogale tapoatafa	Brush-tailed Phascogale	V	-	-	-	-	✓	HN564 HN566 HN604	Prefer dry sclerophyll open forest with sparse groundcover of herbs, grasses, shrubs or leaf litter. Also inhabit heath, swamps, rainforest and wet sclerophyll forest.	-	-	Moderate: suitable habitat present, but no records from the locality.
Phascolarctos cinereus	Koala	V	V	✓	✓	✓	✓	HN564 HN566 HN568 HN604	Inhabits a range of eucalypt forest and woodland communities. Adequate floristic diversity, availability of feed trees (primarily Eucalyptus tereticornis and E. viminalis) and presence of mature trees very important. Preferred food tree species vary with locality and there are quite distinct regional preferences. They are able to persist in fragmented habitats, and even survive in isolated trees across a predominantly agricultural landscape.	11	26/6/2018	Moderate: suitable habitat and feed trees present, but low productivity environment and the development site study area are not likely to represent key breeding habitat.
Planigale maculata	Common Planigale	V	-	-	-	-	-	-	Common Planigales inhabit rainforest, eucalypt forest, heathland, marshland, grassland and rocky areas where there is surface cover, and usually close to water.	-	-	Known: suitable habitat of open forest adjacent to water present.
Pseudomys novaehollandiae	New Holland Mouse	-	V	-	✓	-	-	HN564 HN566 HN568 HN604	Inhabit open heathlands, open woodlands with a heathland understorey, and vegetated sand dunes. Nest in burrows and have a preference for deeper top soils and softer substrates to aid digging. Spends considerable time foraging above-ground for food in areas of high floristic diversity.	-	-	Low: suitable heathy environments not present in the development site or study area and no records from locality

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Pteropus poliocephalus	Grey-headed Flying-fox	V	V	✓	✓	✓	-	HN564 HN566 HN568 HN604	Occur in subtropical and temperate rainforests, tall sclerophyll forests and woodlands, heaths and swamps as well as urban gardens and cultivated fruit crops. Roosting camps are commonly found in gullies, close to water, in vegetation with a dense canopy. They travel up to 50 km to forage, on the nectar and pollen of native trees, in particular Eucalyptus, Melaleuca and Banksia, and fruits of rainforest trees and vines.	25	11/10/2017	High: species ranges widely from roosts and feeds in a broad range of habitats. Suitable feed trees present and known colonies within 50 km at Brownlow Hill, Penrith and Yarramundi.
Saccolaimus flaviventris	Yellow-bellied Sheathtail-bat	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Inhabits eucalypt rainforest, sclerophyll forest and open woodland vegetation. Availability of tree hollows is important for access to roosting sites.	1	1/7/2013	Moderate: suitable woodlands with hollow bearing trees are present and the species is known from the locality.
Scoteanax rueppellii	Greater Broad-nosed Bat	V	-	✓	-	-	-	HN564 HN566 HN568 HN604	Occurs in a variety of habitats including rainforest, dry and wet sclerophyll forest and eucalypt woodland. Large hollow bearing trees required for roosting.	10	30/10/2017	Moderate: suitable woodlands with hollow bearing trees are present and the species is known from the locality
Reptiles												
Aprasia parapulchella	Pink-tailed Worm-lizard	V	V	-	-	✓	-	-	The Pink-tailed Legless Lizard is only known from the Central and Southern Tablelands, and the South Western Slopes. Inhabits sloping, open woodland areas with predominantly native grassy groundlayers, particularly those dominated by Kangaroo Grass (Themeda australis). Sites are typically well-drained, with rocky outcrops or scattered, partially-buried rocks. Commonly found beneath small, partially-embedded rocks and appear to spend considerable time in burrows below these rocks; the burrows have been constructed by and are often still inhabited by small black ants and termites.	-	-	Low: the area is outside of its known range and does not contain suitable rock-strewn habitat.

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Hoplocephalus bungaroides	Broad-headed Snake	E	V	-	✓	✓	✓	HN564 HN566 HN568 HN604	Confined to the Sydney basin within a radius of approximately 200 km. A preferred habitat of sandstone outcrops with woodland, open woodland and/or heath vegetation. Shelters in rock crevices and under flat sandstone rocks on exposed cliff edges and tree hollows.	-	-	Moderate: suitable sandstone habitat is present, but no records from the development site or study area.
Varanus rosenbergi	Rosenberg's Goanna	V	-	-	-	-	✓	HN564 HN566 HN568 HN604	Utilise sandstone outcrops and crevices as an important winter sheltering habitat. Occurs in sandstone woodlands, heath and upland swamps. Also shelters in hollows, burrows and logs.	-	-	Moderate: suitable sandstone habitat is present, but there are no records from the study area.
FLORA												
Ecological Communities												
Blue Gum High Forest in the Sydney Basin Bioregion		CEEC	CE	-	-	✓	-	-	A moist, tall open forest community, with dominant canopy trees of Sydney Blue Gum (*Eucalyptus saligna*) and Blackbutt (*E. pilularis*). Forest Oak (*Allocasuarina torulosa*) and Sydney Red Gum (*Angophora costata*) also occur. Species adapted to moist habitat such as Lilly Pilly (*Acmena smithii*), Sandpaper Fig (*Ficus coronata*), Rainbow Fern (*Calochleana dubia*) and Common Maidenhair (*Adiantum aethiopicum*) may also occur. The remnants mainly occur in the Lane Cove, Willoughby, Ku-ring-gai, Hornsby, Hills, Ryde and Parramatta local government areas.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Castlereagh Scribbly Gum and Agnes Banks Woodland of the Sydney Basin Bioregion		CEEC	E	-	✓	✓	-	-	Dominated by *Eucalyptus parramattensis* subsp. *parramattensis*, *E. sclerophylla* and *Angophora bakeri*. A small tree stratum of *Melaleuca decora* is sometimes present in areas of poor drainage. It has a well-developed sub-stratum of *Banksia spinulosa* var. *spinulosa*, *Melaleuca decora*, *Hakea sericea* and *H. dactyloides*. The groundcover includes forbs such as *Themeda australis*, *Entolasia stricta*, *Dianella revolute* subsp. *revolute* and *Platysace ericoides*. Occurs almost exclusively on soils derived from Tertiary alluvium or on sites adjoining shale or Holocene alluvium.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and South East Queensland		EEC	E	-	✓	-	-	-	Coastal Swamp Oak forest is often found in association with other vegetation types such as coastal saltmarsh, mangroves, freshwater wetlands, littoral rainforests or swamp sclerophyll forests in a 'mosaic' of coastal floodplain communities.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Cooks River/Castlereagh Ironbark Forest in the Sydney Basin Bioregion		EEC	CE	-	✓	✓	-	-	Ranges from open forest to low woodland with a canopy dominated by *Eucalyptus fibrosa* and *Melaleuca decora*. The dense shrubby understorey includes *Melaleuca nodosa* and *Lissanthe strigosa* with a range of other shrubs such as *Dillwynia tenuifolia*, *Pultenaea villosa* and *Daviesia ulicifolia*. Occurs in western Sydney in the Castlereagh and Holsworthy areas. Smaller remnants occur in the Kemps Creek area and eastern parts of the Cumberland Plain. Mainly occurs on clay soils derived from ancient river systems or on shale soils from the Wianamatta Shale.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest		EEC	CE	-	✓	✓	-	-	The Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest typically occurs on flat to undulating or hilly terrain, at elevations up to approximately 350 metres above sea level. Some occurrences may extend onto locally steep sites at slightly higher elevations. Most occurrences are on clay soils derived from Wianamatta Group geology, with limited to rare occurrences on other soil types.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Cumberland Plain Woodland in the Sydney Basin Bioregion		CEEC	CE	-	-	✓	-	-	Dominant canopy trees include *Eucalyptus moluccana*, *E. tereticornis*, *E. crebra*, *E. eugenioides* and *Corymbia maculata*. Shrub layer is dominated by *Bursaria spinosa* and grasses such as *Themeda australis* and *Microlaena stipoides* var. *stipoides* are common. Occurs on heavy clay soils derived from the Wianamatta Shale and through the driest part of the Sydney Basin. The only existing remnants are scattered across the Cumberland Plain.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Elderslie Banksia Scrub Forest in the Sydney Basin Bioregion		CEEC	-	-	-	✓	-	-	A scrub community dominated by Coastal Banksia, *Banksia integrifolia* subsp. *integrifolia*. Other canopy species include Broad-leaved Apple *Angophora subvelutina*. The shrubby understorey is diverse and includes species that usually occur in sandstone areas, such as Wedding Bush *Ricinocarpus pinifolius*, Riceflower *Pimelea linifolia* subsp. *linifolia* and Daphne Heath *Brachyloma daphnoides*. Occurs only in the Elderslie area, near Camden, in Sydney's south-west.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.

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				NSW Atlas	PMST	SEARs	BBCC					
Natural Temperate Grassland of the South Eastern Highlands		-	CE	-	✓	-	-	-	Natural Temperate Grassland is a grassland community dominated by a range of perennial grass species and in highly intact sites, containing a large range of herbaceous species in many plant families, including daisies, peas, lilies, orchids and plants in many other families, all collectively known as forbs, or "wildflowers" in the case of the more showy species. Natural Temperate Grassland is confined to the Southern Tablelands, a region bounded by the ACT, Yass, Boorowa, the Abercrombie River, Goulburn, the Great Eastern Escarpment, the Victorian border and the eastern boundary of Kosciusko National Park. The community occurs in a number of distinct plant associations (see Armstrong et al. 2013).	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Shale Sandstone Transition Forest of the Sydney Basin Bioregion		EEC	CE	-	✓	✓	-	-	Occurs at the edges of the Cumberland Plain, where clay soils form the shale rock intergrade with sandstone soils or where shale caps overlay sandstone. The boundaries are indistinct, and the species composition varies depending on the soil. The main tree species include *Eucalyptus tereticornis*, *E. punctata*, *E. globoidea*, *E. eugenioides*, *E. fibrosa*, and *E. crebra*. Areas of low sandstone influence have an understory that is closer to Cumberland Plain Woodland. Original distribution was around the edges of the Cumberland lowlands throughout western Sydney, most prominently in the southern half. This distribution is now highly fragmented. This community is well adapted to fire, often being close to sandstone areas.	-		Recorded.

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Temperate Highland Peat Swamps on Sandstone		EEC	E	-	-	✓	-	-	Sphagnum bogs and fens occupy the wetter parts while sedge and shrub associations occur in the drier parts of the swamps. Some, like the Blue Mountains Swamps, are hanging swamps that are prominent on steep valley sides, where water exits the ground between sandstone and claystone layers of rock. Other swamps, like Wingecarribee Swamp, occur in natural depressions or along watercourses.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Turpentine-Ironbark Forest of the Sydney Basin Bioregion		EEC	CE	-	✓	✓	-	-	Open forest, with dominant canopy trees including Turpentine *Syncarpia glomulifera*, Grey Gum *Eucalyptus punctata*, Grey Ironbark *E. paniculata* and Thin-leaved Stringybark *E. eugenioides*. In areas of high rainfall (over 1,050 mm per annum) Sydney Blue Gum *E. saligna* is more dominant. The shrub stratum is usually sparse and may contain mesic species such as Sweet Pittosporum *Pittosporum undulatum* and Elderberry Panax *Polyscias sambucifolia*. Occurs in Sydney and is heavily fragmented, with only 0.5 percent its original extent remaining intact. Remnants mostly occur in the Hills, Hornsby, Ku-ring-gai, Parramatta, Ryde, Sutherland and Hurstville local government areas. Good examples can be seen in small reserves such as Wallumatta Nature Reserve and Newington Nature Reserve. A transitional community, between Cumberland Plain Woodland in drier areas and Blue Gum High Forest on adjacent higher rainfall ridges.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.

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				NSW Atlas	PMST	SEARs	BBCC					
Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion		EEC	E	-	✓	✓	-	-	This ecological community has a sparse to dense layer of shrubs and vines, and a diverse understorey of native grasses, forbs, twiners and ferns. The Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion ecological community occurs within the following Catchment Management Authorities (CMAs) in NSW: Hawkesbury-Nepean and Southern Rivers.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Western Sydney Dry Rainforest and Moist Woodland on Shale		EEC	CE	-	✓	✓	-	-	A dry vine scrub community of the Cumberland Plain. Canopy trees include *Melaleuca styphelioides*, *Acacia implexa* and *Alectryon subcinereus*. There are many rainforest species in the shrub layer such as *Notolaea longifolia*, *Clerodendrum tomentosum* and *Pittosporum revolutum*. The vines that combine with the shrub layer include *Aphanopetalum*, *Pandorea pandorana* and *Cayratia clematidea*. This community contains many more species. This community is highly restricted, occurring most commonly in the far southern section of the Cumberland Plain, in the Razorback Range near Picton. Small patches are known to occur as far north as the Hawkesbury LGA. Restricted to hilly country where it occurs on sheltered lower slopes and gullies on clay soils derived from Wianamatta Shale. Is found at higher elevations, in areas with more rainfall than Cumberland Plain Woodland.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
White Box – Yellow Box – Blakely's Red Gum Grassy Woodland and Derived Native Grassland		EEC	CE	-	✓	✓	-	-	This community is found on relatively fertile soils on the tablelands and western slopes of NSW and generally occurs between the 400 and 800 mm isohyets extending from the western slopes, at an altitude of c. 170m to c. 1200 m, on the northern tablelands (Beadle 1981). The community occurs within the NSW North Coast, New England Tableland, Nandewar, Brigalow Belt South, Sydney Basin, South Eastern Highlands and NSW South Western Slopes Bioregions. This community includes those woodlands where the characteristic tree species include one or more of the following species in varying proportions and combinations - *Eucalyptus albens* (White Box), *Eucalyptus melliodora* (Yellow Box) or *Eucalyptus blakelyi* (Blakely's Red Gum). Grass and herbaceous species generally characterise the ground layer. In some locations, the tree overstorey may be absent as a result of past clearing or thinning and at these locations only an understorey may be present. Shrubs are generally sparse or absent, though they may be locally common.	-	-	Nil – vegetation assessment determined the EEC does not occur on the development site.
Plants												
Acacia baueri subsp. *aspera*	-	V	-	-	-	✓	✓	HN566	Occurs in low heathlands, often on exposed rocky outcrops over a wide range of climatic and topographical conditions. Appears to prefer open conditions; rarely observed where there is any shrub or tree canopy development; and many of the observations of this species have been made following fire, suggesting that the species prefers early successional habitats.	-	-	Moderate – some suitable habitat present as floristic and structural associations, edaphic and landscape features.

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				NSW Atlas	PMST	SEARs	BBCC					
Acacia bynoeana	Bynoe's Wattle	E	V	-	✓	✓	✓	HN564 HN566 HN568 HN604	Occurs mainly in heath, open woodland and dry sclerophyll forest with dense to sparse heathy understorey and a grass/sedge groundcover. With sand or sandy clay substrate, often with ironstone gravel and usually well-drained, infertile soil.	-	-	Moderate – some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Acacia flocktoniae	Flockton Wattle	V	V	-	-	-	✓	HN564 HN568	Found in the southern Blue Mountains (Mt Victoria, Megalong Valley and Yerranderie) where it grows in dry sclerophyll forest predominantly on sandstone.	-	-	Moderate – some suitable habitat present as floristic and structural associations, edaphic and landscape features. Site is outside the species known distribution.
Acacia gordonii	Gordon's Wattle	E	E	-	-	✓	✓	HN564 HN566	Grows in dry sclerophyll forest and heathlands among or within rock platforms on sandstone outcrops. Flowers August to September and produces fruit October to February. The fruit is a pod containing hard-coated seed. The seed ultimately forms a persistent soil stored seedbank.	-	-	Moderate – some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Acacia pubescens	Downy Wattle	V	V	-	-	✓	✓	HN564 HN566 HN568 HN604	Occurs on alluviums, shales, and at the intergrade between shales and sandstones. The soils are characteristically gravely soils, often with ironstone. Occurs in open woodland and forest, in a variety of plant communities, including Cooks River/Castlereagh Ironbark Forest, Shale/Gravel Transition Forest and Cumberland Plain Woodland. Within its Cumberland Plain extent, it is concentrated around the Bankstown-Fairfield-Rookwood area and the Pitt Town area, with another smaller extent near Oakdale. There is another centre of distribution in the Colo River catchment around the Bilpin to Mountain Lagoon area.	-	-	Moderate - Some suitable habitat present as floristic and structural associations and edaphic features.

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Acrophyllum australe		V	V	-	-	✓	-	HN566 99993	Grows in sheltered gullies beneath waterfalls and drip zones of rock overhangs and cliff faces, usually with a south-east to south-west aspect. Typically found in areas where there is a more-or-less constant supply of water. Usually grows in shale interbeds at the base of small cliffs, in crevices on the sandstone rock face or on talus slopes. The rock overhangs are of Hawkesbury or Narrabeen Sandstone.	-	-	Low - The development site does not contain suitable edaphic or landscape features, specifically sheltered gullies beneath waterfalls, drip zones of rock overhangs and cliff faces. Moreover, floristic associations for this species are not present on site.
Allocasuarina glareicola		E	E	-	✓	✓	-	HN564	Occurs in Castlereagh woodland on lateritic soil. Primarily restricted to the Richmond (NW Cumberland Plain) district, but with an outlier population found at Voyager Point, Liverpool.	-	-	Low – site does not contain suitable edaphic or vegetation associations. Development site and study area outside of known range.
Ancistrachne maidenii		V	-	✓	-	✓	✓	HN564 HN566	BioNet states that habitat requirements appear to be specific, with populations occurring in distinct bands in areas associated with a transitional geology between Hawkesbury and Watagan soil landscapes. As the species' range occurs in areas well away from Watagan Soil Landscapes, including within the Sydney Basin but also elsewhere in NSW, this information is considered incorrect, incomplete or out of date, suggesting that the overall assessment that the species' specific habitat requirements are not easy to predict, at least in relation to soil landscapes.	1	6/3/1999	Moderate suitable habitat present and record from locality.
Asterolasia elegans		E	E	-	-	✓	✓	HN564 HN566	Occurs in the northern hills of Sydney. Habitat requirements are wet, sheltered sclerophyll forests on the mid to lower slopes of moist gullies and rocky outcrops.	-	-	Moderate – within range and suitable habitat present.

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				NSW Atlas	PMST	SEARs	BBCC					
Astrotricha crassifolia	Thick-leaf Star-hair	V	V	-	-	-	✓	HN566	The nearest records are for near Patonga (Central Coast LGA), in the Royal NP and on the Woronora Plateau. A record mapped in AVH for Kanangra-Boyd appears to be inconsistent with the verbatim transcription of the Royal NP. Occurs in dry sclerophyll woodland on sandstone.	-	-	Moderate – development site and study area out of predicted range but PCT and broad habitat present on site.
Bossiaea oligosperma	Few-seeded Bossiaea	V	V	-	-	✓	-	-	Limited info on this plant's ecology. Occurs on sandstone slopes or ridges in the Yerranderie area. Occurs in low woodland on loamy soil in the Windellama area.	-	-	Low – development site and study area not in known range. Site does not contain suitable edaphic or vegetation associations.
Caesia parviflora subsp. *minor*	Small Pale Grass-lily	E	-	-	-	-	✓	HN564 HN566	Found in damp places in open forest on sandstone.	-	-	Moderate - Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Callistemon megalongensis	Megalong Valley Bottlebrush	CE	CE	-	-	✓	-	N/A	Occurs within swamping and shrubby swamp habitat primarily adjacent to creeklines in the Western Blue Mountains	-	-	Low - site does not contain suitable edaphic or vegetation associations
Cryptostylis hunteriana	Leafless Tongue-orchid	V	V	-	✓	-	✓	HN566	The Leafless Tongue Orchid has been recorded from as far north as Gibraltar Range National Park south into Victoria around the coast as far as Orbost.	-	-	Moderate – too broad a habitat and range to discount.
Cynanchum elegans	White-flowered Wax Plant	E	E	-	✓	✓	-	-	The White-flowered Wax Plant usually occurs on the edge of dry rainforest vegetation. Other associated vegetation types include littoral rainforest; Coastal Tea-tree *Leptospermum laevigatum* – Coastal Banksia *Banksia integrifolia* subsp. *integrifolia* coastal scrub; Forest Red Gum *Eucalyptus tereticornis* aligned open forest and woodland; Spotted Gum *Corymbia maculata* aligned open forest and woodland; and Bracelet Honeymyrtle *Melaleuca armillaris* scrub to open scrub.	-	-	Low - site does not contain suitable edaphic or vegetation associations.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Darwinia biflora		V	V	-	-	✓		HN564 HN566	Occurs on the edges of weathered shale-capped ridges, where these intergrade with Hawkesbury Sandstone. Occurs in Sydney Sandstone Ridgetop Woodland, often on rock shelves. Associated overstorey species include *Eucalyptus haemastoma*, *Corymbia gummifera* and/or *E. squamosa*. The vegetation structure is usually woodland, open forest or scrub-heath.	-	-	Moderate – suitable habitat present.
Darwinia peduncularis		V	-	-	-	-	✓	HN566	Usually grows on or near rocky outcrops on sandy, well-drained, low-nutrient soil over sandstone. Flowers in winter to early spring.	-	-	Moderate - Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Dillwynia tenuifolia		V	-	✓	-	✓	✓	HN564	BioNet states that the species, in western Sydney, may be locally abundant particularly within scrubby/dry heath areas within Castlereagh Ironbark Forest and Shale Gravel Transition Forest on tertiary alluvium or laterised clays. BioNet also states that it may also be common in transitional areas where these communities adjoin Castlereagh Scribbly Gum Woodland, and at Yengo, the species is reported to occur in disturbed escarpment woodland on Narrabeen sandstone. A review of the AVH records from the lower Blue Mountains, suggests that those records include likely associations with the Faulconbridge, Gymea and Hawkesbury soil landscapes which are the three soil landscapes mapped in the development site.	1	6/1/1995	Moderate - Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Epacris purpurascens var. *purpurascens*		V	-	✓	-	✓	-	HN564 HN566 HN604	Found in a range of habitat types, most of which have a strong shale soil influence. Known limit of distribution is Silverdale.	3	5/9/1965	Moderate - Some suitable habitat present as floristic and structural associations, edaphic and landscape features.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Epacris sparsa	Sparse Heath	V	V	-	-	✓	-	-	Grows in riparian sandstone scrub, where it can be found on the base of cliffs or rock faces, on rock ledges or among rocks in the riparian flood zone. Grows in pockets of damp clay soil, chiefly on south-west facing slopes.	-	-	Low – suitable habitat not present.
Eucalyptus aggregata	Black Gum	V	V	-	✓	-	-	-	Grows in the lowest part of the landscape. Grows on alluvial soils, on cold, poorly-drained flats and hollows adjacent to creeks and small rivers. Often grows in association with other cold-adapted eucalypts such as Snow Gum (*Eucalyptus pauciflora*), Manna or Ribbon Gum (*E. viminalis*), Candlebark (*E. rubida*), Black Sallee (*E. stellulata*) and Swamp Gum (*E. ovata*).	-	-	Low – suitable associated trees not present.
Eucalyptus benthamii	Camden White Gum	V	V	✓	✓	✓	-	-	Occurs on the alluvial flats of the Nepean River and its tributaries. Requires a combination of deep alluvial sands and a flooding regime that permits seedling establishment.	93	13/8/2017	Low – suitable habitat not present.
Genoplesium baueri	Bauer's Midge Orchid	V	E	-	✓	✓		HN566	Occurs in coastal areas. Habitats include heathland, open forest, shrubby forest, heathy forest and woodland with sandy/sandy loam and well-draining soils.	-	-	Moderate – Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Gentiana wingecarribiensis	Wingecarribee Gentian			-	-	✓	-	N/A	Wingecarribee Gentian grows in bogs, in Sphagnum Moss humps and in sedge communities. Known only from Hanging Rock Swamp in the Southern Highlands.	-	-	Low – suitable habitat not present.
Grammitis stenophylla	Narrow-leaf Finger Fern	E	-	-	-	-	-	-	High moisture habitat in which this species occurs, such as streams and rainforest gullies, occurs in the development site. This species has been recorded in the Warragamba Gorge immediately outside the development site during the recent surveys.	-	-	High - the species was identified during the project's current surveys as incidental observations approximately 3 km SW of the development footprint.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Grevillea evansiana	Evan's Grevillea	V	V	-	-	-	✓	HN566	Grows in dry sclerophyll forest or woodland, occasionally in swampy heath, in sandy soils, usually over Narrabeen Group sandstone; known only from an area east of Rylstone, mostly on the western catchment but just getting into the Colo River catchment.	-	-	Low - Some suitable habitat present as floristic and structural associations, edaphic and landscape features. Species has a restricted distribution.
Grevillea juniperina subsp. *juniperina*	Juniper-leaved Grevillea	V	-	✓	-	-	-	-	Grows on reddish clay to sandy soils derived from Wianamatta Shale and Tertiary alluvium (often with shale influence), typically containing lateritic gravels.	4	14/9/2016	Low - site does not contain suitable edaphic or vegetation associations.
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	E	-	-	-	-	✓	HN564 HN566 HN604	Occurs in a range of vegetation types from heath and shrubby woodland to open forest. Found over a range of altitudes from flat, low-lying areas to upper slopes and ridge crests. Hunter occurrences are usually 30-70m ASL, while the southern Sydney occurrences are typically at 200-300m ASL. Often occurs in open, slightly disturbed sites such as along tracks.	-	-	Known – observed during incidental vegetation surveys.
Gyrostemon thesioides		E	-	-	-	✓	-	HN564 HN604	Grows on hillsides and riverbanks and may be restricted by fine sandy soils. A fire-opportunist, with recruitment occurring from a soil stored seed bank following fire.	-	-	Low – suitable habitat present within the site, but the species only has a handful of records in the past 60 years.
Hakea dohertyi	Kowmung Hakea	E	E	-	-	✓	-	-	Confined to a small area in the Kowmung Valley of the Kanangra Boyd National Park along with smaller populations at Lake Burragorang, Tonalli Cove and the Bindook area. Grows in dry sclerophyll forest, usually dominated by grey gum or silvertop ash, with a sparse groundcover and midstorey.	-	-	Low – out of predicted range.
Haloragis exalata subsp. *exalata*	Square Raspwort	V	V	-	✓	✓	-	-	Square Raspwort occurs in 4 widely scattered localities in eastern NSW. It is disjunctly distributed in the Central Coast, South Coast and North Western Slopes botanical subdivisions of NSW. Appears to require protected and shaded damp situations in riparian habitats.	-	-	Low – out of predicted range (OEH profile).

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
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Haloragodendron lucasii	Hal	E	E	-	-	✓	✓	HN566	Associated with dry sclerophyll forest. Reported to grow in moist sandy loam soils in sheltered aspects, and on gentle slopes below cliff lines that have creeks. This species is highly clonal implying that the true population size may be much smaller than expected.	-	-	Low - suitable most creek associated habitat present, although no records from locality. The species is only known from the North Shore of Sydney and so the development site is out of the known range.
Hibbertia puberula		E	-	-	-	✓	✓	HN564 HN566 HN568 HN604	Flowering time is October to December, sometimes into January. Occurs on sandy soil often associated with sandstone, or on clay. Habitats are typically dry sclerophyll woodland communities, although heaths are also occupied. One of the recently (2012) described subspecies also favours upland swamps.	-	-	Moderate - suitable woodlands and soil types present.
Hygrocybe anomala var. *iathinomarginata*		V	-	-	-	-	✓	HN566	Occurs in warm temperate forests dominated by *Acmena smithii*, *Backhousia myrtifolia*, *Glochidion ferdinandi* and *Pittosporum undulatum* on alluvial sandy Hawkesbury soil landscape.	-	-	Moderate – associated PCTs and soil landscapes occur within the site.
Kunzea cambagei	Cambage Kunzea	V	V	-	-	✓	-	-	*Kunzea cambagei* mainly occurs in the western and southern parts of the Blue Mountains, NSW, mainly the Yerranderie/Mt Werong area, with four main populations with 20 to 150 individuals. Populations are also located west of Berrima, along the Wingecarribee River; Loombah Plateau east of Mount Werong; the Oberon-Colong Stock Route within Kanangra-Boyd National Park (NP); and Wanganderry Plateau within the Nattai NP.	-	-	Low – the site is outside of the species known distribution. Vegetation and soil types associated with this species are not present within the development site.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
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Kunzea rupestris		V	V	-	-	✓	-	-	Occurs in shallow, sandy, low nutrient soil in depressions on sandstone rock platforms. It is typically found in short to tall shrubland or heathland at altitudes of 50–300 m. Records of the species	-	-	Moderate – associated PCTs and soil landscapes occur within the development site, however, the site fall outside the species known distribution and associated IBRA subregions. .
Lastreopsis hispida		E	-	-	-	-	✓	HN564 HN566	Grows in moist humus-rich soils in wet forest and rainforest gullies. At Mt Wilson, associated species include *Ceratopetalum apetalum*, *Elaeocarpus holopetalus*, *Fieldia australis*, *Cyathea australis*, *Blechnum nudum*, *B. patersonii* and *Leptopteris fraseri*.	-	-	Moderate Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Leucopogon exolasius	Woronora Beard-heath	V	V	-	-	-	✓	HN564 HN566 HN568	Woronora Beard-heath is found along the upper Georges River area and in Heathcote National Park. The plant occurs in woodland on sandstone.	-	-	Moderate - Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Leucopogon fletcheri subsp. *fletcheri*		E	-	-	-	-	✓	HN564 HN566	Occurs in dry eucalypt woodland or in shrubland on clayey lateritic soils, generally on flat to gently sloping terrain along ridges and spurs.	-	-	Moderate - Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Marsdenia viridiflora subsp. *viridiflora*	*Marsdenia Viridiflora* R. Br. subsp. *viridiflora* Population in the Bankstown, Blacktown, Camden, Campbelltown, Fairfield, Holroyd, Liverpool And Penrith LGAs	E	-	✓	-	✓	-	-	Grows in vine thickets and open shale woodland.	210	9/1/2019	Nil - The development site does not occur in the population's associated LGAs.
Melaleuca deanei	Deane's Melaleuca	V	V	✓	✓	✓	✓	HN564 HN566	Endemic to Sydney Basin region and grows in heath on sandstone or flat broad ridge tops. Strongly associated with sandy loam soils that are low in nutrients, sometimes with ironstone present.	1	12/8/2012	Moderate - suitable habitat in form of ridgetop woodlands.

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				NSW Atlas	PMST	SEARs	BBCC					
Melaleuca groveana	Grove's Paperbark	V	-	-	-	-	✓	HN566	Grows in heath, often in exposed sites. Records of the species within Yengo National Park.	-	-	Moderate - Some suitable habitat present as floristic and structural associations, edaphic and landscape features.
Micromyrtus blakelyi		V	V	-	-	✓	-	HN564 HN566	Typically occurs within heathlands in shallow sandy soil in cracks and depressions of sandstone rock platforms. Flowers in Spring from September to November and produces fruit (an indehiscent nut) October to November.	-	-	Moderate – associated PCTs and soil landscapes occur within the development site, however, the site fall outside the species known distribution and associated IBRA subregions.
Micromyrtus minutiflora		E	V	✓	-	✓	-	-	Grows in Castlereagh Scribbly Gum Woodland, Ironbark Forest, Shale/Gravel Transition Forest, open forest on tertiary alluvium and consolidated river sediments.	2	15/7/2014	Low – Vegetation and soil types associated with this species are not present within the development site.
Olearia cordata		V	V	-	-	✓	✓	HN564 HN566	Grows in dry open sclerophyll forest and open shrubland, on sandstone ridges. Flowers November to May, with seed released from February to May, depending on environmental factors.	-	-	Moderate – suitable dry open forest and shrubland present in the development site and study area.
Pelargonium sp. *striatellum*	Omeo Storksbill	E	E	-	-	✓	-	-	Known from only 4 locations in NSW, with three on lake-beds on the basalt plains of the Monaro and one at Lake Bathurst. It occurs at altitudes between 680 to 1,030 m. It has a narrow habitat that is usually just above the high-water level of irregularly inundated or ephemeral lakes, in the transition zone between surrounding grasslands or pasture and the wetland or aquatic communities.	-	-	Low – no known records or habitat in the development site and study area, out of known range.
Persicaria elatior	Tall Knotweed	V	V	-	✓	-	-	-	This species occurs in damp places, especially besides streams and lakes, forested wetlands, and can be associated with disturbance. The species is known from the South Coast through to Grafton area.	-	-	Low – suitable habitat for this species does not occur within the development site.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Persoonia acerosa	Needle Geebung	V	V	-	✓	✓	✓	HN566 HN568	The Needle Geebung occurs in dry sclerophyll forest, scrubby low-woodland and heath on low fertility soils. Plants are likely to be killed by fire and recruitment is solely from seed. This species seems to benefit from the reduced competition and increased light available on disturbance margins including roadsides.	-	-	Moderate - suitable habitat present in the development site and study area and predicted present in OEH profile. Found in sclerophyll forests and woodlands on low fertility soils.
Persoonia hirsuta	Hairy Geebung	E	E	-	✓	✓	✓	HN564 HN566 HN568 HN604	Occurs in shrub-woodlands and dry sclerophyll forest. It grows in sandy to stony soils derived from sandstone or very rarely on shale, from near sea level to 600 m altitude.	-	-	Moderate - suitable habitat present in the development site and study area and predicted as potentially present in OEH profile. Found in sclerophyll forests and woodlands on low fertility soils.
Persoonia nutans	Nodding Geebung	E	E	-	✓	✓	-	-	Restricted to the Cumberland Plain in western Sydney, between Richmond in the north and Macquarie Fields in the south. The species has a disjunct distribution, with the majority of populations (and 99% of individuals) occurring in the north of the species range in the Agnes Banks, Londonderry, Castlereagh, Berkshire Park and Windsor Downs areas. Northern populations are confined to aeolian and alluvial sediments and occur in a range of sclerophyll forest and woodland vegetation communities. The southern and northern populations have distinct habitat differences.	-	-	High - suitable alluvial habitat present and locations within the development site and study area.
Pimelea curviflora var. *curviflora*		V	V	-	✓	-	✓	HN564 HN566 HN604	Confined to the coastal area of the Sydney and Illawarra regions. Occurs on shaley/lateritic soils over sandstone and shale/sandstone transition soils on ridgetops and upper slopes amongst woodlands. Also recorded in Illawarra Lowland Grassy Woodland habitat at Albion Park on the Illawarra coastal plain.	-	-	Moderate – associated PCTs and soil landscapes occur within the development site, however, the site fall outside the species known distribution and associated IBRA subregions.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
Pimelea spicata	Spiked Rice-flower	E	E	✓	✓	✓	-	-	Occurs on an undulating topography on well-structured clay soils. On the Cumberland Plain sites it is associated with Grey Box communities (particularly Cumberland Plain Woodland variants and Moist Shale Woodland) and in areas of ironbark.	4	21/4/2017	Low Construction area - suitable clay-based habitats not present within the development site and study area.
Pomaderris brunnea	Brown Pomaderris	V	V	-	✓	✓	✓	HN564	Brown Pomaderris grows in moist woodland or forest on clay and alluvial soils of flood plains and creek lines.	-	-	Moderate - suitable alluvial based habitats present within the development site and study area.
Pterostylis saxicola	Sydney Plains Greenhood	E	E	-	✓	✓	✓	HN564 HN566	Restricted to western Sydney between Freemans Reach in the north and Picton in the south. Most commonly found growing in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines.	-	-	Low - coastal plain species located on sandstone rock shelves.
Pultenaea elusa	*Pultenaea elusa*	CE	E	-	-	✓	-	-	This species has been recorded twice in 1938 as occurring in swamp. The development site does not contain the known associated PCTs or soil type.	-	-	Nil – suitable vegetation associations and edaphics not present within the development site and study area. Development site is outside known distribution of the species.
Pultenaea glabra	Smooth Bush-pea	V	V	-	✓	✓	-	HN566 HN568	Grows in swamp margins, hillslopes, gullies and creekbanks and occurs within dry sclerophyll forest and tall damp heath on sandstone.	-	-	Moderate – suitable habitat present within the development site and study area.
Pultenaea parviflora		E	V	✓	✓	✓	✓	HN566	Endemic to the Cumberland Plain. Core distribution is from Windsor to Penrith and east to Dean Park. May be locally abundant, particularly within scrubby/dry heath areas within Castlereagh Ironbark Forest and Shale Gravel Transition Forest on tertiary alluvium or laterised clays.	41	29/3/2017	Moderate – suitable habitat present within the development site and study area.

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Pultenaea sp. *Olinda*		E	-	-	-	-	✓	HN566	Grows in crevices between sandstone boulders with other shrubs. Has only been found in a very limited area of pagoda rock formation east of Rylstone. Likely to be fire sensitive, with recruitment occurring from a persistent soil stored seed bank following fire.	-	-	Moderate - Location and habitat suitable and in close enough proximity to known records to be possible.
Pultenaea villifera (Blue Mountains population)		E	-	-	-	-	✓	HN564 HN566	Grows on sandy soils favouring sheltered spots in dry sclerophyll forest and woodlands. Fire sensitive, with recruitment occurring from a persistent soil stored seed bank following fire.	-	-	Nil – development site does not occur within the Blue Mountains LGA.
Rhizanthella slateri	Eastern Australian Underground Orchid	V	E	-	-	✓	✓	-	Occurs from South-East QLD to South-Eastern NSW. In NSW it is currently known from only 10 locations which includes the Blue Mountains. Highly cryptic given that it grows almost completely below the soil surface, with the flowers being the only part of the plant that can occur above ground.	-	-	Low - Vegetation associated with this species are not present within the development site.
Rhodamnia rubescens	Scrub Turpentine	CE	-	✓	-	-	-	-	Shrub or small tree that occurs within littoral, warm temperate, and subtropical rainforest, and wet sclerophyll forest. The development site contains PCTs associated with the species.	3	21/2/2018	Moderate – suitable vegetation associations present within the development site.
Syzygium paniculatum	Magenta Lilly Pilly	E	V	-	✓	-	✓	HN604	Grows in subtropical and littoral rainforest on sandy soils or stabilized dunes near the sea. On the south coast the Magenta Lilly Pilly occurs on grey soils over sandstone, restricted mainly to remnant stands of littoral (coastal) rainforest.	-	-	Moderate.
Tetratheca glandulosa		V	-	✓	-	✓	✓	HN564 HN566 HN568 HN604	Strongly associated with areas of shale-sandstone transition habitat and occupies ridgetops, upper-slopes and mid-slope sandstone benches. Preferred vegetation includes heaths, scrub, woodlands/open woodlands and open forest.	1	23/5/2006	Moderate - suitable habitat in the development site and study area and within range.

Scientific name	Common name	BC Act	EPBC Act	Source				Associated BVT within site	Habitat and distribution	Records within 10 km	Most recent record	Likelihood of occurrence
				NSW Atlas	PMST	SEARs	BBCC					
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. However, it has also been recorded in heathland and moist forest.	-	-	Low – the development site and study area does not encompass LGAs known to contain this species.
Thelymitra kangaloonica	Kangaloon Sun Orchid	CE	CE	-	✓	-	-	-	Only known to occur on the southern tablelands of NSW in the Moss Vale/ Kangaloon/ Fitzroy Falls area at 550-700 m above sea level. It is known to occur at three swamps that are above the Kangaloon Aquifer. Found in swamps in sedge lands over grey silty grey loam soils.	-	-	Low – out of known range.
Thesium australe	Austral Toadflax	V	V	-	✓	✓		-	Suitable habitat for this species includes grassland and grassy woodland, often in damp sites.	-	-	Low - not known or predicted to occur in the development site or in study area based on OEH profile.
Velleia perfoliata		V	V	-	-	-	✓	HN564 HN566	Found in shallow depressions on Hawkesbury sandstone shelves, on rocky hill sides, under cliffs or on rocky/sandy soils along tracks and trails. Occurs on fairly shallow soils of sandy loam texture and can also be found growing on moss and lichen mats formed on rocks.	-	-	Moderate - suitable habitat on sandstone geology present.
Xanthosia scopulicola		V	-	-	-	-	-	-	Grows in cracks and crevices of sandstone cliff faces or on rocky outcrops above the cliffs.	-	-	Moderate - suitable habitat on sandstone geology present.
Zieria involucrata		E	V	-	-	✓	-	-	Occurs primarily on Hawkesbury sandstone however also occurs on Narrabeen Group sandstone. Found primarily in sheltered forests on mid to lower slopes and valleys.	-	-	Moderate - suitable habitat on sandstone geology present.
Zieria murphyi	Velvet Zieria	V	V	-	✓	✓	✓	HN566	Found in sheltered positions in moist gullies of wet eucalypt forest with sandy soil.	-	-	Low – moist forests not present within the development site and study area.

Appendix G Expert report: Red-crowned Toadlet

Member of the Surbana Jurong Group

Warragamba Dam Raising Construction Area

Expert report – Red-crowned Toadlet

Prepared for: Water for NSW
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This report must be read as a whole. The executive summary is not a substitute for this. Any subsequent report must be read in conjunction with this report.

The report supersedes all previous draft or interim reports, whether written or presented orally, before the date of this report. This report has not and will not be updated for events or transactions occurring after the date of the report or any other matters which might have a material effect on its contents or which come to light after the date of the report. SMEC is not obliged to inform you of any such event, transaction or matter nor to update the report for anything that occurs, or of which SMEC becomes aware, after the date of this report.

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Abbreviations and acronyms

Term	Definition
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
DOEE	Commonwealth Department of the Environment and Energy
DPIE	Department of Planning, Industry and Environment
EMP	Environmental Management Plan
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FBA	Framework for Biodiversity Assessment
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature
LGA	Local Government Authority
MNES	Matters of National Environmental Significance
OEH	Office of Environment and Heritage
PMST	Protected Matters Search Tool
TPZ	Technical Advisor
WNSW	Water for New South Wales

1. Introduction

1.1. Background

SMEC has been engaged by Water NSW to undertake and complete an assessment of the impacts of the proposed Warragamba Dam Raising project on threatened Biodiversity.

This expert report will assess the impacts that are predicted to occur as a result of the construction activities that are planned to take place in order to raise the wall of Warragamba Dam. This will Involve direct effects such as clearing of vegetation for roads and material lay-down areas as well as indirect effects including increased levels of dust and noise. These impacts are being assessed using the Framework for Biodiversity Assessment (FBA) as directed by the SEARs provided by OEH 30 June 2017 and reissued 13 March 2018.

1.2. Reasons for the Expert Report

An expert report may be prepared under section 6.6 of the FBA where it states:

> *Using expert reports instead of undertaking a survey*
>
> *6.6.2.1 An expert report may be obtained instead of undertaking a threatened species survey at a development site.*
>
> *6.6.2.2 An expert report must only be prepared by a person who is accredited by the Chief Executive of OEH under section 142B(1)(b) of the TSC Act, or a person who, in the opinion of the Chief Executive of OEH possesses specialised knowledge based on training, study or experience to provide an expert opinion in relation to the biodiversity values to which an expert report relates.*
>
> *6.6.2.3 The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report.*
>
> *6.6.2.4 An expert report can only be used instead of a survey for species to which species credits apply.*
>
> *6.6.2.5 An expert report must set out whether:*
>
> *(a) for development sites – the species is unlikely to be present on the development site – in this case no further assessment of the species is required, or*
>
> *(b) for all development sites – the species is likely to be present on the site – in this case the expert report must provide an estimate of the number of individuals or area of habitat to be impacted by the development or the management actions (according to the unit of measurement identified for the species in the Threatened Species Profile Database).*

An expert report may only be used for those threatened species and populations to which species credits apply, not for any threatened species to which ecosystems apply.

In this case, an expert report has been provided in relation to the Red-crowned Toadlet (*Pseudophryne australis)*, which is listed as vulnerable under the BC Act and is a species credit species. An expert report has been prepared due to the difficulty in meeting the survey requirements set out in the FBA. The area to be covered was too inaccessible, necessitating that an expert report be produced to consider the potential for this species to be present and extent of any possible occurrence.

1.3. Species Expert

Dr Francis Lemckert

Dr Lemckert is an Ecologist that has been undertaking studies into the ecology and management of frogs since 1986 and has been a principal ecological consultant since 2011. His skills include survey design/ implementation/ targeted species surveys, data handling, analysis and interpretation and the production of high level reports including papers published in international peer-reviewed journals and technical reports and recovery plans for the Commonwealth and NSW Governments. He has also been an expert witness in regards to considerations of the impacts of potentially illegal clearing for the Commonwealth, NSW and Local Governments (Hornsby Council) and provided expert advice to NSW DPI in regards to court considerations over the potential for forestry operations to impact on rock outcrop dependent species. At the broadest level Dr Lemckert represented Forests NSW (now Forestry Corporation NSW) as a reptile and amphibian expert in the Comprehensive Regional Assessments and Regional Forest Agreement Process carried out between 2000 and 2002 and as an expert in fauna management for negotiations over a new Threatened Species License for harvesting operations in 2014. He provided an expert review of the developed assessment process for impacts on Matters of National Environmental Significance for two proposed Coal Seam Gas Developments in Queensland and has completed two rounds of expert review of the status of Australia's amphibians for the IUCN.

Dr Lemckert is an acknowledged expert on eastern Australian frogs having completed his Master of Science degree and PhD on the ecology and management of frogs in this region and has published over 70 papers (or book chapters) in Australian and International peer-reviewed journals. He has been used by both the NSW and Commonwealth Governments as an expert witness in court cases assessing the impacts of land clearing on threatened frogs. He is member of the Amphibian Specialist Group of the IUCN, secretary of the NSW Declining Frog Working Group of NSW and past president of the Australian Society of Herpetologists. He has been the co-supervisor of two PhD students and a Master of Applied Science Student who completed theses addressing issues of frog conservation.

In regards to the Red-crowned Toadlet, Dr Lemckert can demonstrate his expertise through the following publications:

Hero, J-M., Morrison, C., Gillespie, G., Roberts, J.D., Newell, D., Meyer, E., McDonald, K., Lemckert, F., Mahony, M., Osborne, W., Hines, H., Richards, S., Hoskin, C., Clarke, J., Doak, N. & Shoo, L. 2006. Overview of the conservation status of Australian Frogs. Pacific Conservation Biology 12:313-320.

Hero, J-M, Richards, S, Alford, R., Allison, A., Bishop, P., Gunther, R., Iskandar, D., Kraus, F., Lemckert, F., Menzies, J., Roberts, D. & Tyler, M. 2008. Amphibians of the Australasian Realm. Pp 65-73 In: Threatened Amphibians of the World. S.N. Stuart, M. Hoffman, J.S., Chanson, N.A. Cox, R.J. Berridge, P.J. Ramani & B.E. Young (Eds.). Lynx Edicions, Barcelona, Spain.

Hero, J-M., Lemckert, F., Robertson, P., Cogger, H. & Littlejohn, M. 2004. *Pseudophryne australis*. The IUCN Red List of Threatened Species 2004: e.T18583A8486801. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T18583A8486801.en.

Hero, J-M., Lemckert, F., Roberston, P., Cogger, H. & Littlejohn, M. 2008. *Pseudophryne australis*. Pp 463 In: Threatened Amphibians of the World. S.N. Stuart, M. Hoffman, J.S., Chanson, N.A. Cox, R.J. Berridge, P.J. Ramani & B.E. Young (Eds). Lynx Edicions, Barcelona, Spain.

Lemckert, F.L. & Mahony, M.J. 2008. Core calling periods of the frogs of temperate New South Wales, Australia. Herpetological Conservation and Biology 3:71-76.

Lemckert, F.L. & Penman, T. 2012. Climate Change and Australia's frogs: how much do we need to worry? Pp 92-98 In: Wildlife and Climate Change: towards robust conservation strategies for Australian fauna. D. Lunney & P. Hutchings (Eds.). Royal Zoological Society of NSW, Mosman, NSW, Australia.

Penman, T. D. and Lemckert, F. L. 2010. Predicted impact of climate change on threatened amphibians. Unpublished report to the Department of the Environment, Climate Change and Water, Hurstville.

In addition, he can demonstrate his recognition as an expert in the species by:

- His contracting by Hornsby Shire Council as an expert witness in a court case regarding the impacts of a proposed housing development on this species.
- The provision of expert opinion on the habitat requirements, sub-population status and reservation requirements for the Red-crowned Toadlet during the NSW Government's Comprehensive Regional Assessment program completed in 2000-2001.
- The provision of expert opinion on the status of this species during assessments undertaken for the IUCN in 2001 and 2016.

Dr Lemckert full CV is provided as Appendix A.

2. Species Information

2.1. Life Cycle

The Red-crowned Toadlet (hereafter RCT) is relatively unusual for an Australian frog in that it can be heard calling during both the day and night and may be heard in any month of the year (Lemckert and Mahony 2008). Calling is likely to be most intense during the late afternoon and early evening and can be expected most often just after periods of rainfall, with the highest activity stated as occurring after thunderstorms in Summer.

The RCT is also relatively unusual for a frog in that females produces an average of 24 large eggs (that are deposited into the terrestrial nest excavated by the male (Anstis 2013). This nest site is located under leaf litter, rocks or in dense vegetation in locations where the calling site will be flooded by rainfall events. The male calls from within the nest to attract a female who deposits her eggs into the calling/nest chamber. These are fertilised by the male who continues to attend and call from the nest chamber and may ultimately tend to multiple clutches of eggs from different females that cover differing ages and developmental states. Females can also lay multiple clutches in a year and may potentially lay only partial clutches at any time, possibly as a bet-hedging strategy (Thumm and Mahony 2002). The females of most other species of *Pseudophryne* frogs lay over 100 eggs at a time, although all species in the genus have the strategy of laying eggs into terrestrial nests (Anstis 2013).

Development in the egg reaches Gosner Stages 26-32 (Anstis 2013) before hatching will take place, which is a significantly more advanced state than for most species of frogs that hatch no later than Gosner Stage 20-24 (Anstis 2013). If the nesting chamber has not already been flooded by the time the eggs are ready to hatch the embryos of the RCT will enter into a state of embryonic diapause where development ceases and they await the flooding of the egg chamber. This can result in several months of suspended development. Upon the flooding of the chamber the eggs hatch, if development is advanced enough, and the tadpoles swim into or are washed into pools where they complete their development. This generally takes a further 1-3 months before metamorphosis occurs (Anstis 2013), with development being faster in warmer months. This strategy is considered to have developed in response to the unpredictable and unseasonal rainfall pattern of the Sydney Basin that means that pools where development can take place are likely only flooded for short periods of time (Thumm and Mahony 2002). The hatching of more developed eggs minimises tadpole development time and the smaller clutches may also allow spreading out of egg laying and so increasing the chances of eggs being produced at a time when they can successfully complete development.

2.2. Distribution and Abundance

All available evidence indicates that the RCT is restricted to the Triassic Hawkesbury and Narrabeen Sandstones of the Sydney Geological Basin, being located in a 250 km arc bounded by Pokolbin in the north, Nowra in the south and Mt Victoria in the Blue Mountains (Cogger 2014). The extent of occurrence of the species is less than 20,000 km² (AmphibiaWeb 2018) and is shown in Figure 1.

Within this geographical range the RCT is widespread and can be locally widespread and relatively abundant. It can be found calling in colonies of 20-30 individuals, although half a dozen calling males is typical, and with colonies scattered broadly along breeding creek lines. It is not known to have suffered the major declines that many other species of Australian frogs went through in the 1980s and 1990s (Hero et al, 2006, 2008). There are no specific population estimates for this species, but it can reasonably be expected that its numbers remain in the millions and it does not appear to have suffered any clear declines from its historic range.

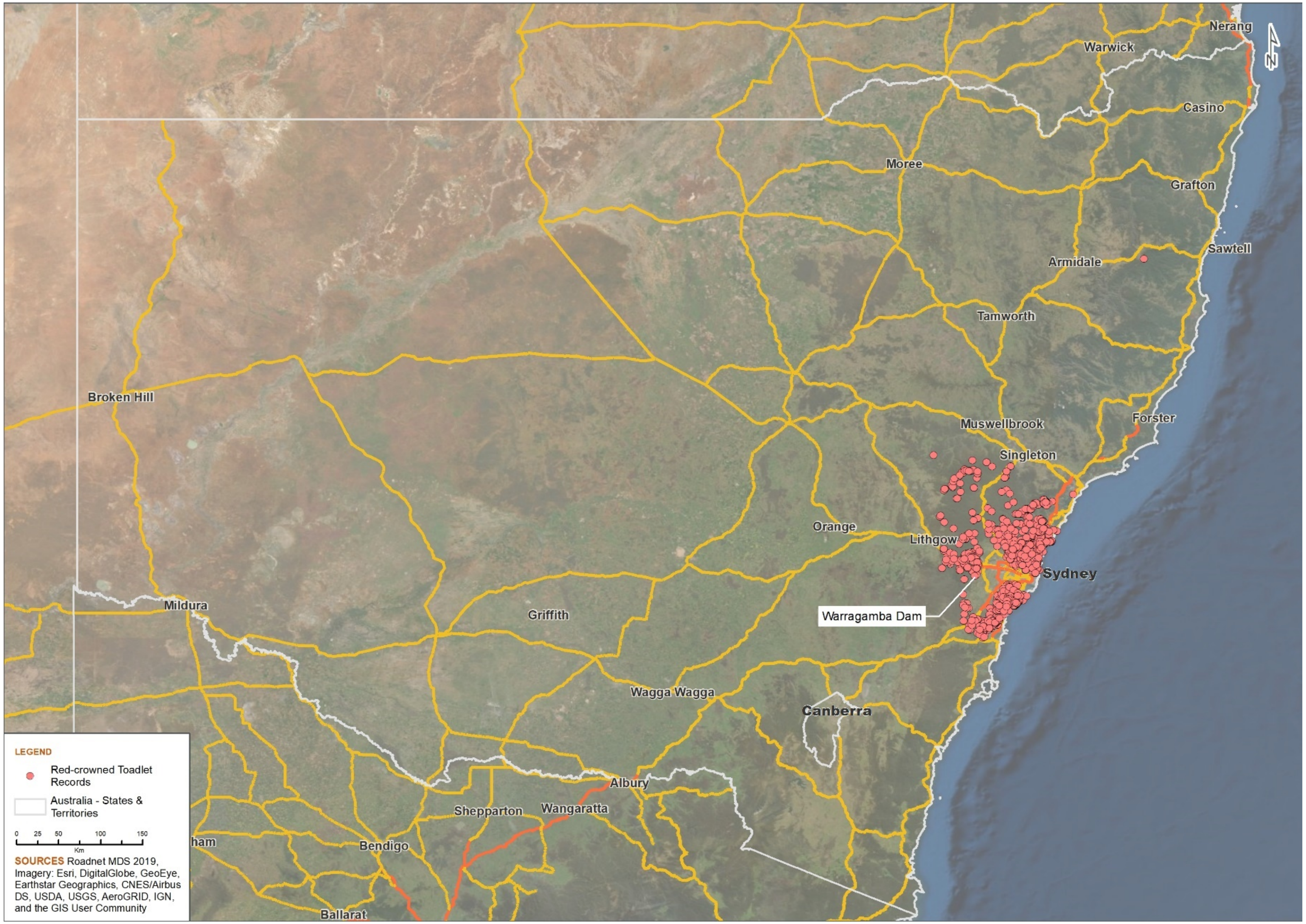

Figure 1. Distribution of the Red-crowned Toadlet in NSW

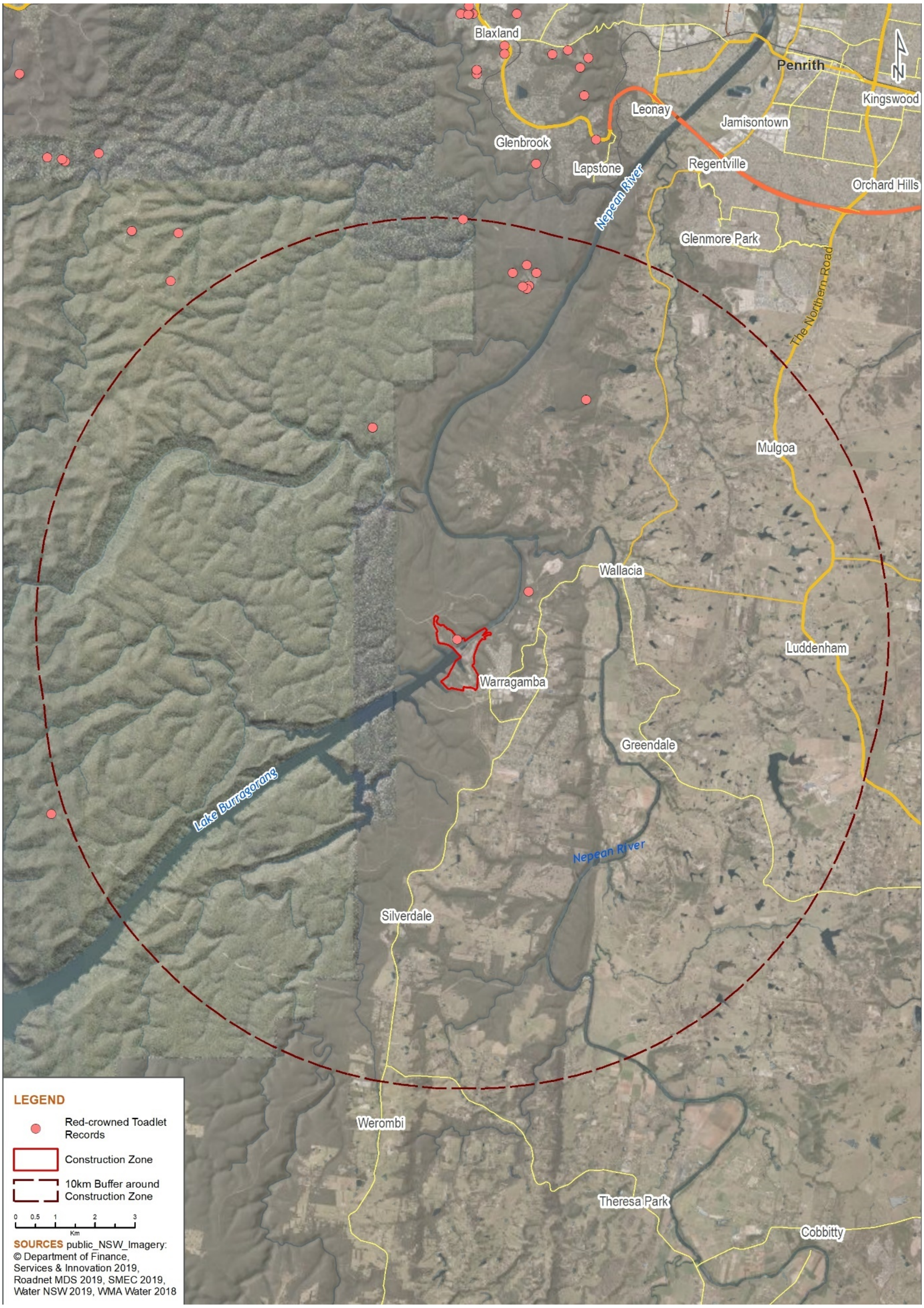

Figure 2. Location of records within 10 km of the study area

2.3. Ecology and Habitat Requirements

The RCT is restricted to living in areas associated with the Triassic Sandstones located around Sydney (Thumm and Mahony 1999). This environment is typified by steep escarpment areas and plateaus, as well as low undulating ranges and outcroppings. Within these geological formations, this species mainly occupies locations within about 100 metres of the ridgetop. Although they can also occur on top of the plateaus or more level rock platforms along the ridgetop, this area is usually less preferred than the first tallus slope areas below the upper escarpment or just below benched rock platforms.

Breeding habitat is first or second order ephemeral drainage lines commonly called 'feeder creeks' which drain the ridges, benches, cliffs and tallus slopes, and these often have shale lenses or cappings that may assist in pooling. These watercourses are often dry or reduced to ponded areas for much of the year and only sustain flow for short periods. The larger eggs with short tadpole periods is presumably a response to this lack of permanent water, allowing the species to breed successfully with limited water availability. Under natural conditions these feeder creeks have flows of high water quality and low nutrient loads and the waters are of a low pH.

During non-breeding times the RCT can remain associated with water courses such as moist soaks or areas of dense ground vegetation or leaf litter along or near head-water stream beds. However, they are recorded also to disperse from their breeding sites to forage and shelter. This includes under flat sandstone rocks ('bush-rock') either resting on bare rock or damp loamy soils, under logs on soil, beneath thick ground litter and in horizontal rock crevices near the ground.

The diet of this species has not been greatly studied, but the genus appears to eat small arthropods and has been known to eat large numbers of termites when they come to the surface.

2.4. BioMetric Vegetation Types

OEH list the RCT as being associated with the following vegetation formations and classes located within the Sydney Basin Interim Biogeographic Region:

Dry sclerophyll forests (shrub/grass sub-formation)

- Central Gorge Dry Sclerophyll Forests

Dry sclerophyll forests (shrubby sub-formation)

- South Coast Sands Dry Sclerophyll Forests
- South East Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Montane Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests
- Western Slopes Dry Sclerophyll Forests

Forested wetlands

- Eastern Riverine Forests

Freshwater wetlands

- Coastal Heath Swamps

Montane Bogs and Fens

Grassy woodlands

- Coastal Valley Grassy Woodlands

Heathlands

- Coastal Heathland Heaths

- Sydney Coastal Heaths
- Sydney Montane Heaths
- Wallum Sand Heaths

Miscellaneous ecosystems

- Rocky cliffs, major rock outcrops etc
- Water bodies, rivers, lakes, streams (not wetlands)

Rainforests

- Littoral Rainforests
- Northern Warm Temperate Rainforests

Wet sclerophyll forests (grassy sub-formation)

- Northern Hinterland Wet Sclerophyll Forests
- Southern Lowland Wet Sclerophyll Forests
- Southern Tableland Wet Sclerophyll Forests

Wet sclerophyll forests (shrubby sub-formation)

- North Coast Wet Sclerophyll Forests
- Southern Escarpment Wet Sclerophyll Forests

This diversity of associated vegetation formations indicates that vegetation present is broadly suitable for the RCT and the species has the potential to occur anywhere within the study area where suitable rock and stream habitat is present.

2.5. Status and Threats

The RCT is currently listed as vulnerable under BC Act and on the IUCN redlist, but is not listed under the EPBC Act.

The IUCN Redlist provides the following in regards to major threats to the RCT: "The entire population is centred around an area of intense human development. Intensified fire regimes, hydrological changes, and increased pollution levels (at edges and wherever human development encroaches into more core areas) are major threats, while the collection of rocks from its habitat, the spread of invasive weeds, and low recruitment rate (about 1% of each clutch survives to metamorphosis) pose additional threats".

OEH list the following as threats to this species:

- Clearing of habitat, particularly along ridges.
- Reduction in water quality flowing from ridges, particularly near urban areas.
- High frequency fire, resulting in changing vegetation structure and composition.
- Collection of bush rock.
- Disease (chytrid fungus).
- Climate change.
- Disturbance to breeding habitat by recreational activity (e.g. bikes, 4WD).
- Forest disturbance associated with forestry operations.

The RCTs specialised terrestrial reproductive strategy and reliance on ephemeral water flow indicates that it will be vulnerable to activities that impact on hydrology or water quality including influxes of town water that has a neutral pH.

Development adjacent or near RCT habitat should assess impacts of runoff, pollution and changes in pH. RCTs are sensitive to changes in pH outside of the range 5.5 to 6.5. RCTs have not been recorded breeding in sites that are even mildly polluted nor in permanently flowing watercourses (Thumm and Mahony 1999).

Most of this species' life is spent under some form of cover, such as rocks, deep leaf-litter, or in rock crevices. It is known that sandstone exfoliations or 'bushrocks' are particularly important to this species, so activities that impact on this microhabitat have the potential to affect this species. Similarly, their utilisation of the ground litter layer may result in them being significantly affected by fire and other activities that cause the destruction of the leaf litter layer.

RCTs are typically found as small colonies scattered along drainage lines or soaks that form the breeding sites. Due to this tendency for discrete populations to concentrate at particular sites, a relatively small localised disturbance may have a significant impact on a population if it occurs on a favoured breeding or refuge site.

The following threats are considered as potentially to occur as a result of the proposed action:

- Clearing of vegetation, particularly along ridges
- Edge effects
- Fragmentation
- Increased siltation
- Changed water flows
- Pollution resulting from runoff from areas with machinery
- Increased weed abundance and distribution
- Increased feral predator activity.

Climate change has been identified as a potentially very serious threat to the RCT based on extrapolations of its current climatic range with that available into the future under varying climate change scenarios (Lemckert and Penman 2012). This species is of particular concern because of its very small geographic range and adaptations to current east coast weather patterns and processes.

Figure 3. Construction footprint

3. Description of the Site

The footprint of the Warragamba Dam Raising development site is provided in Figure 2 and represents the subject site. The following information describing the subject site and its surrounds is taken directly from the Warragamba Dam Raising Construction Biodiversity Assessment Report (SMEC 2010), unless otherwise acknowledged.

3.1. IBRA bioregions and IBRA subregions

The construction study area is located in the Interim Biogeographical Regionalisation of Australia Bioregion of the Sydney Basin and there are two subregions which are relevant to the assessment.

3.1.1. Bioregions

The development site and outer assessment circle are wholly located within the Sydney Basin Bioregion.

Development site: Sydney Basin Bioregion

Outer assessment circle: Sydney Basin Bioregion

OEH provides the following information on the SYB Bioregion:

The Sydney Basin Bioregion lies on the central east coast of NSW and covers an area of approximately 3.6 million hectares, which is the equivalent of 4.5 percent of NSW. The SYB Bioregion is one of two bioregions contained wholly within the state. It consists of a geological basin filled with near horizontal sandstones and shales of Permian to Triassic age that overlie older basement rocks of the Lachlan Fold Belt. The sedimentary rocks have been subject to uplift with gentle folding and minor faulting during the formation of the Great Dividing Range. Erosion by coastal streams has created a landscape of deep, cliffed gorges and remnant plateaus across which an east-west rainfall gradient and differences in soil control the vegetation of eucalypt forests, woodlands and heaths. The Sydney Basin Bioregion includes coastal landscapes of cliffs, beaches and estuaries.

The frontal slope of the Blue Mountains (where the site is located) is formed along the Lapstone monocline. A secondary flexure and similar escarpments occur at the coast forming the Hornsby Plateau and the Illawarra Escarpment. These structural features combine with different rock types and strong trends in joint patterns to control drainage patterns and the distribution of gorges and swamps.

3.1.2. Subregions

The development site is located across two IBRA subregions:

1. Wollemi subregion
2. Burragorang subregion.

Development site: Burragorang (19.59 hectares) and Wollemi (85.26 hectares).

Outer assessment circle: Burragorang (250.08 hectares), Wollemi (708.56 hectares), and Cumberland (40.48).

The outer assessment circle falls within both the Wollemi and Burragorang subregions, as well as within Cumberland subregion. The Wollemi, Burragorang, and Cumberland subregions are described by Morgan (2001), with a summary of this description being provided in Table 1.

Table 1. Description of the subregions within Sydney Basin Bioregion occurring within the development site

SUBREGION	GEOLOGY	CHARACTERISTIC LANDFORMS	TYPICAL SOILS	VEGETATION
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. There are also a number of scattered volcanic necks distributed throughout the Wollemi subregion.	Characterised by the highest part of the Blue Mountains and other sandstone plateaus with benched rock outcrops.	Typically, soils are thin sands or deep yellow earths on plateaus, with thin texture contrast soils on shale benches. Organic sands in line swamps and joint crevices, while slope debris are found below cliffs, and sandy alluvium in pockets along the streams. On basalts, soils are red brown structured loams.	*Corymbia gummifera*, *Corymbia eximia*, *Angophora floribunda*, *Angophora costata*, *Eucalyptus sclerophylla*, and *Eucalyptus punctata* with diverse shrubs and heaths on plateau. Additionally, *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus agglomerata*, and *Syncarpia glomulifera* subsp. *glomulifera* and gully rainforests are present in gullies and canyon heads. *Eucalyptus vimilalis* and Blaxland's Stringybark on basalt. *Casuarina cunninghamiana* is found along main streams.
Burragorang	Comprised of Permian and Triassic sandstones and shales on the western edge of the Sydney Basin.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley	Typically, soils include rocky outcrops, texture contrast soils and uniform sands on sandstone. Cliff bases are generally pillowed with a sandy, clay matrix, alluviums contain rich loams.	Heath, shrubland and woodland with *Eucalyptus sieberi*, *Eucalyptus sclerophylla*, *Eucalyptus piperita* and *Corymbia gummifera* on sandstone similar to other parts of the Basin. *Eucalyptus deanei*, *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerata* immediately below escarpment passing to *Eucalyptus punctata*, *Eucalyptus crebra* and *Eucalyptus eugenoides* on rocky slopes. *Casuarina cunninghamiana* along main streams below the plateaus.
Cumberland	Triassic Wianamatta groups shales and sandstones, which are intruded by a small number of volcanic vents and partly covered by Tertiary river gravels and sands. There is quaternary alluvium along the mains streams.	Low rolling hills and wide valleys in a rain shadow area below the Blue Mountains. Volcanics from low hills in the shale landscapes. Swamps and lagoons on the floodplain of the Nepean River.	Typically, soils include a mixture of clays on volcanics, poor stony soils on older gravels, and high quality loams on floodplain alluvium.	*Eucalyptus moluccana, Eucalyptus tereticornis, Eucalyptus crebra* woodland with some *Corymbia macculata* on the shale hills. *Eucalyptus sclerophylla, Angophora floribunda*, and *Banksia serrata* on alluvial sands and gravels. *Angophora subvelutina, Eucalyptus amplifolia* and *Eucalyptus tereticornis* with abundant *Casuarina glauca* on river flats. Tall spike rush, and juncus with *Eucalyptus parramattensis* in lagoons and swamps.

3.2. NSW landscape regions (Mitchell Landscapes)

The development site is located across four landscape regions:

1. Kurrajong Fault Scarp
2. Lapstone Slopes
3. Burragorang Valley and Gorges
4. Nattai Plateau.

Development site: Kurrajong Fault Scarp (92.95 hectares); Lapstone Slopes (10.31 hectares); Burragorang Valley and Gorges (1.56 hectares); and Nattai Plateau (0.03 hectares)

Outer assessment circle: Kurrajong Fault Scarp (611.99 hectares); Lapstone Slopes (97.60 hectares); Burragorang Valley and Gorges (127.69 hectares); Silverdale Slopes (120.36 hectares); and Nattai Plateau (42.37 hectares)

Kurrajong Fault Scarp occurs over the majority of the development site (as measured by area) followed by Lapstone Slopes, Burragorang Valley and Gorges, and Nattai Plateau. Descriptions of each Mitchell Landscape are provided in Table 2.

Table 2. Description of the Mitchell Landscape

MITCHELL LANDSCAPE	DESCRIPTION
Kurrajong Fault Scarp	Dissected and broken slopes on Triassic Quartz sandstone and shale across the Lapstone monocline and Kurrajong fault scarp. Local dips on the sedimentary rocks up to 300 m, general elevation 100 to 250 m, local relief 100 m. Abundant rock outcrop with pockets of yellow-brown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of: *Eucalyptus agglomerata*, *Syncarpia glomulifera* subsp. *glomulifera*, Red *Corymbia gummifera*. *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus radiata*, *Eucalyptus punctata*, *Eucalyptus pilularis* and *Allocasuarina* sp. Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered *Eucalyptus tereticornis*, *Angophora floribunda* and *Eucalyptus globoidea* on the margins.
Lapstone Slopes	The frontal slope of the Blue Mountains formed by folding and faulting of Triassic quartz sandstone and shale with a veneer of Tertiary river gravels. A southern extension of the Kurrajong Fault Scarp landscape. Larger streams cut through the structural ridge in deep gorges, but smaller streams have accumulated organic sands in swamps and lagoons on the western side of the flexure. General elevation 50 to 300 m, local relief 180 m, steep dip slopes on the eastern face and benched faulted slopes on the west. Extensive rock outcrop, thin sandy soils with gravel and occasional white or yellow clay subsoils. Pockets of deep sand in some streams. *Corymbia gummifera*, *Corymbia eximia*, *Eucalyptus punctata*, *Allocasuarina torulosa*, *Eucalyptus sieberi*, *Eucalyptus radiata* with diverse shrubby understorey.

MITCHELL LANDSCAPE	DESCRIPTION
Burragorang Valley and Gorges	Deep steep sided benched slopes and gorge of the Wollondilly and Coxs Rivers incised into mostly horizontal Triassic quartz sandstone conglomerate, siltstone, and shale, cliffs to 150m high with waterfalls, general elevation 50 to 220 m, local relief 150 m. The gorge widens upstream and exposes underlying Permian chest, mudstones and conglomerate. Very extensive rock outcrop, thin yellow to yellow-brown silty sand and gravel with occasional white clay layers forming either shallow yellow earths or gleyed texture-contrast profiles. *Corymbia gummifera*, *Syncarpia glomulifera*, and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliffs upstream with *Eucalyptus tereticornis*, *Eucalyptus macrorhyncha*, *Eucalyptus crebra*, and *Eucalyptus mannifera*. Moist protected environments with *Eucalyptus saligna*, *Eucalyptus cypellocarpa*, *Eucalyptus muelleriana* and *Eucalyptus smithii*. Gallery forest of *Casuarina cunninghamiana* with *Eucalyptus deanei* and *Eucalyptus benthamii* along the main streams.
Nattai Plateau	Steeply dissected plateau remnants on lower Triassic lithic sandstone, shale and tuff, abundant rock outcrop and cliffs, steep debris slopes, general elevation 600 to 700 m, local relief 80 m. Shallow sand and occasional yellow texture-contrast soils. Forests of *Eucalyptus eugenioides*, *Eucalyptus fibrosa* subsp. *fibrosa*, *Callitris rhomboidea*, *Eucalyptus sieberi*, *Eucalyptus blaxlandii*, *Eucalyptus fastigata* and *Eucalyptus viminalis*.
Silverdale Slopes	Moderately undulating slopes descending to the east on gently dipping Triassic shales and sandstones. General elevation 230 to 630 m, local relief 200 m. Brown to yellow-brown texture-contrast soils. Woodland to forest with a shrubby understorey, common species; *Eucalyptus punctata*, *Eucalyptus albens*, *Eucalyptus paniculata*, *Eucalyptus crebra*, *Eucalyptus fibrosa*, *Eucalyptus moluccana*, *Allocasuarina torulosa*, *Eucalyptus eugenioides*, and occasional *Syncarpia glomulifera*.

3.3. Rivers and streams

The development site falls within the Warragamba catchment. Bordered on the west by the Great Dividing Range, the catchment stretches from north of Lithgow at the head of the Coxs River in the Blue Mountains, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River.

The proposed construction area includes areas of Lake Burragorang, the dam wall spillway and Warragamba River. Up until the dam wall, Lake Burragorang is considered to be a 9^{th} order stream in accordance with the Strahler stream ordering method. The current geomorphological condition at the dam is characterised by altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplains.

3.4. Wetlands

One wetland (Lake Burragorang) has been mapped within the construction study area within the NSW Wetland shapefile. No important or local wetlands occur within the development site or outer assessment circle. There are a number of smaller dams mapped to the east of the development site, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 km of the development site.

3.5. Native vegetation

The development site is centred around Warragamba Dam, which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, the vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation. Instead much of the development site is comprised of vegetation typical of ridgetops on skeletal soils. The majority of the development site supports dry sclerophyll forest of shrubby sub-formation, as well as an area of wet sclerophyll forest. To the west of Warragamba Dam, to both the north and south of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenoides*, *Eucalyptus sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest which extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest Critically Endangered Ecological Community.

The development site is 104.85 hectares in size. A total of 54.37 ha of native vegetation has been mapped within the site with Table 3 providing a summary of the PCTs mapped as occurring, including vegetation formation, percent cleared within the Hawkesbury-Nepean catchment and extent within the development site. All of this vegetation is suitable for the RCT to use as shelter and feeding habitat.

Table 3. Summary of PCTs occurring within the development site

PCT CODE/ BVT CODE	PCT NAME	VEGETATION FORMATION	VEGETATION CLASS	% CLEARED WITHIN HN CATCHMENT	AREA WITHIN SITE (HA)
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	40	16.96
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	25	24.78
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	20	8.69
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Wet Sclerophyll Forests (Grassy sub-formation)	Northern Hinterland Wet Sclerophyll Forests	90	4.94

3.6. Landform, geology and soils

The study area is approximate 104.85 hectares and is located at and adjacent to Warragamba Dam. The elevation within the study area is varied, ranging between 21 metres AHD at its lowest point to

195 metres AHD at its highest point. The study area slopes from the top of the gorge down to the dam and Warragamba River.

The Soil Landscapes of Penrith 1:100,000 soil landscape sheet has mapped four soil landscapes within the outer assessment circle as outlined in Table 4 below.

Table 4. Soil landscape description

NAME	LANDSCAPE	SOILS	LIMITATIONS
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 meters, slopes 10-15%. Rock outcrop 25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop with broken scarps.	Shallow to moderately deep (30-100 cm) yellow earths and earthy sands on crests and on insides of benches; shallow siliceous sands on leading edges of benches; localised gleyed podzolic soils and yellow podzolic soils on shale lenses; shallow to moderately deep (<100 cm) siliceous sands and leached sands along drainage lines.	Steep slopes, water erosion hazard, rock outcrop, localised rockfall hazard, localised non-cohesive soils, shallow highly permeable soil, very low soil fertility.
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces on Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop.	Shallow (<50 cm) earthy sands and yellow earths; some siliceous sands / lithosols associated with rock outcrop.	Shallow, highly permeable soil, localised non-cohesive soils, very low soil fertility, localised water erosion hazard, localised rick outcrop.
Hawkesbury	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200 m, slopes >25%. Rock outcrop >50%. Narrow crests and ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders.	Shallow (<30 cm) discontinuous lithosols / siliceous sands, associated with rock outcrop; earthy sands, yellow earths and some locally deep sands on inside of benches and along joins and fractures; localised yellow and red podzolic soils associated with shale lenses, siliceous sands and secondary yellow earths along drainage lines.	Steep slopes, mass movement hazard, rockfall hazard, water erosion hazard, shallow soils, rock outcrop, non-cohesive soils (localised), stony, highly permeable soils of low fertility.
Blacktown	Gently undulating rises on Wianamatta Group shales. Local relief to 30 m, slopes usually >5%. Broad rounded crests and ridges with gently inclined slopes.	Shallow to moderately deep (>100 cm) hardsetting mottled texture contrast soils, red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and drainage lines.	Localised seasonal waterlogging, localised water erosion hazard, moderately reactive highly plastic subsoil, localised surface movement potential.

3.7. Hydrology

Lake Burragorang is the dominant hydrological feature of the study area. Created by damming the Warragamba River and flooding the Burragorang Valley, Lake Burragorang is four times the size of Sydney Harbour and is currently managed as Sydney's water supply dam.

Downstream of the dam is the Warragamba River. Water is discharged into Warragamba River when the dam spills. Water is also released into the Warragamba River (downstream of the Warragamba Weir) to provide a secure water supply to the population of North Richmond. Warragamba River is a 9th order Strahler stream and there are several small, unnamed ephemeral tributaries within study area.

3.8. Land uses

The development footprint is located on land zoned as SP2 Infrastructure (Water Supply) under the *Wollondilly Local Environmental Plan (LEP) 2011* (Figure 4). This land around the dam serves as operational support for the existing dam and consists of cleared and vegetated areas, dam support facilities, access roads and parks. The proposed works would be permissible within this land zone type and construction activities would be contained within this zone.

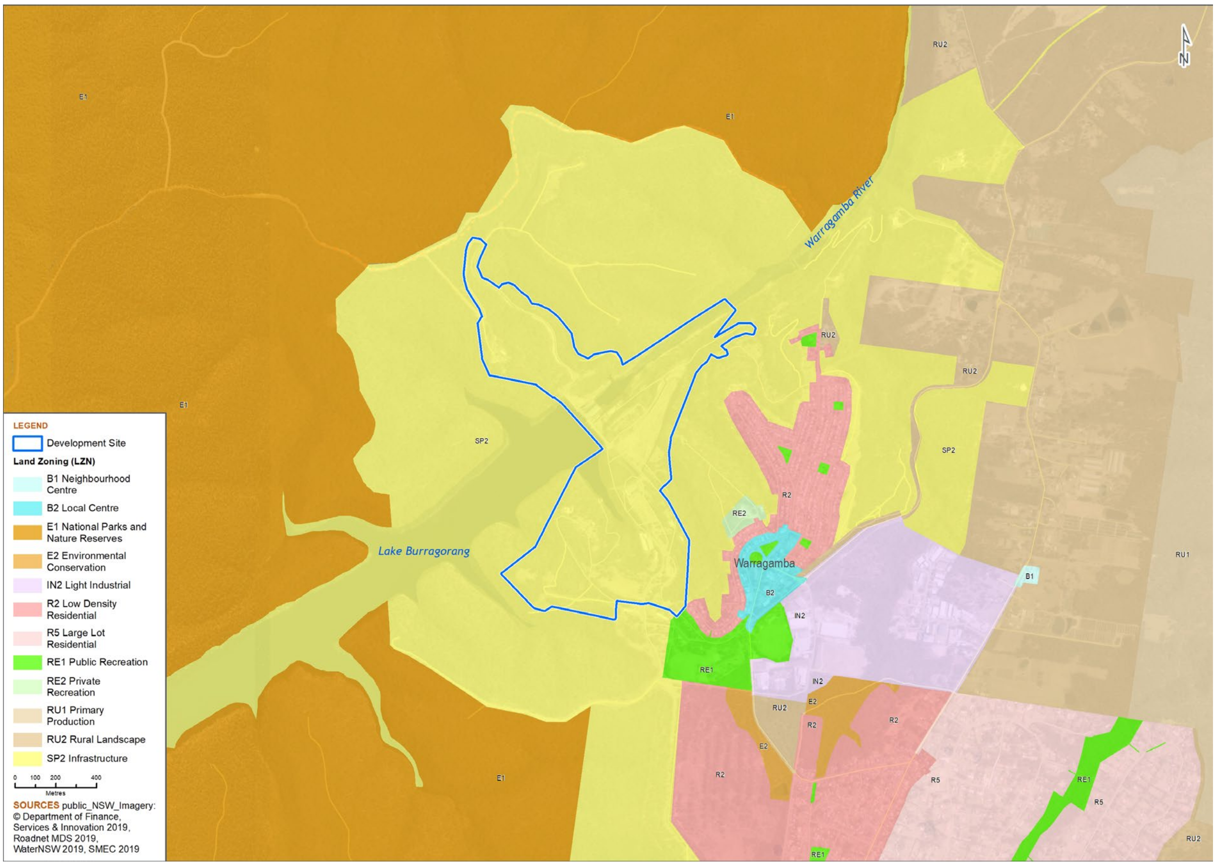

Figure 4. Land use zones

3.9. Habitat

The construction area (Figure 5) is comprised mainly of areas of sclerophyll woodland growing on the slopes of a steeply incised river valley. Rock outcrops are present broadly across the construction study area and there are several gully lines that hold ephemeral first or second order streams that occur on both sides of the main river valley and feed into it (Figure 6).

The vegetation present around the dam wall on the slopes of the valley is generally intact due to the prohibited access to the Warragamba Dam catchment. Hence the vegetation represents suitable habitat for the RCT and the water quality of the ephemeral creeks feeding into the Warragamba River and the dam itself should not have been affected by surrounding urbanisation.

The Warragamba River directly below the dam wall has a highly modified flow and exists only as a series of large pools and sometimes stagnant pools. This is a result of the outflow pipe being situated not on the other side of the wall, but instead approximately 1.7 km downstream of the wall. The vegetation lining the river up to the outflow pipe is a disturbed community with a significant presence of weeds.

Some vegetation has been historically cleared to provide infrastructure for the dam that includes the dam itself as well as the ancillary roads, buildings and areas for tourism (e.g., picnic areas) (Figure 5).

The study site retains full connectivity with large undisturbed tracts of wet/ mesic/ dry/ swamp sclerophyll forests that are retained in the catchment and the impacts of roads and the effects of rural land uses (i.e. managed midstorey) are minimal.

The site was surveyed for opportunistically surveyed for RCT as part of construction survey works (Figure 7) and visited and viewed by myself on the days of the 12th and 13th of December 2017.

Figure 5. Construction footprint

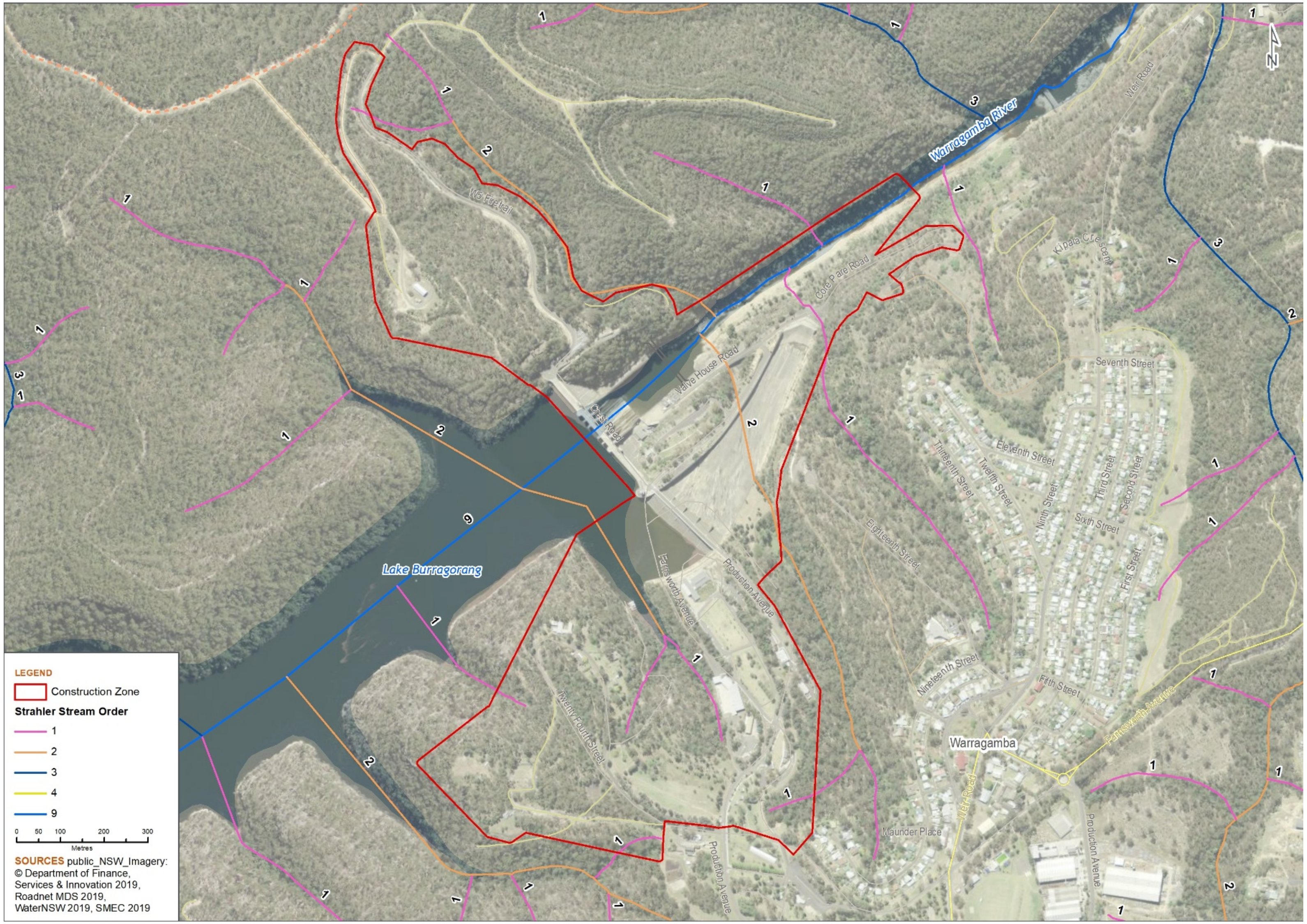

Figure 6. Stream order

Figure 7. Location of survey sites and records for the Red-crowned Toadlet within the study area

4. Expert Assessment and Conclusion

4.1.1. Local records

There are 15 Wildlife Atlas database records of the RCT within a 10 km radius of the site (Figure 2). One of these records one is located within the subject site (Figure 7). However, RCTs were heard calling within the construction area at a further two locations during surveys in this study (Figure 7).

4.1.2. Breeding Habitat

The RCT is reliant for breeding on ephemeral streams and drainage lines that flow only intermittently, but contain small pools (typically no larger than 2 m X 1 m) that remain flooded for several weeks after rain events. Site investigations found that the study area contained a number of 1st and 2nd order streams that are provide apparently suitable breeding habitat for this species (Figure 6) and the RCT was heard calling at one of these 1st order streams.

4.1.3. Shelter Habitat

The RCT shelters in a range of sites including deep leaf litter, under logs and rocks or within cracks within rock outcrops. All of this is available within the remaining areas of native vegetation present in the construction area with the exception of the disturbed vegetation lining the Warragamba River immediately below the dam wall.

4.1.4. Foraging Habitat

The RCT has no known specific dietary requirements that might limit its distribution across the landscape. Individuals are known to move away from the breeding water bodies into surrounding areas of rock outcrop and vegetation to undertake foraging. All areas of native vegetation remaining that is within 100 m of a suitable breeding should represent potential foraging habitat.

4.1.5. Total area of habitat impacted

The total area of RCT habitat impacted by the proposed construction footprint is 8.25 ha. This covers the mapped length of 1st and 2nd order streams located within the subject site as well as all areas of suitable native vegetation connected to and located within 100 m of identified suitable sections of streams (Figure 8). It is notable that both breeding and non-breeding elements must be available and connected to ensure that the RCT is able to persist within an environment.

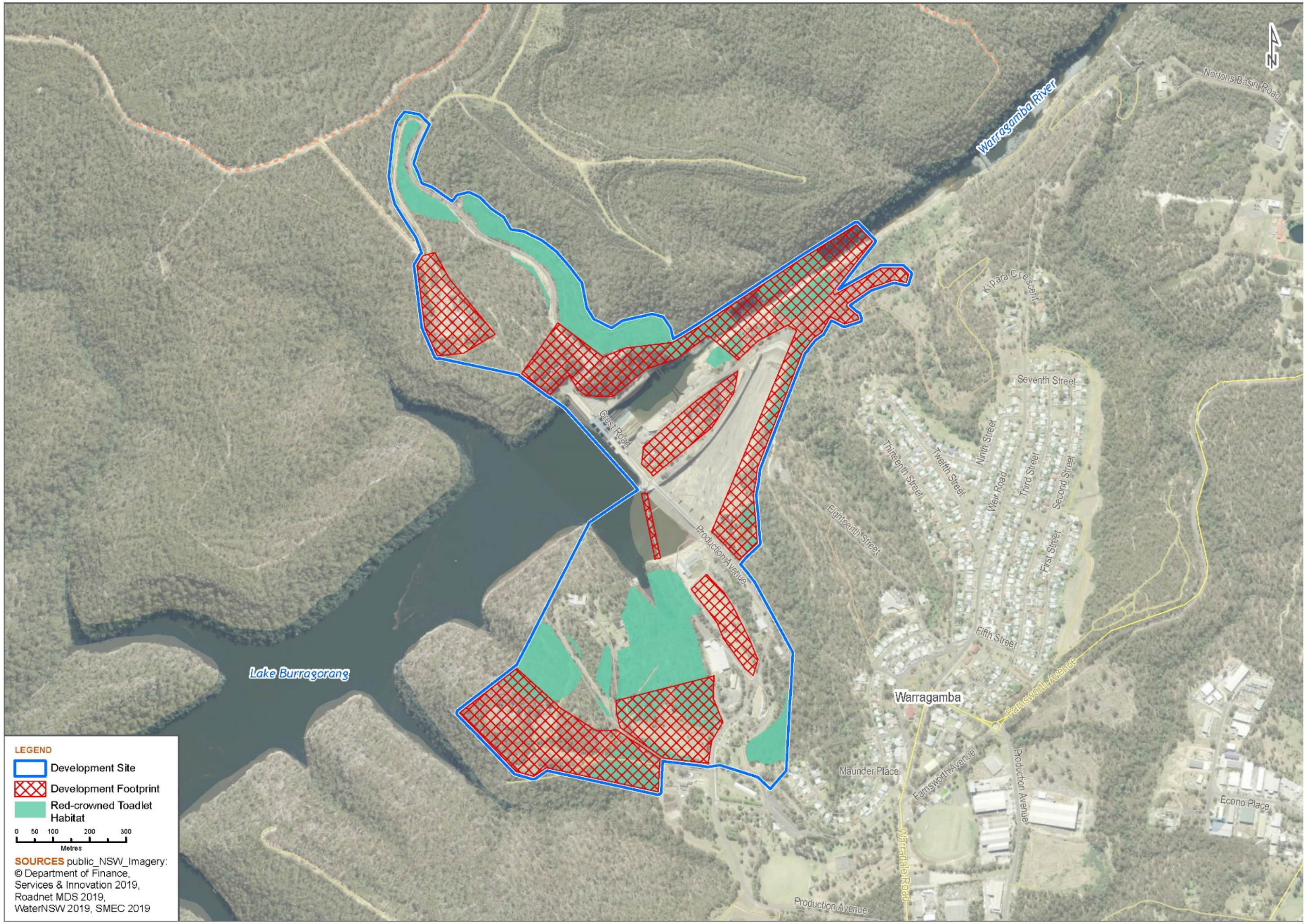

Figure 8. Area of Red-crowned Toadlet habitat impacted by the proposed works

5. Conclusion

The Red-crowned Toadlet is known to be present within the WDR construction study area and is assumed to be present on all areas of 1st and 2nd order streams located on Triassic sandstones that occur within this footprint. This is based on the following:

- The species has been recorded in the locality.
- The presence of suitable breeding stream habitat along with suitable adjacent vegetation and rock outcropping to provide foraging and shelter habitat.

The impacts of the proposed construction works will have a significant impact on the RCT by removing currently suitable habitat as this species is not known to be able to use areas without native vegetation and areas that are subject to significant disturbance. Any vegetation and streams permanently lost or altered as a result of the proposed works will also represent a permanent loss of habitat for the RCT. Areas subject to only temporary disturbance may eventually be recolonised, although the time taken for this to occur is unknown and dependent on the regeneration of the native vegetation and return of normal water quality.

A species polygon has been developed that covers the areas of available suitable breeding habitat and all suitable native vegetation that occurs within a 100 m radius that would form the area of potential breeding and shelter habitat for frogs. This polygon provides the extent of credits required to be retired for the RCT.

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4 Appendix A. CV – Dr. Frank Lemckert

Frank has been a professional scientist since 1992, specialising in understanding and managing the ecology and management of threatened species and particularly frogs. Frank has conducted ecological work throughout eastern Australia (NSW, Victoria, Queensland), establishing long-term research and monitoring programs into the management of fauna and developing strategies to mitigate the impacts of human disturbances. He has worked extensively with the NSW state and federal Governments on varying issues of fauna and flora management including the preparation of a draft NSW/National recovery plan for the Giant Burrowing Frog (*Heleioporus australiacus*) and is an accredited expert on the Green and Golden Bell Frog (*Litoria aurea*). Frank has prepared reports on endemism and representation in reserves of flora and fauna for the Commonwealth, represented the NSW Forestry Commission in license negotiations for the Comprehensive Regional Assessment process (2000) and provided expert ecological advice on illegal land clearing for the NSW and Commonwealth Governments. He has authored over 90 peer-reviewed publications. Frank is a research associate with the Australian Museum and University of Newcastle, convenor of the NSW Declining Frog Working Group and a member of the IUCN's Amphibian Specialist Group. He is a recognised expert in frog ecology and management, but has completed management related projects and works on a range of terrestrial vertebrate fauna.

Frank's primary role as a consultant has been to use his expertise and experience in technical writing and threatened species legislation to develop and maintain quality assurance in project reporting including:

- Two Species Impact Statements.
- >100 flora and fauna reports and assessments of significance using the EP&A Act and EPBC Act.
- Biodiversity Assessment Reports for Warragamba Dam Raising, Nowra Bridge, Golden Highway and Eurobodalla Dam.
- Manager for the Oxley Highway to Kempsey and Frederickton to Eungai ecological monitoring program.
- Construction and Environmental Management Plans, Monitoring Plans and Vegetation Management Plans for roads at Port Macquarie, Berry to Bomaderry and South Nowra.
- Nest Box, microbat and Green and Golden Bell Frog management plans for the Berry to Bomaderry and Oxley Highway to Kempsey Highway Upgrades.
- Review of monitoring strategies for the Woolgoolga to Ballina and Warrell Creek to Nambucca Heads programs for the Pacific Highway Upgrade.
- Review of two proposed Coal Seam Gas Impact Assessment methods for Matters of National Environmental Significance (contracted by the Commonwealth Government).
- Provision of species credit species expert reports for the Warragamba Dam raising project and Western Sydney Growth Centres Biocertification.

QUALIFICATIONS

- Bachelor of Science, University of Sydney, 1984 (Terrestrial Ecology and Marine Management)
- Master of Science, University of Sydney, 1991 (Population biology of the Common Froglet)
- PhD, University of Newcastle, 2009 (Management of forest frogs in timber production forests of NSW)

PROJECT EXPERIENCE

Ecological impact assessment

- Expert report on the green and golden bell frog for the western sydney growth areas biocertification project (2018-2019)
- Warragamba dam raising project target surveys, impact assessments, expert reporting (six species) and q/a for water nsw (2018-19)
- Shading impacts for proposed building works at homebush, nsw, piety pty ltd (2018)
- Granite hills windfarm bird and bat strike modelling and ecological impact assessment, nimmitabel, akuo energy (2018) and elysian windfarm, nimmitabel, akuo energy (2018)
- Vegetation removal and threatened frog management strategies, new intercity fleet management facility, john holland group (2018-19)
- Eurobodalla dam biodiversity assessment report, eurobodalla shire council (2017-18)
- Nowra bridge eis ecological assessments, nsw rms (2018)
- Heathcote road upgrade impact assessment and review of mitigation measures, nsw rms (2018-2019)
- Mona vale road threatened fauna expert survey and impact assessment, ecosure and nsw rms (2015-2016).

Government reviews/reports

- Biodiversity assessment method frog survey guidelines for species credit species (2019)
- Expert review of biodiversity impact assessment report for the hornsby quarry rehabilitation project (2019)
- Review of impact assessment pathways for two lpng projects, commonwealth government (2013)
- Expert advice on impacts of illegal land clearing at somersby, commonwealth government (2015)
- Expert advice on impacts of illegal land clearing at evans head, nsw state government (2016)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Review of monitoring strategies for the woolgoolga to ballina and warrell creek to nambucca heads programs for the pacific highway upgrade, nsw rms (2014)
- Hornsby council expert witness for development impacts at dural, hornsby shire council (2016)
- Expert representing forests nsw in the comprehensive reginal assessment program for the regional forest agreement program (1999-2001)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Flora and fauna representation in the australian reserve system, commonwealth government (2010)
- Flora and fauna endemism patterns across australia, commonwealth government (2009)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Expert review of fauna and flora impacts for 13 nsw forestry commission eis reports (1992-94).

EPBC referrals

- Green and golden bell frog (*litoria aurea*) referrals for the princes highway upgrade at south nowra, nsw rms
- Austen quarry (*eucalyptus pulverulenta*), hartley, hy-tec industries (2014-15)
- Marys mount koala (*phascolarctos cinereus*) referral, gunnedah quarry products (2015).

Monitoring programs

- Oxley highway to kempsey threatened biodiversity monitoring, nsw rms (2013-2017)
- Green and golden bell frog baseline monitoring program at meroo lakes, nsw oeh (2016-17)
- Fcnsw statewide ecological monitoring program, forestry corporation of nsw (2009-10)
- Threatened fauna monitoring hume highway, kapooka, nsw rms (2018).

Plans of management / strategies

- Commonwealth/nsw giant burrowing frog recovery plan, dewha/decc (2012)
- Eastern bentwing-bat management plan, gerringong, nsw rms (2014)
- Nestbox, microbat and green and golden bell frog management plans, berry to bomaderry upgrade of the princes highway, nsw rms (2017)
- Green and golden bell frog surveys and monitoring, princes highway upgrades at south nowra and berry to bomaderry, nsw rms (2012-2017)
- Green and golden bell frog management strategy, princes highway upgrade, nsw rms (2012-2014)
- Green and golden bell frog pre-clearing works kooragang island (daracon 2016 & current)
- Microbat management plan for clarencetown bridge, nsw rms (2016)
- Expert review of threatened frog management plan - woolgoolga to ballina upgrade, nsw rms (2014)
- Threatened microbat management plan for warringah mall, northern beaches council (2014)
- Threatened frog modelled habitat requirements, hornsby shire council (2016).

Training

- Lead instructor > 50 wildlife training schools run in nsw, act and victoria providing presentations on the survey, identification and management of all flora and fauna. This included detailed instruction on the management of threatened wading and aquatic birds and other aquatic species presented to queensland, victorian, nsw and commonwealth government staff (1993-2017)
- Private forestry survey requirements, victorian timber (2016).

Publications

Book Chapters

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Appendix H Expert Report: Giant Burrowing Frog

Member of the Surbana Jurong Group

Warragamba Dam Raising Construction Area

Expert report – Giant Burrowing Frog

Prepared for: Water for NSW

Reference No: 30012078

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SMEC Australia

This report is confidential and is provided solely for the purposes of providing an expert report to assess the expected distribution and abundance of the Giant Burrowing Frog in the area to be impacted by the construction works being completed to raise the wall of Warragamba Dam. This report is provided pursuant to a Consultancy Agreement between SMEC Australia Pty Limited ("SMEC") and Water NSW under which SMEC undertook to perform a specific and limited task for Water NSW. This report is strictly limited to the matters stated in it and subject to the various assumptions, qualifications and limitations in it and does not apply by implication to other matters. SMEC makes no representation that the scope, assumptions, qualifications and exclusions set out in this report will be suitable or sufficient for other purposes nor that the content of the report covers all matters which you may regard as material for your purposes.

This report must be read as a whole. The executive summary is not a substitute for this. Any subsequent report must be read in conjunction with this report.

The report supersedes all previous draft or interim reports, whether written or presented orally, before the date of this report. This report has not and will not be updated for events or transactions occurring after the date of the report or any other matters which might have a material effect on its contents or which come to light after the date of the report. SMEC is not obliged to inform you of any such event, transaction or matter nor to update the report for anything that occurs, or of which SMEC becomes aware, after the date of this report.

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Abbreviations and acronyms

Term	Definition
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
DOEE	Commonwealth Department of the Environment and Energy
DPIE	Department of Planning, Industry and Environment
EMP	Environmental Management Plan
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FBA	Framework for Biodiversity Assessment
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature
LGA	Local Government Authority
MNES	Matters of National Environmental Significance
OEH	Office of Environment and Heritage
PMST	Protected Matters Search Tool
TPZ	Technical Advisor
WNSW	Water for New South Wales

1. Introduction

1.1. Background

SMEC has been engaged by Water NSW to undertake and complete an assessment of the impacts of the proposed Warragamba Dam Raising project on threatened Biodiversity.

This expert report will assess the impacts that are predicted to occur as a result of the construction activities that are planned to take place in order to raise the wall of Warragamba Dam. This will Involve direct effects such as clearing of vegetation for roads and material lay-down areas as well as indirect effects including increased levels of dust and noise. These impacts are being assessed using the Framework for Biodiversity Assessment (FBA) as directed by the SEARs provided by OEH on 30 June 2017 and reissued 13 March 2018.

1.2. Reasons for the Expert Report

An expert report may be prepared under section 6.6 of the FBA where it states:

Using expert reports instead of undertaking a survey

6.6.2.1 An expert report may be obtained instead of undertaking a threatened species survey at a development site.

6.6.2.2 An expert report must only be prepared by a person who is accredited by the Chief Executive of OEH under section 142B(1)(b) of the TSC Act, or a person who, in the opinion of the Chief Executive of OEH possesses specialised knowledge based on training, study or experience to provide an expert opinion in relation to the biodiversity values to which an expert report relates.

6.6.2.3 The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report.

6.6.2.4 An expert report can only be used instead of a survey for species to which species credits apply.

6.6.2.5 An expert report must set out whether:

(a) for development sites – the species is unlikely to be present on the development site – in this case no further assessment of the species is required, or

(b) for all development sites – the species is likely to be present on the site – in this case the expert report must provide an estimate of the number of individuals or area of habitat to be impacted by the development or the management actions (according to the unit of measurement identified for the species in the Threatened Species Profile Database).

An expert report may only be used for those threatened species and populations to which species credits apply, not for any threatened species to which ecosystems apply.

In this case, an expert report has been provided in relation to the Giant Burrowing Frog (*Heleioporus australiacus)*, which is listed as vulnerable under the BC Act, and under the EPBC Act, and is a species credit species. An expert report has been prepared due to the difficulty in meeting the survey requirements set out in the FBA. The area to be covered was too inaccessible, especially during the necessary wet conditions for surveys, necessitating that an expert report be produced to consider the potential for this species to be present and extent of any possible occurrence.

1.3. Species Expert

Dr Francis Lemckert

Dr Lemckert is an Ecologist that has been undertaking studies into the ecology and management of frogs since 1986 and has been a principal ecological consultant since 2011. His skills include survey design/ implementation/ targeted species surveys, data handling, analysis and interpretation and the production of high level reports including papers published in international peer-reviewed journals and technical reports and recovery plans for the Commonwealth and NSW Governments. He has also been an expert witness in regards to considerations of the impacts of potentially illegal clearing for the Commonwealth, NSW and Local Governments (Hornsby Council) and provided expert advice to NSW DPI in regards to court considerations over the potential for forestry operations to impact on rock outcrop dependent species. Dr Lemckert represented Forests NSW (now Forestry Corporation NSW) as a reptile and amphibian expert in the Comprehensive Regional Assessments and Regional Forest Agreement Process carried out between 2000 and 2002 and as an expert in fauna management for negotiations over a new Threatened Species License for harvesting operations in 2014. He provided an expert review of the developed assessment process for impacts on Matters of National Environmental Significance for two proposed Coal Seam Gas Developments in Queensland and has completed two rounds of expert review of the status of Australia's amphibians for the IUCN.

Dr Lemckert is an acknowledged expert on eastern Australian frogs having completed his Master of Science degree and PhD on the ecology and management of frogs in this region and has published over 70 papers (or book chapters) in Australian and International peer-reviewed journals. He has been used by both the NSW and Commonwealth Governments as an expert witness in court cases assessing the impacts of land clearing on threatened frogs. He is member of the Amphibian Specialist Group of the IUCN, secretary of the NSW Declining Frog Working Group of NSW and past president of the Australian Society of Herpetologists. He has been the co-supervisor of two PhD students and a Master of Applied Science Student who completed theses addressing issues of frog conservation.

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Dr Lemckert has also undertaken the following actions as a result of his recognised expertise in this species:

- Contracted to provide expert advice to the Commonwealth Department of the Environment and Energy in regards to the impacts of suspected illegal clearing on the Giant Burrowing Frog at Somersby on the Central Coast of NSW.
- Contracted by OEH to prepare and co-author a NSW and National Recovery Plan for the Giant Burrowing Frog. The draft recovery plan was completed in 2009 and submitted to the Commonwealth, but has never been published as a result of the decision of NSW OEH to cease the publication of recovery plans.
- Provided expert opinion on the habitat requirements, sub-population status and reservation requirements for the Giant Burrowing Frog during the NSW Government's Comprehensive Regional Assessment program completed in 2000-2001.

Dr Lemckert full CV is provided as Appendix A.

2. Species Information

Breeding activity is associated with 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 (Anstis 2013; Recsei 1997). It is also found in ephemeral to permanent artificial drainage ditches and culverts on roadsides (with a rock or sand/clay base) (Recsei 1997). Of most importance in any situation is the presence of a still water body with a relatively long hydroperiod to allow the tadpoles the time to reach metamorphosis that may include an over-wintering phase.

Calling has been recorded in most months of the year (Lemckert and Mahony 2008), however Penman et al. (2004) state that males are most commonly heard in late summer or autumn following heavy rains. Calling typically occurs from concealed locations, including partially flooded burrows or beneath dense vegetation, beside creeks and swampy ground (Anstis 2013; Gillespie 1990; Littlejohn & Martin 1967; Penman et al. 2004). However, the Giant Burrowing Frog has been recorded calling in more exposed locations (Lemckert, 2008).

Eggs are deposited as foamy egg masses in standing or flowing water, either concealed in vegetation or within burrows on the banks of water bodies (Daly 1996; Watson and Martin 1973). Tadpoles hatch from the foam mass and either move into the water body, or await flooding to allow them to do so, and metamorphosis occurs between 3 and 11 months after hatching (Daly 1996). The tadpoles reach a relatively large size (7-8 cm) and are rotund and slow moving (Anstis 2013; Watson & Martin 1973), reflecting adaptations to sites with little or no water flow. Tadpoles have been recorded in clear water with a pH 4.3–6.5 and with a temperature range of 8.5-26.5°C (Recsei 1997) and there are indications that the tadpoles are intolerant of neutral water conditions (Green et al. 1999).

2.1. Distribution

The Giant Burrowing Frog occurs on the coast and Great Dividing Range from Wollemi National Park, New South Wales (Penman et al. 2004), south to Walhalla in the central highlands of eastern Victoria (Littlejohn & Martin 1967). The species has been found from near sea level up to 1000 m and from the coast to uplands areas almost 100 km inland (Gillespie 1990; Rescei 1997).

The extent of occurrence of the species has been estimated to be approximately 80 000 km^2 (Gillespie & Hines 1999; Lemckert et al. 2004).

The Giant Burrowing Frog is currently listed as vulnerable under both the EPBC and BC Acts and also under the IUCN red list. The IUCN has classified this species as vulnerable because of “a population decline, estimated to be more than 30% over the last ten years, inferred from an observed decline in numbers, and from habitat destruction and degradation”.

The Giant Burrowing Frog may exist as two distinct subpopulations with a northern population located on the sandstone geology associated with the Sydney Basin and a southern population occurring from around Narooma through to eastern Victoria (Penman et al. 2005). There is some evidence suggesting a limited genetic divergence between the two groups. The population in the study area is part of the Sydney Basin group.

The records available from the study area are provided in Figure 1 and demonstrate that there are relatively few records for this species, possibly because of the lack of access. The available records are confined to areas of Gulguer Nature Reserve, Euroka clearing, Kangara Reserve, Castlereagh, Warrimoo, North Richmond, Grose River, Cattai, South Maroota, Berowra Valley National Park, Ku-ring-gai National Park, Brisbane Waters National Park, Nattai National Park, Royal National Park and Upper Nepean SCA.

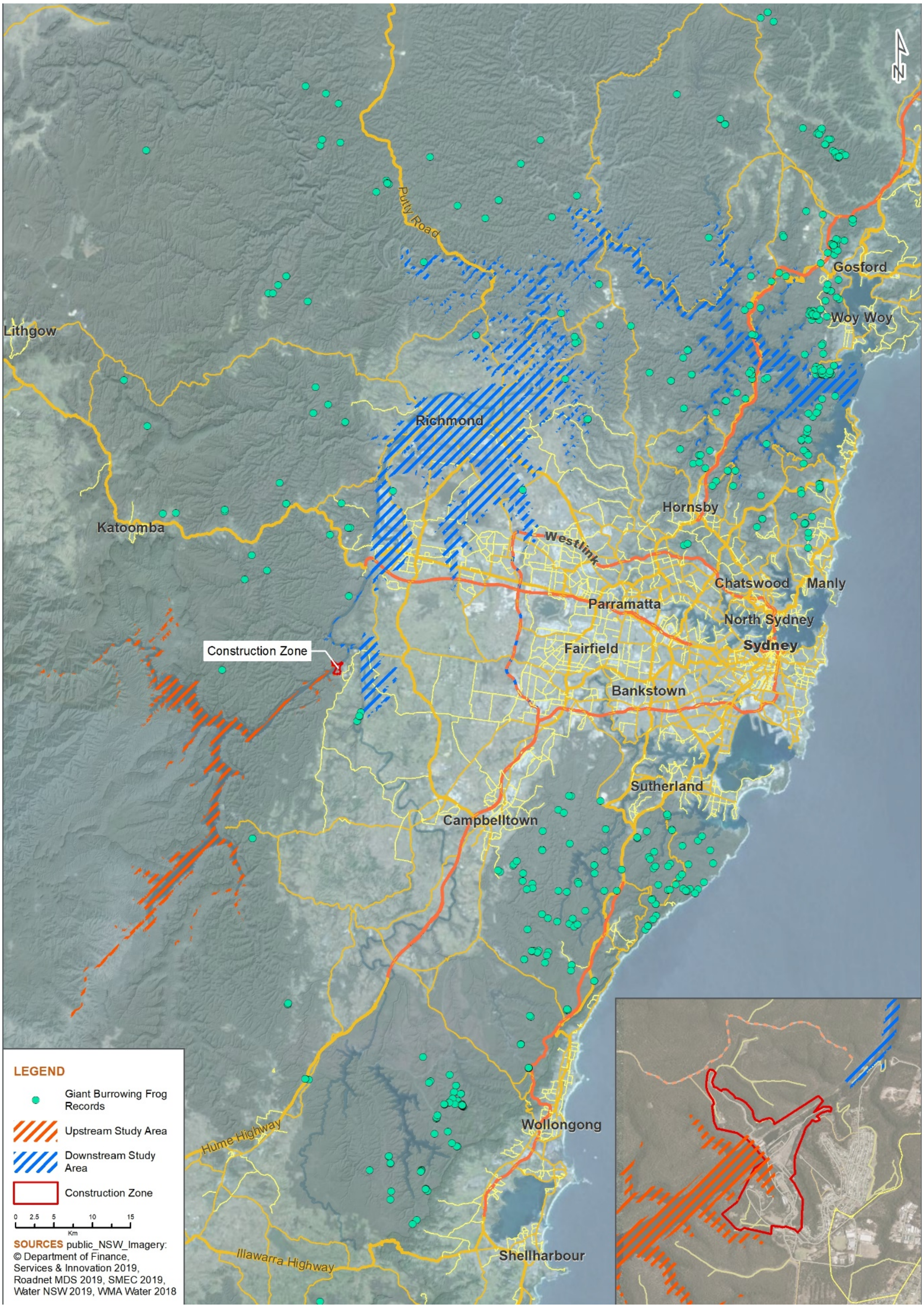

Figure 1. Location of Giant Burrowing Frog records in relation to the Warragamba Dam raising study area

2.2. Ecology and Habitat Requirements

Most records for this species occur in dry sclerophyll forests and reported use of wetter forest types and habitats are associated with the use of breeding sites (Penman et al. 2004). The NSW Department of Environment and Climate Change (NSW DECC 2005) suggests that this species is found in heath, woodland and open forest with sandy soils. In the area of the Sydney Basin the Giant Burrowing Frog is typically associated with areas of Hawkesbury Sandstone.

A BIOCLIM analysis suggests that the species is not climatically suited to large river valleys, most of which have been cleared for agriculture (Penman et al. 2005).

Of importance to note is that Giant Burrowing Frogs are not restricted to riparian area, with individuals being most commonly found on ridges away from breeding sites (Penman et al. 2004; Penman et al. 2007). Most radio-tracking locations in Yambulla and Olney State Forests were on the mid and upper slopes, more than 50 m from a stream, and up to 500 m from water (Lemckert & Brassil 2003), a finding mirrored in the study by Penman et al. (2006a). Observations from a radio-tracking studies indicate that daylight hours are nearly always spent below ground in unformed burrows, but occasionally under logs or fallen branches, in grass trees or sitting on the leaf litter (Lemckert & Brassil 2003; Penman et al. 2004). Most animals are active within discrete activity areas and migrate to breeding sites irregularly (Lemckert & Brassil 2003; Penman 2006a).

The Giant Burrowing Frog appears to be dependent on areas of retained native vegetation (Daly 1996; Gillespie 1990; Penman et al. 2004).

2.3. BioMetric Vegetation Types

In this Sydney Basin Region the Giant Burrowing Frog is listed to be associated with the following vegetation formations and classes:

Dry sclerophyll forests (shrub/grass sub-formation)

- Central Gorge Dry Sclerophyll Forests
- Cumberland Dry Sclerophyll Forests
- Southern Hinterland Dry Sclerophyll Forests

Dry sclerophyll forests (shrubby sub-formation)

- Coastal Dune Dry Sclerophyll Forests
- South Coast Wet Sclerophyll Forests
- South East Dry Sclerophyll Forests
- Southern Tableland Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Montane Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests
- Western Slopes Dry Sclerophyll Forests

Forested wetlands

- Coastal Floodplain Wetlands
- Coastal Swamp Forests
- Eastern Riverine Forests

Freshwater wetlands

- Coastal Freshwater Lagoons
- Coastal Heath Swamps

- Montane Bogs and Fens

Grassy woodlands

- Coastal Valley Grassy Woodlands
- Southern Tableland Grassy Woodlands
- Western Slopes Grassy Woodlands

Heathlands

- Coastal Headland Heaths
- South Coast Heaths
- Sydney Coastal Heaths
- Sydney Montane Heaths
- Wallum Sand Heaths

Miscellaneous ecosystems Water bodies, rivers, lakes, streams (not wetlands) Water bodies, rivers, lakes, streams (not wetlands)

Rainforests

- Dry Rainforests
- Littoral Rainforests
- Northern Warm Temperate Rainforests
- Southern Warm Temperate Rainforests

Wet sclerophyll forests (grassy sub-formation)

- Northern Hinterland Wet Sclerophyll Forests
- Southern Lowland Wet Sclerophyll Forests

Wet sclerophyll forests (shrubby sub-formation)

- North Coast Wet Sclerophyll Forests
- Southern Escarpment Wet Sclerophyll Forests.

2.4. Threats

Penman et al. (2004) indicate the following to be threats to the Giant Burrowing Frog: timber harvesting, cattle grazing, fuel reduction burning, introduced terrestrial and aquatic predators, high nutrient flows and pH changes in waterbodies, disturbances such as headwater erosion and habitat loss resulting from urbanisation (particularly in the northern part of the range), and clearing for agriculture (particularly in the southern part of the range). Road mortality may also represent a threat in some instances (Mahony 1993) and there is a potential for foxes and cats to be a threat to this species as frogs have been detected in the diet of these pest species (Gillespie & Hines 1999). This species does exude a sticky white secretion that may deter predators (F. Lemckert Pers. Obs.).

The chytrid fungus has been identified in Giant Burrowing Frogs collected from Springwood, NSW, (Speare & Berger 2000), which is located approximately 40 km from the study area. This highly virulent fungal pathogen of amphibians is capable at the minimum of causing sporadic deaths in some populations, and 100 per cent mortality in other populations and so is a serious concern. However, there is no indication yet of this disease having a major effect on the Giant Burrowing Frog.

Figure 2. Construction footprint

3. Description of the Site

The footprint of the Warragamba Dam Raising development site is provided in Figure 2 and represents the development site. The following information describing the development site and its surrounds is taken directly from the Warragamba Dam Raising Construction Biodiversity Assessment Report (SMEC 2010), unless otherwise acknowledged.

3.1. IBRA bioregions and IBRA subregions

The construction study area is located in the Interim Biogeographical Regionalisation of Australia (IBRA) Bioregion of the Sydney Basin and there are two subregions which are relevant to the assessment.

3.1.1. Bioregions

The development site and outer assessment circle are wholly located within the Sydney Basin (SYB) Bioregion (DoEE 2018).

Development site: Sydney Basin (SYB) Bioregion

Outer assessment circle: Sydney Basin (SYB) Bioregion

OEH provides the following information on the SYB Bioregion (OEH 2016):

The Sydney Basin Bioregion lies on the central east coast of NSW and covers an area of approximately 3.6 million hectares, which is the equivalent of 4.5 percent of NSW. The SYB Bioregion is one of two bioregions contained wholly within the state. It consists of a geological basin filled with near horizontal sandstones and shales of Permian to Triassic age that overlie older basement rocks of the Lachlan Fold Belt. The sedimentary rocks have been subject to uplift with gentle folding and minor faulting during the formation of the Great Dividing Range. Erosion by coastal streams has created a landscape of deep, cliffed gorges and remnant plateaus across which an east-west rainfall gradient and differences in soil control the vegetation of eucalypt forests, woodlands and heaths. The Sydney Basin Bioregion includes coastal landscapes of cliffs, beaches and estuaries.

The frontal slope of the Blue Mountains (where the site is located) is formed along the Lapstone monocline. A secondary flexure and similar escarpments occur at the coast forming the Hornsby Plateau and the Illawarra Escarpment. These structural features combine with different rock types and strong trends in joint patterns to control drainage patterns and the distribution of gorges and swamps.

3.1.2. Subregions

The development site is located across two IBRA subregions (DoEE 2018):

1. Wollemi subregion
2. Burragorang subregion.

Development site: Burragorang (19.59 hectares) and Wollemi (85.26 hectares).

Outer assessment circle: Burragorang (250.08 hectares), Wollemi (708.56 hectares), and Cumberland (40.48).

The outer assessment circle falls within both the Wollemi and Burragorang subregions, as well as within Cumberland subregion. The Wollemi, Burragorang, and Cumberland subregions are described by Morgan (2001), with a summary of this description being provided in Table 1.

Table 1. Description of the subregions within Sydney Basin Bioregion occurring within the development site

SUBREGION	GEOLOGY	CHARACTERISTIC LANDFORMS	TYPICAL SOILS	VEGETATION
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. There are also a number of scattered volcanic necks distributed throughout the Wollemi subregion.	Characterised by the highest part of the Blue Mountains and other sandstone plateaus with benched rock outcrops.	Typically, soils are thin sands or deep yellow earths on plateaus, with thin texture contrast soils on shale benches. Organic sands in line swamps and joint crevices, while slope debris are found below cliffs, and sandy alluvium in pockets along the streams. On basalts, soils are red brown structured loams.	*Corymbia gummifera*, *Corymbia eximia*, *Angophora floribunda*, *Angophora costata*, *Eucalyptus sclerophylla*, and *Eucalyptus punctata* with diverse shrubs and heaths on plateau. Additionally, *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus agglomerata*, and *Syncarpia glomulifera* subsp. *glomulifera* and gully rainforests are present in gullies and canyon heads. *Eucalyptus vimilalis* and Blaxland's Stringybark on basalt. *Casuarina cunninghamiana* is found along main streams.
Burragorang	Comprised of Permian and Triassic sandstones and shales on the western edge of the Sydney Basin.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley	Typically, soils include rocky outcrops, texture contrast soils and uniform sands on sandstone. Cliff bases are generally pillowed with a sandy, clay matrix, alluviums contain rich loams.	Heath, shrubland and woodland with *Eucalyptus sieberi*, *Eucalyptus sclerophylla*, *Eucalyptus piperita* and *Corymbia gummifera* on sandstone similar to other parts of the Basin. *Eucalyptus deanei*, *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerata* immediately below escarpment passing to *Eucalyptus punctata*, *Eucalyptus crebra* and *Eucalyptus eugenoides* on rocky slopes. *Casuarina cunninghamiana* along main streams below the plateaus.
Cumberland	Triassic Wianamatta groups shales and sandstones, which are intruded by a small number of volcanic vents and partly covered by Tertiary river gravels and sands. There is quaternary alluvium along the mains streams.	Low rolling hills and wide valleys in a rain shadow area below the Blue Mountains. Volcanics from low hills in the shale landscapes. Swamps and lagoons on the floodplain of the Nepean River.	Typically, soils include a mixture of clays on volcanics, poor stony soils on older gravels, and high quality loams on floodplain alluvium.	*Eucalyptus moluccana, Eucalyptus tereticornis, Eucalyptus crebra* woodland with some *Corymbia macculata* on the shale hills. *Eucalyptus sclerophylla, Angophora floribunda*, and *Banksia serrata* on alluvial sands and gravels. *Angophora subvelutina, Eucalyptus amplifolia* and *Eucalyptus tereticornis* with abundant *Casuarina glauca* on river flats. Tall spike rush, and juncus with *Eucalyptus parramattensis* in lagoons and swamps.

3.2. NSW landscape regions (Mitchell Landscapes)

The development site is located across four landscape regions:

3. Kurrajong Fault Scarp
4. Lapstone Slopes
5. Burragorang Valley and Gorges
6. Nattai Plateau.

Development site: Kurrajong Fault Scarp (92.95 hectares); Lapstone Slopes (10.31 hectares); Burragorang Valley and Gorges (1.56 hectares); and Nattai Plateau (0.03 hectares)

Outer assessment circle: Kurrajong Fault Scarp (611.99 hectares); Lapstone Slopes (97.60 hectares); Burragorang Valley and Gorges (127.69 hectares); Silverdale Slopes (120.36 hectares); and Nattai Plateau (42.37 hectares)

Kurrajong Fault Scarp occurs over the majority of the development site (as measured by area) followed by Lapstone Slopes, Burragorang Valley and Gorges, and Nattai Plateau. Descriptions of each Mitchell Landscape are provided in Table 2.

Table 2. Description of the Mitchell Landscape (DECC 2002)

MITCHELL LANDSCAPE	DESCRIPTION
Kurrajong Fault Scarp	Dissected and broken slopes on Triassic Quartz sandstone and shale across the Lapstone monocline and Kurrajong fault scarp. Local dips on the sedimentary rocks up to 300 m, general elevation 100 to 250 m, local relief 100 m. Abundant rock outcrop with pockets of yellow-brown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of: *Eucalyptus agglomerata*, *Syncarpia glomulifera* subsp. *glomulifera*, Red *Corymbia gummifera*. *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus radiata*, *Eucalyptus punctata*, *Eucalyptus pilularis* and *Allocasuarina* sp. Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered *Eucalyptus tereticornis*, *Angophora floribunda* and *Eucalyptus globoidea* on the margins.
Lapstone Slopes	The frontal slope of the Blue Mountains formed by folding and faulting of Triassic quartz sandstone and shale with a veneer of Tertiary river gravels. A southern extension of the Kurrajong Fault Scarp landscape. Larger streams cut through the structural ridge in deep gorges, but smaller streams have accumulated organic sands in swamps and lagoons on the western side of the flexure. General elevation 50 to 300 m, local relief 180 m, steep dip slopes on the eastern face and benched faulted slopes on the west. Extensive rock outcrop, thin sandy soils with gravel and occasional white or yellow clay subsoils. Pockets of deep sand in some streams. *Corymbia gummifera*, *Corymbia eximia*, *Eucalyptus punctata*, *Allocasuarina torulosa*, *Eucalyptus sieberi*, *Eucalyptus radiata* with diverse shrubby understorey.

MITCHELL LANDSCAPE	DESCRIPTION
Burragorang Valley and Gorges	Deep steep sided benched slopes and gorge of the Wollondilly and Coxs Rivers incised into mostly horizontal Triassic quartz sandstone conglomerate, siltstone, and shale, cliffs to 150m high with waterfalls, general elevation 50 to 220 m, local relief 150 m. The gorge widens upstream and exposes underlying Permian chest, mudstones and conglomerate. Very extensive rock outcrop, thin yellow to yellow-brown silty sand and gravel with occasional white clay layers forming either shallow yellow earths or gleyed texture-contrast profiles. *Corymbia gummifera*, *Syncarpia glomulifera*, and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliffs upstream with *Eucalyptus tereticornis*, *Eucalyptus macrorhyncha*, *Eucalyptus crebra*, and *Eucalyptus mannifera*. Moist protected environments with *Eucalyptus saligna*, *Eucalyptus cypellocarpa*, *Eucalyptus muelleriana* and *Eucalyptus smithii*. Gallery forest of *Casuarina cunninghamiana* with *Eucalyptus deanei* and *Eucalyptus benthamii* along the main streams.
Nattai Plateau	Steeply dissected plateau remnants on lower Triassic lithic sandstone, shale and tuff, abundant rock outcrop and cliffs, steep debris slopes, general elevation 600 to 700 m, local relief 80 m. Shallow sand and occasional yellow texture-contrast soils. Forests of *Eucalyptus eugenioides*, *Eucalyptus fibrosa* subsp. *fibrosa*, *Callitris rhomboidea*, *Eucalyptus sieberi*, *Eucalyptus blaxlandii*, *Eucalyptus fastigata* and *Eucalyptus viminalis*.
Silverdale Slopes	Moderately undulating slopes descending to the east on gently dipping Triassic shales and sandstones. General elevation 230 to 630m, local relief 200m. Brown to yellow-brown texture-contrast soils. Woodland to forest with a shrubby understorey, common species; *Eucalyptus punctata*, *Eucalyptus albens*, *Eucalyptus paniculata*, *Eucalyptus crebra*, *Eucalyptus fibrosa*, *Eucalyptus moluccana*, *Allocasuarina torulosa*, *Eucalyptus eugenioides*, and occasional *Syncarpia glomulifera*.

3.3. Rivers and streams

The development site falls within the Warragamba catchment. Bordered on the west by the Great Dividing Range, the catchment stretches from north of Lithgow at the head of the Coxs River in the Blue Mountains, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River (WaterNSW 2018).

The proposed construction area includes areas of Lake Burragorang, the dam wall spillway and Warragamba River. Up until the dam wall, Lake Burragorang is considered to be a 9th order stream in accordance with the Strahler stream ordering method. The current geomorphological condition at the dam is characterised by altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplains (BMT 2018).

The Project would impact upon all of the riparian buffers within the development site.

3.4. Wetlands

One wetland (Lake Burragorang) has been mapped within the construction study area within the NSW Wetland shapefile (OEH 2010). No important or local wetlands occur within the development site or outer assessment circle. There are a number of smaller dams mapped to the east of the development site, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 kilometres of the development site.

3.5. Native vegetation

The development site is centred around Warragamba Dam, which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, the vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation. Instead much of the development site is comprised of vegetation typical of ridgetops on skeletal soils. The majority of the development site supports dry sclerophyll forest of shrubby sub-formation, as well as an area of wet sclerophyll forest. To the west of Warragamba Dam, to both the north and south of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenoides*, *Eucalyptus sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest which extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest Critically Endangered Ecological Community (CEEC).

The development site is 104.85 hectares in size. A total of 54.37 ha of native vegetation has been mapped within the site with Table 3 providing a summary of the PCTs mapped as occurring, including vegetation formation, percent cleared within the Hawkesbury-Nepean catchment and extent within the development site. A all of this vegetation is suitable for the Giant Burrowing Frog to use as shelter and feeding habitat.

Table 3. Summary of PCTs occurring within the development site

PCT CODE/ BVT CODE	PCT NAME	VEGETATION FORMATION	VEGETATION CLASS	% CLEARED WITHIN HN CATCHMENT	AREA WITHIN SITE (HA)
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	40	16.96
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	25	24.78
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	20	8.69
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Wet Sclerophyll Forests (Grassy sub-formation)	Northern Hinterland Wet Sclerophyll Forests	90	4.94

3.6. Landform, geology and soils

The study area is approximate 104.85 hectares and is located at and adjacent to Warragamba Dam. The elevation within the study area is varied, ranging between 21 metres AHD at its lowest point to

195 metres AHD at its highest point. The study area slopes from the top of the gorge down to the dam and Warragamba River.

The Soil Landscapes of Penrith 1:100,000 soil landscape sheet has mapped four soil landscapes within the outer assessment circle as outlined in Table 4 below.

Table 4. Soil landscape description (source: OEH 2018)

NAME	LANDSCAPE	SOILS	LIMITATIONS
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 meters, slopes 10-15%. Rock outcrop 25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop with broken scarps.	Shallow to moderately deep (30-100 cm) yellow earths and earthy sands on crests and on insides of benches; shallow siliceous sands on leading edges of benches; localised gleyed podzolic soils and yellow podzolic soils on shale lenses; shallow to moderately deep (<100 cm) siliceous sands and leached sands along drainage lines.	Steep slopes, water erosion hazard, rock outcrop, localised rockfall hazard, localised non-cohesive soils, shallow highly permeable soil, very low soil fertility.
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces on Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop.	Shallow (<50 cm) earthy sands and yellow earths; some siliceous sands / lithosols associated with rock outcrop.	Shallow, highly permeable soil, localised non-cohesive soils, very low soil fertility, localised water erosion hazard, localised rick outcrop.
Hawkesbury	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200 m, slopes >25%. Rock outcrop >50%. Narrow crests and ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders.	Shallow (<30 cm) discontinuous lithosols / siliceous sands, associated with rock outcrop; earthy sands, yellow earths and some locally deep sands on inside of benches and along joins and fractures; localised yellow and red podzolic soils associated with shale lenses, siliceous sands and secondary yellow earths along drainage lines.	Steep slopes, mass movement hazard, rockfall hazard, water erosion hazard, shallow soils, rock outcrop, non-cohesive soils (localised), stony, highly permeable soils of low fertility.
Blacktown	Gently undulating rises on Wianamatta Group shales. Local relief to 30 m, slopes usually >5%. Broad rounded crests and ridges with gently inclined slopes.	Shallow to moderately deep (>100 cm) hardsetting mottled texture contrast soils, red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and drainage lines.	Localised seasonal waterlogging, localised water erosion hazard, moderately reactive highly plastic subsoil, localised surface movement potential.

3.7. Hydrology

Lake Burragorang is the dominant hydrological feature of the study area. Created by damming the Warragamba River and flooding the Burragorang Valley, Lake Burragorang is four times the size of Sydney Harbour and is currently managed as Sydney's water supply dam (WaterNSW 2015a).

Downstream of the dam is the Warragamba River. Water is discharged into Warragamba River when the dam spills. Water is also released into the Warragamba River (downstream of the Warragamba Weir) to provide a secure water supply to the population of North Richmond. Warragamba River is a 9th order Strahler stream and there are several small, unnamed ephemeral tributaries within study area.

3.8. Land uses

The development footprint is located on land zoned as SP2 Infrastructure (Water Supply) under the *Wollondilly Local Environmental Plan (LEP) 2011* (Figure 3). This land around the dam serves as operational support for the existing dam and consists of cleared and vegetated areas, dam support facilities, access roads and parks. The proposed works would be permissible within this land zone type and construction activities would be contained within this zone.

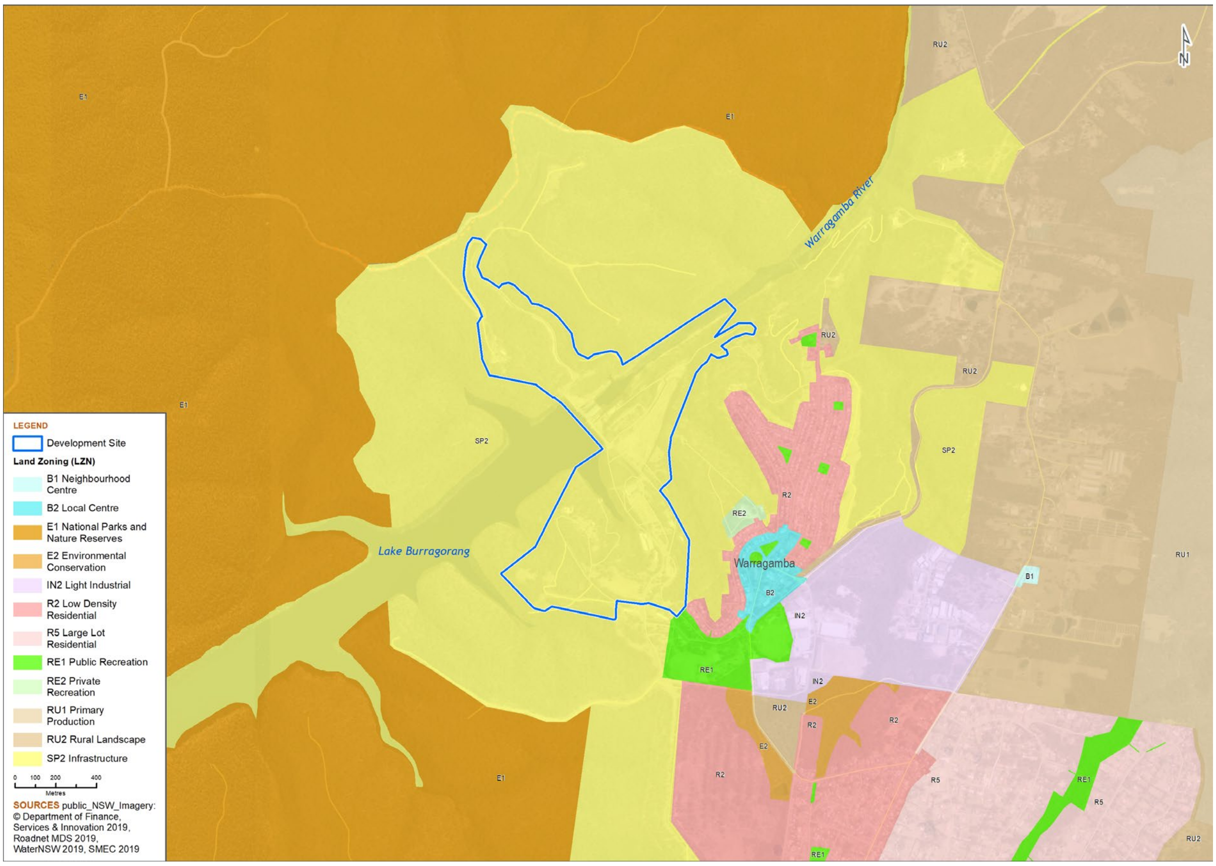

Figure 3. Land use zones

3.9. Habitat present for the Giant Burrowing Frog

The construction area is comprised mainly of areas of sclerophyll woodland growing on the slopes of a steeply incised river valley. Rock outcrops are present broadly across the construction study area and there are several gully lines that hold ephemeral water courses that occur on both sides of the main river valley and feed into it at the level of the dam or the Warragamba River.

The vegetation present around the dam wall on the slopes of the valley is generally intact due to the prohibited access to the Warragamba Dam catchment. The vegetation represents suitable habitat for the Giant Burrowing Frog and the water quality of the ephemeral creeks feeding into the Warragamba River and the dam itself should not have been affected by surrounding urbanisation.

The Warragamba River directly below the dam wall has a highly modified flow and exists only as a series of large pools and sometimes stagnant pools. This is a result of the outflow pipe being situated not on the other side of the wall but instead approximately 1.7 km downstream of the wall. The vegetation lining the river up to the outflow pipe is a disturbed community with a significant presence of weeds.

Some vegetation has been historically cleared to provide infrastructure for the dam that includes the dam itself as well as the ancillary roads, buildings and areas for tourism (e.g., picnic areas) (Figure 3).

The site retains full connectivity with large undisturbed tracts of sclerophyll forests that are retained in the catchment and the impacts of roads and the effects of rural land uses (i.e. managed midstorey) are minimal.

The site was viewed by myself on the days of the 12th and 13th of December 2017.

4. Expert Assessment of Impacts

4.1. Impacts to the environment

A total of 22.51 ha of native vegetation will be directly cleared through the construction process. Indirect impacts may result in further loss of native vegetation. The combined direct and indirect impacts areas will lead to fragmentation through the creation of discontinuities of the extent of vegetation communities

4.2. Local records

There are 5 Wildlife Atlas database records of the Giant Burrowing Frog within a 10 km radius of the site (Figure 1). However, none of these occur within the construction site and the closest more than 5 km away.

4.3. Breeding Habitat

The Giant Burrowing Frog is reliant for breeding on ephemerally flowing streams that contain near-permanent pools at least occasionally along the creek bed. I have seen and know of pools as small as 1 m in diameter and larger than 4 m X 10 m in size being consistently used by this species as breeding sires. Such streams appear to be used as they lack typical fish predators, but contain bodies of water that can generally last long enough to allow the tadpoles of this species to reach metamorphosis (this can take nearly a year).

Investigations of the construction area indicate that any of the ephemeral streams feeding into the Warragamba Dam around the wall or the Warragamba River immediately downstream of the dam wall provide suitable habitat where they reach a second or third Strahler order level, having been fed by multiple first order streams. These are all on sandstone and should maintain a suitable pH and provide flows and pools suited to the Giant Burrowing Frog. Any stream area impacted by construction works would represent an expected impact on this species. These sections of streams have been mapped in Figure 4.

Impacts on 1st order streams would not directly impact on the Giant Burrowing Frog, but it would be necessary to show through hydrological studies that the hydrology of the downstream 2nd and 3rd order streams is not being significantly impacted.

The Dam and Warragamba River and not suitable breeding habitat as they provide permanent aquatic habitats with fish, which the Giant Burrowing Frog does not breed in.

4.4. Shelter Habitat

The Giant Burrowing Frog shelters mainly by burrowing into loose sandy soils, usually just below the soil surface, but digging deeper in dryer weather. It has also been recorded to occasionally shelter under logs or fallen vegetation. Shelter sites are located up to 300 m away from the breeding site and individuals move regularly through a defined activity area when not breeding. This area may be exclusive of other Giant Burrowing Frog. The species is not known to seek shelter within areas cleared of native vegetation or that are significantly impacted by weeds.

All of the remaining areas of intact native vegetation located within 300 m of suitable breeding habitat has been determined to represent suitable non-breeding shelter habitat and a polygon covering all suitable areas of habitat is provided in Figure 5. The disturbed vegetation lining the Warragamba River immediately below the dam wall has been excluded from the polygon as it is considered that this area would not be used by the Giant Burrowing Frog.

4.5. Foraging Habitat

The Giant Burrowing Frog has no specific dietary requirements that might limit its distribution across the landscape and it is assumed that this species is foraging in the same area as it the sheltering habitat. Hence the polygon mapped as sheltering habitat in Figure 4 also covers the essential foraging habitat for the Giant Burrowing Frog.

4.6. Total area of habitat impacted

The total area of Giant Burrowing Frog habitat impacted by the proposed construction footprint is 3.66 ha. This covers the mapped length of 2nd and 3rd order ephemerally flowing streams located within the development site as well as all areas of native vegetation connected to and located within 300 m of identified suitable sections of streams (Figure 4).

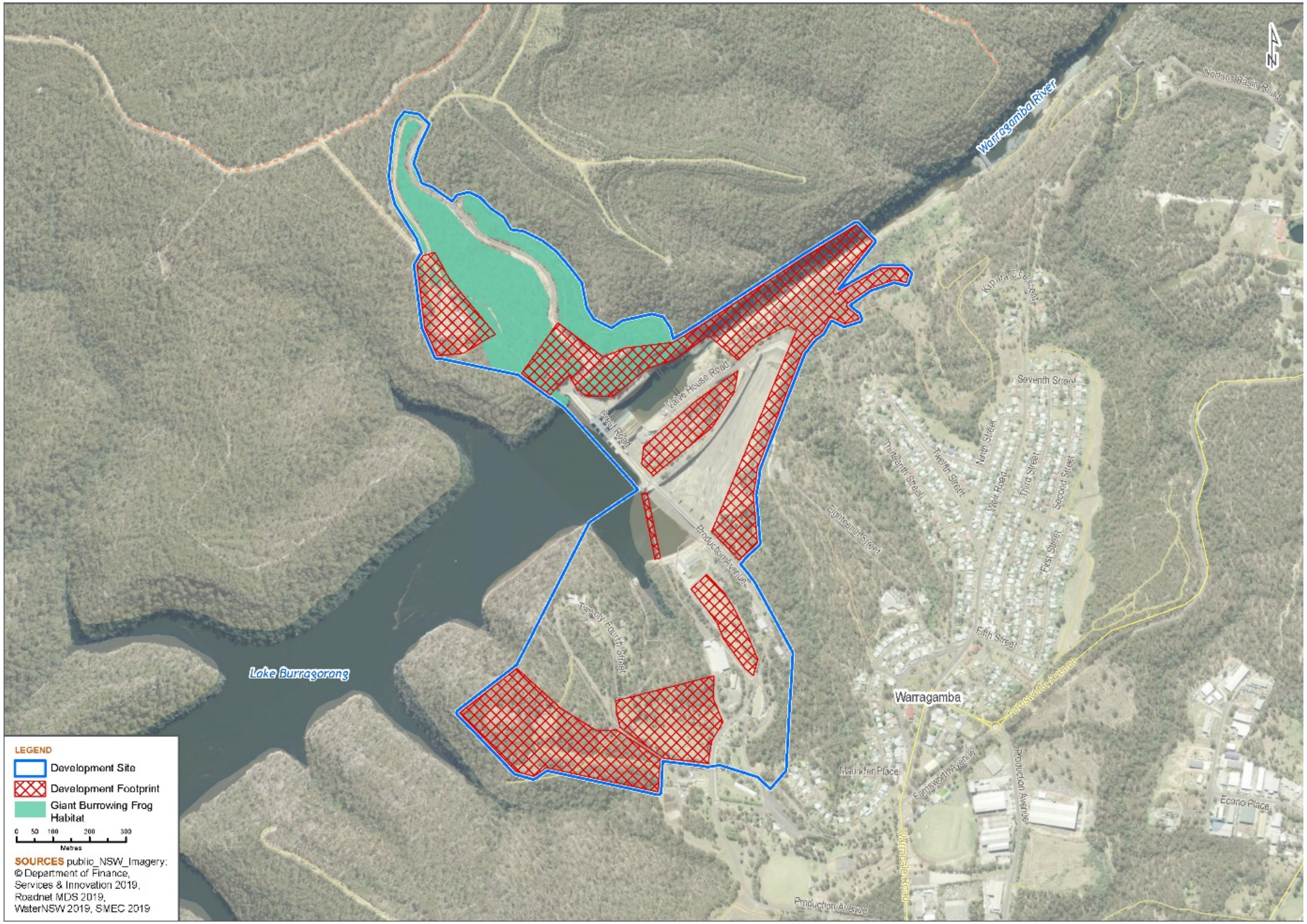

Figure 4. Area of Giant Burrowing Frog habitat impacted by the proposed works

5. Conclusion

The Giant Burrowing Frog is not known to be present within the WDR construction study area, but surveys have not been able to be carried out effectively to determine the presence or absence of the species. Ephemeral flowing streams on sandstone located within intact native woodlands that this species is known to inhabit are present and constitute the preferred habitat of this species. Hence, as a precaution, it has been assumed that the Giant Burrowing Frog would be present where suitable breeding habitat is present on Triassic sandstones.

The impacts of the proposed construction works can be expected to have a significant impact on the Giant Burrowing Frog within the development site as this species is not known to be able to use areas without native vegetation and areas that are subject to significant disturbance. Any vegetation and suitable area of breeding habitat permanently lost or altered as a result of the proposed works will represent a permanent loss of habitat for the Giant Burrowing Frog. Areas subject to only temporary disturbance may eventually be recolonised, although the time taken for this to occur is unknown and dependent on the regeneration of the native vegetation and return of normal water quality.

A species polygon has been developed that covers the areas of available suitable breeding habitat and all suitable native vegetation that occurs within a 300 m radius that would form the area of potential breeding and shelter habitat for frogs. This polygon provides the extent of credits required to be retired for the Giant Burrowing Frog.

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7. Appendix A. CV – Frank Lemckert

Frank has been a professional scientist since 1992, specialising in understanding and managing the ecology and management of threatened species and particularly frogs. Frank has conducted ecological work throughout eastern Australia (NSW, Victoria, Queensland), establishing long-term research and monitoring programs into the management of fauna and developing strategies to mitigate the impacts of human disturbances. He has worked extensively with the NSW state and federal Governments on varying issues of fauna and flora management including the preparation of a draft NSW/National recovery plan for the Giant Burrowing Frog (*Heleioporus australiacus*) and is an accredited expert on the Green and Golden Bell Frog (*Litoria aurea*). Frank has prepared reports on endemism and representation in reserves of flora and fauna for the Commonwealth, represented the NSW Forestry Commission in license negotiations for the Comprehensive Regional Assessment process (2000) and provided expert ecological advice on illegal land clearing for the NSW and Commonwealth Governments. He has authored over 90 peer-reviewed publications. Frank is a research associate with the Australian Museum and University of Newcastle, convenor of the NSW Declining Frog Working Group and a member of the IUCN's Amphibian Specialist Group. He is a recognised expert in frog ecology and management, but has completed management related projects and works on a range of terrestrial vertebrate fauna.

Frank's primary role as a consultant has been to use his expertise and experience in technical writing and threatened species legislation to develop and maintain quality assurance in project reporting including:

- Two Species Impact Statements.
- >100 flora and fauna reports and assessments of significance using the EP&A Act and EPBC Act.
- Biodiversity Assessment Reports for Warragamba Dam Raising, Nowra Bridge, Golden Highway and Eurobodalla Dam.
- Manager for the Oxley Highway to Kempsey and Frederickton to Eungai ecological monitoring program.
- Construction and Environmental Management Plans, Monitoring Plans and Vegetation Management Plans for roads at Port Macquarie, Berry to Bomaderry and South Nowra.
- Nest Box, microbat and Green and Golden Bell Frog management plans for the Berry to Bomaderry and Oxley Highway to Kempsey Highway Upgrades.
- Review of monitoring strategies for the Woolgoolga to Ballina and Warrell Creek to Nambucca Heads programs for the Pacific Highway Upgrade.
- Review of two proposed Coal Seam Gas Impact Assessment methods for Matters of National Environmental Significance (contracted by the Commonwealth Government).
- Provision of species credit species expert reports for the Warragamba Dam raising project and Western Sydney Growth Centres Biocertification.

QUALIFICATIONS

- Bachelor of Science, University of Sydney, 1984 (Terrestrial Ecology and Marine Management)
- Master of Science, University of Sydney, 1991 (Population biology of the Common Froglet)
- PhD, University of Newcastle, 2009 (Management of forest frogs in timber production forests of NSW)

PROJECT EXPERIENCE

Ecological impact assessment

- Expert report on the green and golden bell frog for the western sydney growth areas biocertification project (2018-2019)
- Warragamba dam raising project target surveys, impact assessments, expert reporting (six species) and q/a for water nsw (2018-19)
- Shading impacts for proposed building works at homebush, nsw, piety pty ltd (2018)
- Granite hills windfarm bird and bat strike modelling and ecological impact assessment, nimmitabel, akuo energy (2018) and elysian windfarm, nimmitabel, akuo energy (2018)
- Vegetation removal and threatened frog management strategies, new intercity fleet management facility, john holland group (2018-19)
- Eurobodalla dam biodiversity assessment report, eurobodalla shire council (2017-18)
- Nowra bridge eis ecological assessments, nsw rms (2018)
- Heathcote road upgrade impact assessment and review of mitigation measures, nsw rms (2018-2019)
- Mona vale road threatened fauna expert survey and impact assessment, ecosure and nsw rms (2015-2016).

Government reviews/reports

- Biodiversity assessment method frog survey guidelines for species credit species (2019)
- Expert review of biodiversity impact assessment report for the hornsby quarry rehabilitation project (2019)
- Review of impact assessment pathways for two lpng projects, commonwealth government (2013)
- Expert advice on impacts of illegal land clearing at somersby, commonwealth government (2015)
- Expert advice on impacts of illegal land clearing at evans head, nsw state government (2016)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Review of monitoring strategies for the woolgoolga to ballina and warrell creek to nambucca heads programs for the pacific highway upgrade, nsw rms (2014)
- Hornsby council expert witness for development impacts at dural, hornsby shire council (2016)
- Expert representing forests nsw in the comprehensive reginal assessment program for the regional forest agreement program (1999-2001)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Flora and fauna representation in the australian reserve system, commonwealth government (2010)
- Flora and fauna endemism patterns across australia, commonwealth government (2009)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Expert review of fauna and flora impacts for 13 nsw forestry commission eis reports (1992-94).

EPBC referrals

- Green and golden bell frog (*litoria aurea*) referrals for the princes highway upgrade at south nowra, nsw rms
- Austen quarry (*eucalyptus pulverulenta*), hartley, hy-tec industries (2014-15)
- Marys mount koala (*phascolarctos cinereus*) referral, gunnedah quarry products (2015).

Monitoring programs

- Oxley highway to kempsey threatened biodiversity monitoring, nsw rms (2013-2017)
- Green and golden bell frog baseline monitoring program at meroo lakes, nsw oeh (2016-17)
- Fcnsw statewide ecological monitoring program, forestry corporation of nsw (2009-10)
- Threatened fauna monitoring hume highway, kapooka, nsw rms (2018).

Plans of management / strategies

- Commonwealth/nsw giant burrowing frog recovery plan, dewha/decc (2012)
- Eastern bentwing-bat management plan, gerringong, nsw rms (2014)
- Nestbox, microbat and green and golden bell frog management plans, berry to bomaderry upgrade of the princes highway, nsw rms (2017)
- Green and golden bell frog surveys and monitoring, princes highway upgrades at south nowra and berry to bomaderry, nsw rms (2012-2017)
- Green and golden bell frog management strategy, princes highway upgrade, nsw rms (2012-2014)
- Green and golden bell frog pre-clearing works kooragang island (daracon 2016 & current)
- Microbat management plan for clarencetown bridge, nsw rms (2016)
- Expert review of threatened frog management plan - woolgoolga to ballina upgrade, nsw rms (2014)
- Threatened microbat management plan for warringah mall, northern beaches council (2014)
- Threatened frog modelled habitat requirements, hornsby shire council (2016).
-
- Lead instructor > 50 wildlife training schools run in nsw, act and victoria providing presentations on the survey, identification and management of all flora and fauna. This included detailed instruction on the management of threatened wading and aquatic birds and other aquatic species presented to queensland, victorian, nsw and commonwealth government staff (1993-2017)
- Private forestry survey requirements, victorian timber (2016).

Publications

Book Chapters

Hecnar S. J., & Lemckert, F.L. 2012. Habitat Protection: Refuges and Reserves. Pp 3636-3675 In Biology of the Amphibia Volume 10 - Conservation and Decline of Amphibians: Ecology, Effects of Humans, and Management. H. Heatwole (Ed.). Surrey-Beatty and Sons, Sydney.

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Appendix I Expert Report: Green and Golden Bell Frog

Warragamba Dam Raising Construction Area

Expert report – Green and Golden Bell Frog

Prepared for: Water for NSW
Reference No: 30012078
12/09/2019

Document/Report Control Form

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Revision #	Date	Prepared by	Reviewed by	Approved for Issue by
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This report is confidential and is provided solely for the purposes of providing an expert report to assess the expected distribution and abundance of the Green and Golden Bell Frog in the area to be impacted by the construction works being completed to raise the wall of Warragamba Dam. This report is provided pursuant to a Consultancy Agreement between SMEC Australia Pty Limited ("SMEC") and Water NSW under which SMEC undertook to perform a specific and limited task for Water NSW. This report is strictly limited to the matters stated in it and subject to the various assumptions, qualifications and limitations in it and does not apply by implication to other matters. SMEC makes no representation that the scope, assumptions, qualifications and exclusions set out in this report will be suitable or sufficient for other purposes nor that the content of the report covers all matters which you may regard as material for your purposes.

This report must be read as a whole. The executive summary is not a substitute for this. Any subsequent report must be read in conjunction with this report.

The report supersedes all previous draft or interim reports, whether written or presented orally, before the date of this report. This report has not and will not be updated for events or transactions occurring after the date of the report or any other matters which might have a material effect on its contents or which come to light after the date of the report. SMEC is not obliged to inform you of any such event, transaction or matter nor to update the report for anything that occurs, or of which SMEC becomes aware, after the date of this report.

Unless expressly agreed otherwise in writing, SMEC does not accept a duty of care or any other legal responsibility whatsoever in relation to this report, or any related enquiries, advice or other work, nor does SMEC make any representation in connection with this report, to any person other than Water NSW. Any other person who receives a draft or a copy of this report (or any part of it) or discusses it (or any part of it) or any related matter with SMEC, does so on the basis that he or she acknowledges and accepts that he or she may not rely on this report nor on any related information or advice given by SMEC for any purpose whatsoever.

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Abbreviations and acronyms

Term	Definition
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
DOEE	Commonwealth Department of the Environment and Energy
DPIE	Department of Planning, Industry and Environment
EMP	Environmental Management Plan
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FBA	Framework for Biodiversity Assessment
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature
LGA	Local Government Authority
MNES	Matters of National Environmental Significance
OEH	Office of Environment and Heritage
PMST	Protected Matters Search Tool
TPZ	Technical Advisor
WNSW	Water for New South Wales

1. Introduction

1.1. Background

SMEC has been engaged by Water NSW to undertake and complete an assessment of the impacts of the proposed Warragamba Dam Raising project on threatened Biodiversity.

This expert report will assess the impacts that are predicted to occur as a result of the construction activities that are planned to take place in order to raise the wall of Warragamba Dam. This will Involve direct effects such as clearing of vegetation for roads and material lay-down areas as well as indirect effects including increased levels of dust and noise. These impacts are being assessed using the Framework for Biodiversity Assessment (FBA) as directed by the SEARs provided by OEH on 30 June 2017 and reissued 13 March 2018.

1.2. Reasons for the Expert Report

An expert report may be prepared under section 6.6 of the FBA where it states:

> *Using expert reports instead of undertaking a survey*
>
> *6.6.2.1 An expert report may be obtained instead of undertaking a threatened species survey at a development site.*
>
> *6.6.2.2 An expert report must only be prepared by a person who is accredited by the Chief Executive of OEH under section 142B(1)(b) of the TSC Act, or a person who, in the opinion of the Chief Executive of OEH possesses specialised knowledge based on training, study or experience to provide an expert opinion in relation to the biodiversity values to which an expert report relates.*
>
> *6.6.2.3 The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report.*
>
> *6.6.2.4 An expert report can only be used instead of a survey for species to which species credits apply.*
>
> *6.6.2.5 An expert report must set out whether:*
>
> *(a) for development sites – the species is unlikely to be present on the development site – in this case no further assessment of the species is required, or*
>
> *(b) for all development sites – the species is likely to be present on the site – in this case the expert report must provide an estimate of the number of individuals or area of habitat to be impacted by the development or the management actions (according to the unit of measurement identified for the species in the Threatened Species Profile Database).*

An expert report may only be used for those threatened species and populations to which species credits apply, not for any threatened species to which ecosystems apply.

In this case, an expert report has been provided in relation to the Green and Golden Bell Frog (*Litoria aurea)*, which is listed as vulnerable under the BC Act and is a species credit species. An expert report has been prepared due to the difficulty in meeting the survey requirements set out in the FBA. The area to be covered was too inaccessible, necessitating that an expert report be produced to consider the potential for this species to be present and extent of any possible occurrence.

1.3. Species Expert

Dr Francis Lemckert

Dr Lemckert is an Ecologist that has been undertaking studies into the ecology and management of frogs since 1986 and has been a principal ecological consultant since 2011. His skills include survey design/ implementation/ targeted species surveys, data handling, analysis and interpretation and the production of high level reports including papers published in international peer-reviewed journals and technical reports and recovery plans for the Commonwealth and NSW Governments. He has also been an expert witness in regards to considerations of the impacts of potentially illegal clearing for the Commonwealth, NSW and Local Governments (Hornsby Council) and provided expert advice to NSW DPI in regards to court considerations over the potential for forestry operations to impact on rock outcrop dependent species. Dr Lemckert represented Forests NSW (now Forestry Corporation NSW) as a reptile and amphibian expert in the Comprehensive Regional Assessments and Regional Forest Agreement Process carried out between 2000 and 2002 and as an expert in fauna management for negotiations over a new Threatened Species License for harvesting operations in 2014. He provided an expert review of the developed assessment process for impacts on Matters of National Environmental Significance for two proposed Coal Seam Gas Developments in Queensland and has completed two rounds of expert review of the status of Australia's amphibians for the IUCN.

Dr Lemckert is an acknowledged expert on eastern Australian frogs having completed his Master of Science degree and PhD on the ecology and management of frogs in this region and has published over 70 papers (or book chapters) in Australian and International peer-reviewed journals. He has been used by both the NSW and Commonwealth Governments as an expert witness in court cases assessing the impacts of land clearing on threatened frogs. He is member of the Amphibian Specialist Group of the IUCN, secretary of the NSW Declining Frog Working Group of NSW and past president of the Australian Society of Herpetologists. He co-supervised two PhD students, a Master of Applied Science Student and three Bachelor of Science (Honours) students who completed theses addressing issues of frog biology and conservation.

In regards to the Green and Golden Bell Frog (*Litoria aurea*), Dr Lemckert can demonstrate his expertise through the following publications:

Lemckert, F.L., & Mahony, M.J. 2018. The status of Decline and Conservation of Frogs in Temperate Coastal South-eastern Australia. Pp 59-72 In: Amphibian Biology Volume 11 - Conservation and Decline of Amphibians: Eastern Hemisphere (Australia, New Zealand and Pacific Islands). H. Heatwole and J. Rowley (Eds.). CSIRO Publishing, Melbourne.

Lemckert, F.L. 2017. Surveys for the Green and Golden Bell Frog at Meroo for the Saving our Species Research Program. Report to NSW Office of Environment and Heritage.

Mahony, M.J., Hamer, A.J., Pickett, E.J., McKenzie, D.J., Stockwell, M.P. Garnham, J.I., Keely, C.C., Deboo, M., O'Meara, J., Pollard, C.J., Clulow, S., Lemckert, F.L., Bower, D.S., & Clulow, J. 2013. Identifying conservation and research priorities in the face of uncertainty: a review of the threatened bell frog complex in eastern Australia. Herpetological Conservation and Biology 8:519-538.

Penman, T.D. & Lemckert F.L. 2008. Monitoring the green and golden bell frog: current problems and an alternative approach. Australian Zoologist 34:373-378.

Hero, J-M., Gillespie, G., Cogger, H., Lemckert, F. & Roberston, P. 2008. *Litoria aurea*. Pp 256 In: Threatened Amphibians of the World. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P.J. Ramani & B.E. Young (Eds). Lynx Edicions, Barcelona, Spain.

Hero, J-M., Gillespie, G., Cogger, H., Lemckert, F. & Robertson, P. 2004. *Litoria aurea*. The IUCN Red List of Threatened Species 2004: e.T12143A3325402. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T12143A3325402.en. Downloaded on 17 May 2018.

Lemckert, F.L. 1998. Survey report for the green and golden bell frog at Badgerys Creek, NSW. Unpublished report for Biosis Pty. Ltd.

Lemckert, F.L. 1996. Surveys for the green and golden bell frog, *Litoria aurea*, by the State Forests of New South Wales. Australian Zoologist 30:208-213.

In addition, he is recognised as an expert in the species by the Office of Environment and Heritage having been asked to be part of the expert panel determining the categorisation of this species under the SOS program and in determining the populations requiring specific management to meet the SOS requirement to have a viable population maintained 100 years into the future. He has been engaged by:

- NSW Roads and Maritime Services to conduct expert surveys for this species in the area around Sydney Airport, Gerringong, Shortland to Sandgate, South Nowra and Berry to Bomaderry
- Port Kembla Coal Terminal to conduct ongoing monitoring of this species at Port Kembla
- John Holland and Port of Newcastle to provide expert advice on this species at Kooragang Island
- Provided expert opinion on the habitat requirements, sub-population status and reservation requirements for the Green and Golden Bell Frog during the NSW Government's Comprehensive Regional Assessment program completed in 2000-2001.
- Provided expert opinion on the status of this species during assessments undertaken for the IUCN in 2001 and 2016.
- Was accepted as an expert on the Green and Golden Bell Frog for the Southwest Growth Centres Biocertification project and provided an expert report for this species.
- Is an accredited and listed expert for the Green and Golden Bell Frog under the Biodiversity Assessment Method.

Dr Lemckert's full CV is provided as Appendix A of this report.

2. Species Information

Unless otherwise clearly referenced, the information presented for this species has been drawn from the Commonwealth Department of Environment and Energy's Species Profile and Threats (SPRAT) Database (DoE 2018).

2.1. Species Description

The Green and Golden Bell Frog (GGBF) is an endemic Australian tree frog that is a member of the family Hylidae. It is a relatively large species, ranging in an adult size for males of 57-69 mm and females 65-108 mm snout to vent length (Tyler and Knight 2009). The species gets its name from the typical colour of the body which is often a vivid green splotched with gold. However, in some individuals the back may be almost entirely green whereas other have dominant gold markings (See Plates 1-3 in Appendix 2). There is a pale creamish-white stripe running along the side, extending from the upper eyelids usually almost to the groin. The species also has blue or bluish-green markings in the thighs and groin. The snout is relatively pointy and the belly granular. There is rarely a mid-dorsal stripe, which distinguishes this frog from the Southern Bell Frog, *Litoria raniformis*.

2.2. Life Cycle

The GGBF is considered to have a calling season that extends from spring to autumn (Lemckert and Mahony 2008). Within that period of time calling is tied strongly to rainfall events. The advertisement call is a "whaaark whaark whark" that is produced by the male. Calling occurs mainly at night, but occasionally males will call during the day when conditions are especially favourable (DEC 2005). The males call in groups floating on the surface of the water usually holding on to emergent vegetation, with males synchronising their calls with a lead calling male so that they all call essentially at the same time (Barker et al, 1995; Pyke and White 2001). This may help to confuse predators by masking individual calls. Male GGBF reach sexual maturity at around 45–50 mm snout-vent length (DEC 2005), which would usually be reached in the first season after metamorphosis.

Females of the GGBF reach sexual maturity at a snout-vent length of around 65 mm, which usually takes to their second season after metamorphosis (DEC 2005). Female GGBF produce a particularly large number of eggs for an Australian species, with Pyke and White (2001) suggesting an average clutch size is about 3700 eggs, but with van de Mortel & Goldingay (1996) recording a maximum clutch of 11,682 eggs. Egg size is around 4 mm in diameter.

Spawn is laid among aquatic vegetation, with it initially floating on the water surface as a mass, but sinking within 24 hours of being laid. The eggs typically hatch 2–5 days after ovipositing/fertilisation (Anstis 2013) with water temperature playing a role in development time (eggs hatch faster in warmer water) and can hatch in less than one day.

The tadpoles can tolerate salinity levels of six parts per thousand (ppt) without any apparent effects, while salinity of 8 ppt or higher decreases growth rates and increases mortality rates (Christy and Dickman 2002). The pH of a pond does not appear to affect the likelihood of the eggs to hatch (Pyke and White 2001).

Tadpoles grow at variable rates depending on conditions and availability of food. They can reach up to 80 mm in length before metamorphosis, although they will do so at smaller body lengths. Time to metamorphosis is variable and dependent on conditions and time of year, taking between two and eleven months, but with a mean of three months (Anstis 2013). Tadpoles may overwinter if breeding occurs late in autumn. They would be expected to typically eat algae and other aquatic vegetation and can often be seen sucking at the surface of the water, presumably to take in organic material floating on the water surface. But their actual diet has not been studied. As for most species, it is likely that tadpoles will also eat dead animal material if it is available, including other tadpoles.

2.3. Distribution and Abundance

The distribution has been recorded as from Yuraygir National Park on the far North Coast of NSW to around Lakes Entrance in south-eastern Victoria (White and Pyke 2008). Notably, Courtice and Grigg (1975) completed a detailed study of the distribution of the GGBF and in Gippsland found it only as far west as Marlo where it abutted and had a potential hybrid zone with *Litoria raniformis*, which was the species found to the west of that point. In the mid-1980s the species was recorded at least 60 km further west at Nowa Nowa and *Litoria raniformis* were no longer present in that location (F. Lemckert Pers. Obs.) and then 15 km further west at Lakes Entrance by White and Pyke (2008). This may suggest a slight westward expansion of the species in Victoria since the 1970s. Historically the GGBF was known from a number of sites at least 50 km inland into the NSW ranges including at Bathurst (White and Pyke 1999), Bungendore (Humphries 1979) and 30 km inland at Ulong on the NSW north coast (Moore 1961) (Figure 1). The furthest and now only extant "inland" population is near Hoskinstown in the Southern Tablelands of NSW (Osborne et al. 2008). Natural GGBF populations are also known from three islands off the coast of NSW; Bowen Island, Kooragang Island and Broughton Island (DEC 2005). Extra-limital populations have been introduced to New Zealand (Pyke et al. 2002), and New Caledonia and Vanuatu (Pyke and White 2001) with the species occurring in high densities in some areas (M. Mahony Pers. Comm.).

The extent of occurrence of the species in 1999 within Australia was estimated to be approximately 150,000 km^2 (Mahony 1999), but there are no more recent estimate and the extent of occurrence is probably continuing to reduce as populations are known to be continuing to decline (Mahony et al. 2013). The species records in NSW are generally coastal (Figure 1).

Records from general locality of the WDR Construction study area are provided in Figure 2 and demonstrate a general apparent absence of the GGBF from far western Sydney. The Draft GGBF Recovery Plan does not include the WDR area as part of any key population.

Of specific importance for the GGBF in regards to assessments is the decline of the species. The GGBF was recorded as once being a very abundant and widespread frog (Goldingay 1996). Fletcher (1889) stated that this species was commonly be encountered in the Sydney area and Harrison (1922) noted that this species was "probably our best known frog" and was "known to me since childhood". Extensive surveys for the species by Courtice and Grigg (1975) in the early 1970s recorded it very regularly and abundantly across coastal NSW and into southeast Victoria. However, there was a serious decline of the species in the 1980s, with the timing being uncertain, but with frogs having disappeared from many historic sites by 1987 (F. Lemckert Pers. Obs.). By 1996 the GGBF was regarded as rare by White & Pyke (1996) and its recorded declines recognised to be of concern (White 1995). Populations of over 1000 frogs were (and likely still are) present at Kooragang Island, Broughton Island and Homebush (Hamer et al. 2002), but the other locations it is known from are much smaller populations (DEC 2005). Even in 2005 the GGBF was recognised as having declined to less than 50 populations in NSW (DEC 2005) and the declines have been continuing (Mahony et al. 2013). The amphibian chytrid fungus has been implicated as the main driver of these severe declines (Mahony et al. 2013), although habitat loss (Goldingay 1996) and introduced predatory fish (Pyke and White 1999, Goldingay 2008) have also been suggested to have played significant roles in population declines and losses.

Over the short-term the GGBF can exhibit significant local population fluctuations when conditions result in high tadpole survivorship (e.g., Daly 2014). The GGBF has a life cycle that fits what is termed to be an R-selected species (Hamer and Mahony 2007), producing large numbers of offspring and adults have relatively shorter lifespans. Hence, there is a relatively rapid turnover of individuals and survival of the local population depends on occasional very successful seasons, when population size and area utilised rapidly increase, interspersed with years of low recruitment when numbers fall away and there are local extinctions in less favourable areas of habitat. This is considered to be a typical pattern for amphibians (Alford and Richards 1999), although it may not be true of many other Australian frog species. The GGBF has been stated to be a colonising species with a series of its attributes suit this lifestyle: habitat generalist, high fecundity, rapid growth, early sexual maturity, and relative high dispersal ability (Hamer & Mahony 2007). White and Pyke (1999) suggests that the GGBF rapidly move into areas of newly created breeding habitat that represent sites with little competition for the developing tadpoles from other species, are open and so provide good thermal environments and lack or have minimal predators such as dragonfly larvae or fish present. Such a lifestyle is atypical of frog species that have undergone significant broader declines.

Nearly all currently known populations within Australia are located within 10 kilometres of coastal locations (Mahony et al., 2013). This is most likely due to the inhibition of the amphibian chytrid fungus by salt, either through flooding or as windborn material, as the fungus in relatively intolerant of salt (Stockwell et al 2012). Salinity levels of at least 1–2 ppt can be beneficial to the GGBF because this kills pathogens such as the chytrid fungus. Christy and Dickman (2002) identified saltwater intrusion in coastal wetlands due to landscape changes to be a potential threat to GGBF breeding sites, but recent works suggest that the species is relatively tolerant of intermittent salt intrusions.

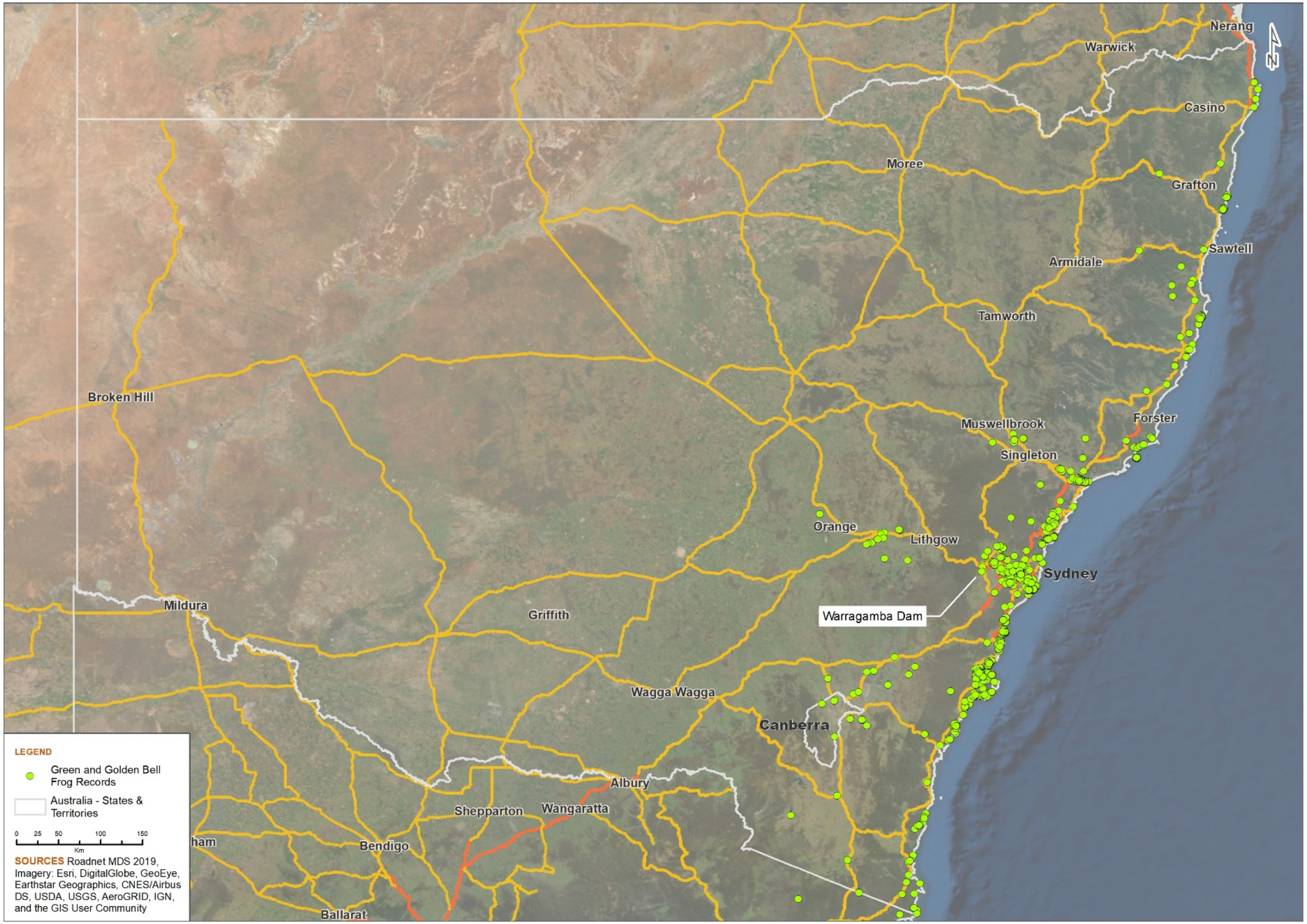

Figure 1. Distribution of the Green and Golden Bell Frog in NSW

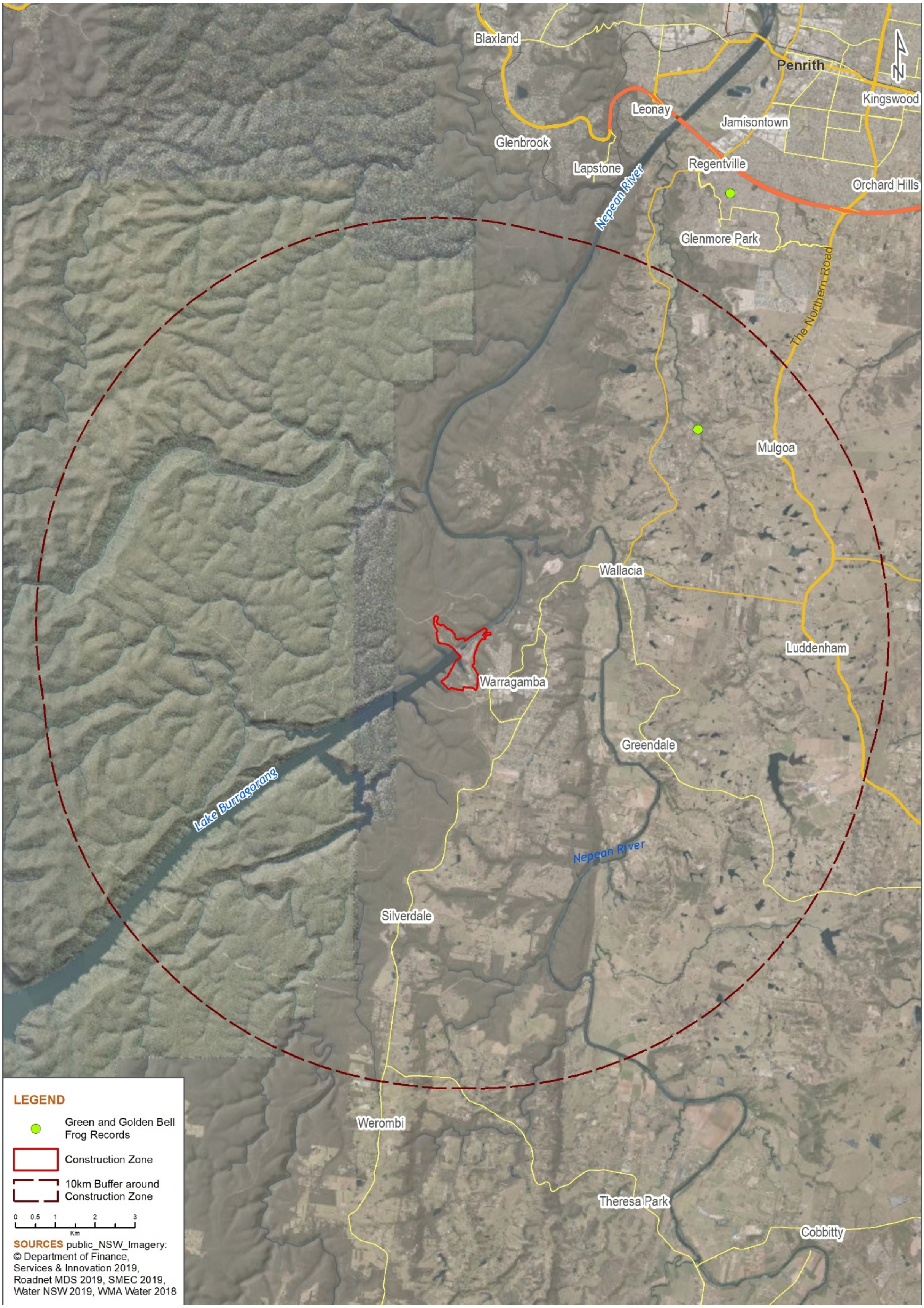

Figure 2. Location of records within 10 km of the study area

2.4. Ecology and Habitat Requirements

2.4.1. Breeding Habitat

Breeding sites for the GGBF include a wide range of natural water bodies and the species has been recorded inhabiting all but fast flowing streams (Pyke & White 1996). It also inhabits many human-created environments, including highly disturbed sites such as abandoned mines and quarries (Pyke et al. 2002), as well as artificial wetlands that have been created at both Kooragang Island (Hamer et al. 2002) and Sydney Olympic Park (Darcovich and O'Meara 2008). Pyke & White (1996) undertook a review of the known breeding habitat of the GGBF and found that they preferred to breed in water bodies that were still, shallow, ephemeral, unshaded, with aquatic plants and free of the Plague Minnow (Gambusia holbrooki) and other predatory fish. This study also found that breeding occurs in a significantly higher proportion of sites with ephemeral (temporary) ponds, rather than sites with fluctuating or permanent ponds. Hamer et al. (2002) found a similar result for the GGBF populations at Kooragang Island where larger males would move to ephemeral water bodies to opportunistically breed at them, although reproduction was also associated with permanent water bodies. The frogs in that study also tended to remain relatively faithful to one water. The presence of the Plague Minnow does not exclude GGBF from breeding in a water body, but success appears to be dependent on the presence of more complex aquatic vegetation, which allows the GGBF to breed successfully (Hamer et al. 2002). Hence the Plague Minnow does still appear to have a significant role in determining the likely presence of the GGBF in most situations.

2.4.2. Non-breeding habitat

Non-breeding habitat for the GGBF is unusual for an Australian frog in that the species appears to remain generally associated with water bodies (remain within 50 metres) rather than dispersing away from water bodies into more terrestrial non-breeding habitats (100-300 metres from the breeding site), which is typical of most frogs (Lemckert 2004). Terrestrial habitats immediately adjacent to water bodies are used for foraging and shelter and preferably consist of grassy areas and vegetation no higher than woodlands and contain a range of diurnal shelter sites such as logs, rocks or dense vegetation (Pyke and White 1996). However, there are observations of GGBF using taller forests (e.g. dry sclerophyll forest at Nowra; M. Greenlees Pers. Comm. and dense woodlands at Meroo, FL Pers. Obs.) and foraging in suburban backyards (DEC 2005), again demonstrating the apparent adaptability and lack of habitat specificity of this frog. Females have been observed to show site fidelity for shelter and foraging sites in areas adjacent to breeding sites (Hamer 1998, Pyke and White 2001).

Shelter sites are used when GGBFs are inactive and so vulnerable and are of added importance in providing secure over-wintering locations. Studies at Kooragang Island have suggested that females may use slightly different non-breeding areas to males and may have very important and specific over-wintering areas located in dense vegetation (M. Mahony Pers. Comm.). Whether this is the same for other populations is unknown, but there is evidence from Sydney Olympic Park that females there also concentrate in certain locations (J. O'Meara Pers. Com.).

Another unusual aspect of the GGBF is its well-known habit of basking, typically within areas of aquatic vegetation, apparently to increase body temperatures (Pyke and White 2001). Basking in frogs is unusual (being generally nocturnal), but such activities in ectotherms typically allow for periods of greater activity or faster digestion of food items and, whilst the importance of this activity for its physiological requirements is not known, individual GGBF appear to bask regularly. On this basis, it is likely that basking is an important physiological activity for the GGBF. Basking typically occurs within or on the edge of emergent aquatic vegetation, which likely allows individuals the option to make a rapid escape from diurnal predators. The presence of water bodies that contain emergent vegetation is a known important determinant of the presence of GGBF (Pyke and White 1996; Hamer et al. 2002) and such sites form an important resource for the GGBF and in the consideration of their potential presence.

Whilst GGBF may retain a closer association with water bodies and appear to generally be faithful to a single water body for their general activities, they can move along and between different water bodies, particularly as part of migrations to and from breeding sites (Hamer et al. 2002). Studies have revealed that the species move distances of up to 1 kilometre (Hamer et al. 2008) and mark/recapture studies have found individuals moved up to 3 kilometres (Pyke & White 2001). Individual GGBF even have the potential to disperse as far as 10 kilometres (White & Pyke 2008). There are records of GGBFs several hundred metres from major drainage lines or other waterbodies (Gillespie 1996) and this may represent long-distance dispersal between water bodies. Hamer et al. (2008) noted that male GGBFs at Kooragang Island often moved > 200 metres to reach an ephemeral breeding site, crossing over extended grassland areas and other habitats including disturbed habitats.

Christy (2001) and Muir (2008) indicated that terrestrial movements of the GGBF are primarily undertaken through more open environments that contained patches of shelter such as rocks, logs or ponds or areas of think vegetation. Such habitats provide relatively little impediment to the movements of frogs, but allow for individuals to seek shelter as required. Terrestrial movements are typically undertaken at night and are most likely associated with rainfall events (F. Lemckert Pers. Obs.) which would provide protection against desiccation.

Mahony (1999) cautions that the studies that have been carried out since the declines of the GGBF do not necessarily identify the actual preferred requirements of the species. He notes that the changed environment and factors causing the declines may have “altered” the optimal habitats for the species in comparison to their habitat use patterns prior to the declines. This is based on the fact that the use of ephemeral breeding sites was not noted for the bell frog group in earlier habitat descriptions. Such altered habitat use has been noted for other species such as Litoria lorica that now is only present in open rocky streams whereas it was once known as a rainforest stream species (Puschendorf 2011). This change is attributed to the impacts of the chytrid fungus, with the frog only surviving in a relatively extreme environment where the fungus is affected by the hotter conditions. Given the chytrid fungus appears also to have been at least a significant contributor (and probably the major one) to the decline of the GGBF, there is a significant potential that the GGBF is now living successfully only in a different set of environments to what it historically did. However, that is unlikely to ever be confirmed.

2.4.3. Connectivity

A critical consideration in the likely presence/absence of the GGBF are metapopulation dynamics. The GGBF is considered to follow a classical metapopulation structure with the “local” population consisting as a series of patchy populations within the larger metapopulation. Individuals move regularly between a mosaic of wetlands across a broad area throughout a single breeding season (Hamer et al. 2008; Hamer & Mahony 2010). There is high site-specific population turnover with local extinctions being balanced by colonisations by regularly dispersing individuals, but with the overall population remaining stable. There are core sites that provide ongoing and regular reproductive success and that maintain long-term populations, but the major part of the population dynamics is driven by inter-year success of breeding at a range of available breeding sites, with years of very good reproductive success leading to opportunities to expand ranges and colonise new sites. On Kooragang Island, GGBF typically reside in permanent waterbodies where they exhibit high site fidelity, but during periods of high rainfall disperse over several hundred metres to breed at ephemeral water bodies that have flooded (Hamer et al. 2008). Reproductive activity (e.g. calling) typically occurs over several nights at these ephemeral waterbodies, with individuals returning to core permanent waterbodies. In times of poor rainfall, the core sites become the refuges for the species and Valdez et al. (2015) found that probability of occupancy of a site increased at large and permanent wetlands.

Following on from this is the identified need for connected sites to allow this population interaction. Hamer (2016) found that the presence of the GGBF at sites at Nowra was dependent on accessibility of ponds, a factor mediated both by the presence of vegetation and the extent of roads in the area, with the presence of roads providing a likely serious barrier to pond use. The presence of vegetation directly around ponds correlated significantly with the potential for greater species diversity. The type of pond available also was important, with the species avoiding steep sided concrete ponds. The apparent negative impacts of roads was confirmed in follow up work (Hamer 2018) where it was again found that the extent of accessible habitat (habitat close to ponds and not isolated from the pond by a road) positively influenced the likelihood of pond occupancy. Extinctions of GGBF were significantly more likely to occur at ponds in areas with higher densities of roads, but were significantly less likely at ponds with higher aquatic vegetation cover. The spatial arrangement of wetlands and the extent of wetlands measured in a 1 kilometre radius has been found to be an important predictor of pond occupancy by GGBF in studies by Hamer et al. (2002), Hamer and Mahony (2010) and Valdez et al. (2015) with more ponds, closer together ponds and already occupied ponds increasing the potential for the GGBF to be present or occupy a previously unoccupied pond (Puschendorf et al. 2011).

This information provides the following important points when trying to assess the potential presence of the GGBF in any area:

- The GGBF is more likely to be present where multiple suitable breeding sites are within a close enough proximity for frogs to migrate between them with relative ease
- The GGBF is more likely to be present where multiple non-breeding water bodies are present in an area and within close enough proximity to allow migration between them (and breeding sites) with relative ease
- The GGBF is more likely to be present where the connectivity of breeding and non-breeding habitat contains a matrix (vegetation and shelter) that facilitates migration
- The GGBF is more likely to be present at a location when there are other GGBF occupied ponds in close proximity.

2.5. BioMetric Vegetation Types

The OEH profile records the GGBF to be associated with a broad range of vegetation formations and classes within the Sydney Basin Interim Biogeographic Region, the location of the GAs (https://www.environment.nsw.gov.au/threatenedspeciesapp/profileData.aspx?id=10483&cmaName=Sydney+Basin). These are:

Dry sclerophyll forests (shrub/grass sub-formation)

- Cumberland Dry Sclerophyll Forests
- Hunter-Macleay Dry Sclerophyll Forests
- North-west Slopes Dry Sclerophyll Woodlands

Dry sclerophyll forests (shrubby sub-formation)

- Coastal Dune Dry Sclerophyll Forests
- South Coast Sands Dry Sclerophyll Forests
- Southern Tableland Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests

Forested wetlands

- Coastal Floodplain Wetlands
- Coastal Swamp Forests

- Eastern Riverine Forests

Freshwater wetlands

- Coastal Freshwater Lagoons
- Coastal Heath Swamps
- Montane Bogs and Fens

Grasslands

- Maritime Grasslands
- Temperate Montane Grasslands

Grassy woodlands

- Coastal Valley Grassy Woodlands
- Southern Tableland Grassy Woodlands

Heathlands

- Coastal Headland Heaths
- Sydney Coastal Heaths
- Wallum Sand Heaths

Miscellaneous ecosystems

- Highly disturbed areas with no or limited native vegetation
- Marine environments
- Rocky islands
- Water bodies, rivers, lakes, streams (not wetlands)

Rainforests

- Dry Rainforests
- Littoral Rainforests
- Northern Warm Temperate Rainforests

Saline wetlands

- Mangrove Swamps
- Saltmarshes

Wet sclerophyll forests (grassy sub-formation)

- Northern Hinterland Wet Sclerophyll Forests
- Southern Tableland Wet Sclerophyll Forests

Wet sclerophyll forests (shrubby sub-formation)

- North Coast Wet Sclerophyll Forests
- Southern Escarpment Wet Sclerophyll Forests

The most important feature to note is that this list of vegetation associations is very broad in the types of environments included, covering grasslands, swamps, saline environments, heathlands and dry and wet sclerophyll forests. That is essentially all possible environments present within the Sydney Basin Bioregion and reflects the understanding that the GGBF is a very adaptable species with little in the way of habitat limitations. This also conforms with the GGBF being recognised for its use of highly disturbed environments and areas without native vegetation. In the context of assessing the likely presence/absence and, if present, the abundance of this species, the type of vegetation present has little relevance. The value of vegetation is it being present to provide GGBF shelter and locations where food may be found.

2.6. Status and Threats

The GGBF is listed as is listed as endangered under the BC Act and vulnerable under EPBC Act. The IUCN lists the threats to the GGBF as:

> *"The cause(s) of the apparent declines observed in populations of all taxa within the L. aurea complex are unclear (Gillespie et al. 1995). Investigations of disappearances among the group have primarily focused on L. aurea and L. castanea and two major directions in research have been pursued: the role of increased ultraviolet radiation; and the impact of the introduced fish, Gambusia (Mahony 1999). It is also possible that disease, such as a viral infection or chytrid fungus, might have contributed to the decline of this species (W. Osborne pers. comm.). Chytrid fungus was detected in this species in Hoskinstown and Homebush Bay in Sydney, New South Wales".*

The OEH profile for this species lists the following as threats to this species:

- Alteration of drainage patterns and stormwater runoff.
- Frog Chytrid Fungus, a fungal pathogen.
- Predation by feral animals such as foxes.
- Herbicides and other weed-control measures.
- Road mortality, where populations are already small due to other threats.
- Predation by exotic fish such as Plague Minnow.
- Loss of suitable breeding habitat through alteration by infilling and destruction of wetlands.
- Current knowledge of the status of the population and threats to the population is poor.
- Species occurs on private land where land management practices may not be suitable for the species, e.g. grazing and loss of breeding habitat.
- Changes in salinity due to sea level rise. Frogs are unable to breed in waters with salt concentrations of greater than 6 parts per 1000.
- Overgrowth of pond vegetation leading to declining water temperature.
- Small population size.
- Lack of information regarding habitat permanency.
- Drying of breeding habitat as a result of increased temperatures and more frequent droughts.
- Lack of landscape connectivity leading to isolation of small populations.
- Heavy metal pollution.
- Four-wheel drives impacting habitat.

The SPRAT profile for this species lists the following threats:

- Habitat removal.
- Habitat degradation (which includes siltation, changes to aquatic vegetation diversity or structure reducing shelter, increased light and noise, grazing, mowing, fire).
- Habitat fragmentation.
- Reduction in water quality and hydrological changes (for example, pollution, siltation erosion and changes to timing, duration or frequency of flood events).
- Disease (for example, infection of the frog with chytrid fungus (*Batrachochytrium dendrobatidis*) resulting in chytridiomycosis).
- Predation by introduced predators including the Plague Minnow (Gambusia holbrooki), Cats (Felis catus) or Foxes (Vulpes vulpes).
- Introduction or intensification of public access to GGBF habitats.

One specific consideration for the likely presence and abundance of the GGBF is the location of a site relative to the coast with essentially all currently known populations located within 10 kilometres of the ocean (Mahony et al, 2013). This is considered to be a result of the impacts of the amphibian chytrid fungus, with the influence of salt closer to the coast inhibiting the growth of the fungus to a sufficient degree to minimise its otherwise very serious negative effects.

Figure 3. Construction footprint

3. Description of the Site

The footprint of the Warragamba Dam Raising development site is provided in Figure 2 and represents the development site. The following information describing the development site and its surrounds is taken directly from the Warragamba Dam Raising Construction Biodiversity Assessment Report (SMEC 2019), unless otherwise acknowledged.

3.1. IBRA bioregions and IBRA subregions

The construction study area is located in the Interim Biogeographical Regionalisation of Australia (IBRA) Bioregion of the Sydney Basin and there are two subregions which are relevant to the assessment.

3.1.1. Bioregions

The development site and outer assessment circle are wholly located within the Sydney Basin Bioregion (DoEE 2018).

Development site: Sydney Basin Bioregion

Outer assessment circle: Sydney Basin Bioregion

OEH provides the following information on the Sydney Basin Bioregion:

The Sydney Basin Bioregion lies on the central east coast of NSW and covers an area of approximately 3.6 million hectares, which is the equivalent of 4.5 percent of NSW. The Sydney Basin Bioregion is one of two bioregions contained wholly within the state. It consists of a geological basin filled with near horizontal sandstones and shales of Permian to Triassic age that overlie older basement rocks of the Lachlan Fold Belt. The sedimentary rocks have been subject to uplift with gentle folding and minor faulting during the formation of the Great Dividing Range. Erosion by coastal streams has created a landscape of deep, cliffed gorges and remnant plateaus across which an east-west rainfall gradient and differences in soil control the vegetation of eucalypt forests, woodlands and heaths. The Sydney Basin Bioregion includes coastal landscapes of cliffs, beaches and estuaries.

The frontal slope of the Blue Mountains (where the site is located) is formed along the Lapstone monocline. A secondary flexure and similar escarpments occur at the coast forming the Hornsby Plateau and the Illawarra Escarpment. These structural features combine with different rock types and strong trends in joint patterns to control drainage patterns and the distribution of gorges and swamps.

3.1.2. Subregions

The development site is located across two IBRA subregions:

1. Wollemi subregion
2. Burragorang subregion.

Development site: Burragorang (19.59 hectares) and Wollemi (85.26 hectares).

Outer assessment circle: Burragorang (250.08 hectares), Wollemi (708.56 hectares), and Cumberland (40.48).

The outer assessment circle falls within both the Wollemi and Burragorang subregions, as well as within Cumberland subregion. The Wollemi, Burragorang, and Cumberland subregions are described in Table 1.

Table 1. Description of the subregions within Sydney Basin Bioregion occurring within the development site

SUBREGION	GEOLOGY	CHARACTERISTIC LANDFORMS	TYPICAL SOILS	VEGETATION
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. There are also a number of scattered volcanic necks distributed throughout the Wollemi subregion.	Characterised by the highest part of the Blue Mountains and other sandstone plateaus with benched rock outcrops.	Typically, soils are thin sands or deep yellow earths on plateaus, with thin texture contrast soils on shale benches. Organic sands in line swamps and joint crevices, while slope debris are found below cliffs, and sandy alluvium in pockets along the streams. On basalts, soils are red brown structured loams.	*Corymbia gummifera*, *Corymbia eximia*, *Angophora floribunda*, *Angophora costata*, *Eucalyptus sclerophylla*, and *Eucalyptus punctata* with diverse shrubs and heaths on plateau. Additionally, *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus agglomerata*, and *Syncarpia glomulifera* subsp. *glomulifera* and gully rainforests are present in gullies and canyon heads. *Eucalyptus viminalis* and Blaxland's Stringybark on basalt. *Casuarina cunninghamiana* is found along main streams.
Burragorang	Comprised of Permian and Triassic sandstones and shales on the western edge of the Sydney Basin.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley	Typically, soils include rocky outcrops, texture contrast soils and uniform sands on sandstone. Cliff bases are generally pillowed with a sandy, clay matrix, alluviums contain rich loams.	Heath, shrubland and woodland with *Eucalyptus sieberi*, *Eucalyptus sclerophylla*, *Eucalyptus piperita* and *Corymbia gummifera* on sandstone similar to other parts of the Basin. *Eucalyptus deanei*, *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerata* immediately below escarpment passing to *Eucalyptus punctata*, *Eucalyptus crebra* and *Eucalyptus eugenoides* on rocky slopes. *Casuarina cunninghamiana* along main streams below the plateaus.
Cumberland	Triassic Wianamatta groups shales and sandstones, which are intruded by a small number of volcanic vents and partly covered by Tertiary river gravels and sands. There is quaternary alluvium along the mains streams.	Low rolling hills and wide valleys in a rain shadow area below the Blue Mountains. Volcanics from low hills in the shale landscapes. Swamps and lagoons on the floodplain of the Nepean River.	Typically, soils include a mixture of clays on volcanics, poor stony soils on older gravels, and high quality loams on floodplain alluvium.	*Eucalyptus moluccana, Eucalyptus tereticornis, Eucalyptus crebra* woodland with some *Corymbia maculata* on the shale hills. *Eucalyptus sclerophylla, Angophora floribunda*, and *Banksia serrata* on alluvial sands and gravels. *Angophora subvelutina, Eucalyptus amplifolia* and *Eucalyptus tereticornis* with abundant *Casuarina glauca* on river flats. Tall spike rush, and juncus with *Eucalyptus parramattensis* in lagoons and swamps.

3.2. NSW landscape regions (Mitchell Landscapes)

The development site is located across four landscape regions:

1. Kurrajong Fault Scarp
2. Lapstone Slopes
3. Burragorang Valley and Gorges
4. Nattai Plateau.

Development site: Kurrajong Fault Scarp (92.95 hectares); Lapstone Slopes (10.31 hectares); Burragorang Valley and Gorges (1.56 hectares); and Nattai Plateau (0.03 hectares)

Outer assessment circle: Kurrajong Fault Scarp (611.99 hectares); Lapstone Slopes (97.60 hectares); Burragorang Valley and Gorges (127.69 hectares); Silverdale Slopes (120.36 hectares); and Nattai Plateau (42.37 hectares)

Kurrajong Fault Scarp occurs over the majority of the development site (as measured by area) followed by Lapstone Slopes, Burragorang Valley and Gorges, and Nattai Plateau. Descriptions of each Mitchell Landscape are provided in Table 2.

Table 2. Description of the Mitchell Landscape

MITCHELL LANDSCAPE	DESCRIPTION
Kurrajong Fault Scarp	Dissected and broken slopes on Triassic Quartz sandstone and shale across the Lapstone monocline and Kurrajong fault scarp. Local dips on the sedimentary rocks up to 300 m, general elevation 100 to 250 m, local relief 100 m. Abundant rock outcrop with pockets of yellow-brown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of: *Eucalyptus agglomerata*, *Syncarpia glomulifera* subsp. *glomulifera*, Red *Corymbia gummifera*. *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus radiata*, *Eucalyptus punctata*, *Eucalyptus pilularis* and *Allocasuarina* sp. Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered *Eucalyptus tereticornis*, *Angophora floribunda* and *Eucalyptus globoidea* on the margins.
Lapstone Slopes	The frontal slope of the Blue Mountains formed by folding and faulting of Triassic quartz sandstone and shale with a veneer of Tertiary river gravels. A southern extension of the Kurrajong Fault Scarp landscape. Larger streams cut through the structural ridge in deep gorges, but smaller streams have accumulated organic sands in swamps and lagoons on the western side of the flexure. General elevation 50 to 300 m, local relief 180 m, steep dip slopes on the eastern face and benched faulted slopes on the west. Extensive rock outcrop, thin sandy soils with gravel and occasional white or yellow clay subsoils. Pockets of deep sand in some streams. *Corymbia gummifera*, *Corymbia eximia*, *Eucalyptus punctata*, *Allocasuarina torulosa*, *Eucalyptus sieberi*, *Eucalyptus radiata* with diverse shrubby understorey.

MITCHELL LANDSCAPE	DESCRIPTION
Burragorang Valley and Gorges	Deep steep sided benched slopes and gorge of the Wollondilly and Coxs Rivers incised into mostly horizontal Triassic quartz sandstone conglomerate, siltstone, and shale, cliffs to 150m high with waterfalls, general elevation 50 to 220 m, local relief 150 m. The gorge widens upstream and exposes underlying Permian chest, mudstones and conglomerate. Very extensive rock outcrop, thin yellow to yellow-brown silty sand and gravel with occasional white clay layers forming either shallow yellow earths or gleyed texture-contrast profiles. *Corymbia gummifera*, *Syncarpia glomulifera*, and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliffs upstream with *Eucalyptus tereticornis*, *Eucalyptus macrorhyncha*, *Eucalyptus crebra*, and *Eucalyptus mannifera*. Moist protected environments with *Eucalyptus saligna*, *Eucalyptus cypellocarpa*, *Eucalyptus muelleriana* and *Eucalyptus smithii*. Gallery forest of *Casuarina cunninghamiana* with *Eucalyptus deanei* and *Eucalyptus benthamii* along the main streams.
Nattai Plateau	Steeply dissected plateau remnants on lower Triassic lithic sandstone, shale and tuff, abundant rock outcrop and cliffs, steep debris slopes, general elevation 600 to 700 m, local relief 80 m. Shallow sand and occasional yellow texture-contrast soils. Forests of *Eucalyptus eugenioides*, *Eucalyptus fibrosa* subsp. *fibrosa*, *Callitris rhomboidea*, *Eucalyptus sieberi*, *Eucalyptus blaxlandii*, *Eucalyptus fastigata* and *Eucalyptus viminalis*.
Silverdale Slopes	Moderately undulating slopes descending to the east on gently dipping Triassic shales and sandstones. General elevation 230 to 630 m, local relief 200 m. Brown to yellow-brown texture-contrast soils. Woodland to forest with a shrubby understorey, common species; *Eucalyptus punctata*, *Eucalyptus albens*, *Eucalyptus paniculata*, *Eucalyptus crebra*, *Eucalyptus fibrosa*, *Eucalyptus moluccana*, *Allocasuarina torulosa*, *Eucalyptus eugenioides*, and occasional *Syncarpia glomulifera*.

3.3. Rivers and streams

The development site falls within the Warragamba catchment. Bordered on the west by the Great Dividing Range, the catchment stretches from north of Lithgow at the head of the Coxs River in the Blue Mountains, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River.

The proposed construction area includes areas of Lake Burragorang, the dam wall spillway and Warragamba River. Up until the dam wall, Lake Burragorang is considered to be a 9^{th} order stream in accordance with the Strahler stream ordering method. The current geomorphological condition at the dam is characterised by altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplains.

3.4. Wetlands

One wetland (Lake Burragorang) has been mapped within the construction study area within the NSW Wetland shapefile. No important or local wetlands occur within the development site or outer assessment circle. There are a number of smaller dams mapped to the east of the development site, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 km of the development site.

3.5. Native vegetation

The development site is centred around Warragamba Dam, which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, the vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation. Instead much of the development site is comprised of vegetation typical of ridgetops on skeletal soils. The majority of the development site supports dry sclerophyll forest of shrubby sub-formation, as well as an area of wet sclerophyll forest. To the west of Warragamba Dam, to both the north and south of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenoides*, *Eucalyptus sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest which extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest Critically Endangered Ecological Community.

The development site is 104.85 hectares in size. A total of 54.37 ha of native vegetation has been mapped within the site with Table 3 providing a summary of the PCTs mapped as occurring, including vegetation formation, percent cleared within the Hawkesbury-Nepean catchment and extent within the development site. All of this vegetation is suitable for the GGBF to use as shelter and feeding habitat as is non-native vegetation and many areas that are relatively clear of vegetation, but have cover such as logs and rocks.

Table 3. Summary of PCTs occurring within the development site

PCT CODE/ BVT CODE	PCT NAME	VEGETATION FORMATION	VEGETATION CLASS	% CLEARED WITHIN HN CATCHMENT	AREA WITHIN SITE (HA)
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	40	16.96
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	25	24.78
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	20	8.69
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Wet Sclerophyll Forests (Grassy sub-formation)	Northern Hinterland Wet Sclerophyll Forests	90	4.94

3.6. Landform, geology and soils

The study area is approximate 104.85 hectares and is located at and adjacent to Warragamba Dam. The elevation within the study area is varied, ranging between 21 metres AHD at its lowest point to 195 metres AHD at its highest point. The study area slopes from the top of the gorge down to the dam and Warragamba River.

The Soil Landscapes of Penrith 1:100,000 soil landscape sheet has mapped four soil landscapes within the outer assessment circle as outlined in Table 4 below.

Table 4. Soil landscape description

NAME	LANDSCAPE	SOILS	LIMITATIONS
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 meters, slopes 10-15%. Rock outcrop 25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop with broken scarps.	Shallow to moderately deep (30-100 cm) yellow earths and earthy sands on crests and on insides of benches; shallow siliceous sands on leading edges of benches; localised gleyed podzolic soils and yellow podzolic soils on shale lenses; shallow to moderately deep (<100 cm) siliceous sands and leached sands along drainage lines.	Steep slopes, water erosion hazard, rock outcrop, localised rockfall hazard, localised non-cohesive soils, shallow highly permeable soil, very low soil fertility.
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces on Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop.	Shallow (<50 cm) earthy sands and yellow earths; some siliceous sands / lithosols associated with rock outcrop.	Shallow, highly permeable soil, localised non-cohesive soils, very low soil fertility, localised water erosion hazard, localised rick outcrop.
Hawkesbury	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200 m, slopes >25%. Rock outcrop >50%. Narrow crests and ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders.	Shallow (<30 cm) discontinuous lithosols / siliceous sands, associated with rock outcrop; earthy sands, yellow earths and some locally deep sands on inside of benches and along joins and fractures; localised yellow and red podzolic soils associated with shale lenses, siliceous sands and secondary yellow earths along drainage lines.	Steep slopes, mass movement hazard, rockfall hazard, water erosion hazard, shallow soils, rock outcrop, non-cohesive soils (localised), stony, highly permeable soils of low fertility.
Blacktown	Gently undulating rises on Wianamatta Group shales. Local relief to 30 m, slopes usually >5%. Broad rounded crests and ridges with gently inclined slopes.	Shallow to moderately deep (>100 cm) hardsetting mottled texture contrast soils, red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and drainage lines.	Localised seasonal waterlogging, localised water erosion hazard, moderately reactive highly plastic subsoil, localised surface movement potential.

3.7. Hydrology

Lake Burragorang is the dominant hydrological feature of the study area. Created by damming the Warragamba River and flooding the Burragorang Valley, Lake Burragorang is four times the size of Sydney Harbour and is currently managed as Sydney's water supply dam.

Downstream of the dam is the Warragamba River. Water is discharged into Warragamba River when the dam spills. Water is also released into the Warragamba River (downstream of the Warragamba Weir) to provide a secure water supply to the population of North Richmond. Warragamba River is a 9th order Strahler stream and there are several small, unnamed ephemeral tributaries within study area.

3.8. Climate

There are no weather stations within the construction area, but Table 5 provides summaries of the weather conditions for stations located around the area. The climate for the area is mild with moderate rainfalls.

Table 5. Key climatic statistics for weather stations near the survey area.

WEATHER STATION	MEAN ANNUAL RAINFALL (MM)	MEAN MAXIMUM TEMPERATURE (°C)	MEAN MINIMUM TEMPERATURE (°C)
Jenolan Caves (1895-) (24 km W, 690 m higher)	970.6	25.6	0.2
Penrith Lakes AWS (1995-) (20 km NNE, 90 m lower)	718.6	31.0	5.3
Springwood (1883-) (21 km N, 250 m higher)	1082.1	29.0	6.5
Katoomba (1885-) (15 km N, 890 m higher)	1399.6	23.4	2.6
Picton Council Depot (1880-) (15 km SE, 60 m higher)	794.3	29.3	1.7

3.9. Land uses

The development footprint is located on land zoned as SP2 Infrastructure (Water Supply) under the *Wollondilly Local Environmental Plan (LEP) 2011* (Figure 4). This land around the dam serves as operational support for the existing dam and consists of cleared and vegetated areas, dam support facilities, access roads and parks. The proposed works would be permissible within this land zone type and construction activities would be contained within this zone.

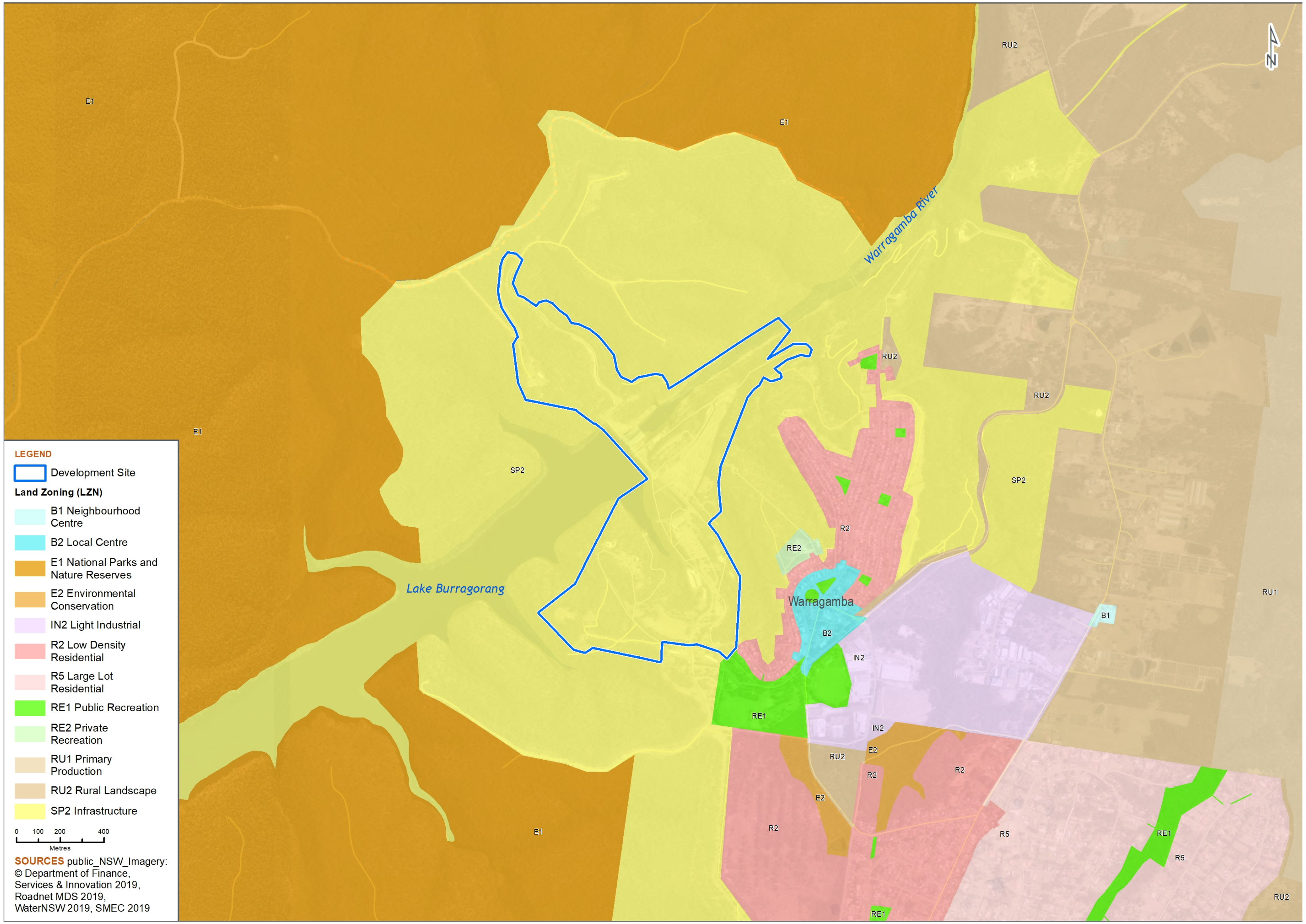

Figure 4. Land use zones

4. Description of the Site

4.1.1. Local records

There is one Wildlife Atlas database record of the GGBF within a 10 km radius of the site (Figure 2). This record is not located within the development site and the record comes from floodplain and not from the sandstone environments typical of that located in the development site. The nearest recent records are from Riverstone, approximately 33 km to the east, and these records are highly likely to be individuals dispersing from a semi-captive population present in the yards of a local resident (Lance Jurd). Records outside of those near Riverstone and the likely semi-captive raised population are all from before 2000, in keeping with the broad extinction of this species from natural habitats across the western Sydney Basin.

The development site was viewed on the 12th and 13th of December 2017.

4.1.2. Breeding Habitat

The GGBF has been found to breed in a wide variety of water bodies with two specific factors most likely to determine the use of a water body. One is the presence of emergent vegetation and the other is the presence of fish and particularly the Plague Minnow. The ephemeral streams flowing in from the surrounding ridges are unlikely to have any suitable breeding habitat as they lack pools that contain the typical emergent vegetation used by this species including reeds (*Typha* spp.) or sedges (*Carex* and *Juncus* spp.) could use the pools below the dam. Pools present there are going to be small (< 5m diameter) and the GGBF rarely appears to use sites in native forest environments. The aquatic habitat around on the upstream side of the dam has shallow areas as well as deep water immediately adjacent to the dam, but has very little emergent vegetation and has large numbers of fish present, including European Carp. The absence of emergent vegetation and presence of fish would make this area highly unsuitable for use as breeding habitat. The most likely breeding habitat would be the pools on the downstream side of the dam. These are large and only flow after heavy flooding. The do not contain extensive areas of emergent vegetation and are likely to have some fish, but much reduced numbers. The presence of reduced quality bankside vegetation would suit the GGBF as it prefers lower grassy areas for feeding and is not dependent in any way on native vegetation being present.

4.1.3. Shelter Habitat

The GGBF generally shelters within emergent aquatic vegetation or on the edges of water bodies. Overwintering habitat can be within the pond itself, buried in the mud, or within dense vegetation or under logs and rocks immediately adjacent to the water body. Suitable emergent vegetation is present mainly in the downstream area, but logs and rocks that could be used as shelter are present all along the banks of the main channel and along the edge of the dam.

Terrestrial environments away from water bodies are only used intermittently when frogs disperse between water bodies to breed or find other shelter. In these instances the frogs will travel across areas of native and non-native vegetation and are likely to prefer shorter vegetation. Any part of the development site is likely to be suitable for use as shelter habitat, but the disturbed areas adjacent to the downstream section of the Warragamba River provides an area of shorter vegetation that the species may prefer.

4.1.4. Foraging Habitat

The GGBF has no known specific dietary requirements that might limit its distribution across the landscape. Individuals are known to move short distances away from water bodies into surrounding areas of vegetation to undertake foraging. All areas of native and non-native vegetation within 50 m of suitable breeding habitat (so the downstream section of the Warragamba River) provides suitable foraging habitat.

4.1.5. Total area of habitat impacted

The lack of records for this species from the locality over the last 20 years indicates that the GGBF is not present in the study area. Populations now exist either only within 10 km of the coast or in areas subject to industrial or mining contamination, or as a result of human interventions (e.g. semi-captive breeding populations). The study area does not fit into either category of disturbed environment. On that basis, I consider that the GGBF is currently extinct in the study area and would not be impacted by the construction works associated with raising the Warragamba Dam.

5. Conclusion

I consider that the GGBF is not likely to be present within the Construction Area of the Warragamba Dam raising project. Whilst the study area is within the known range of this species and there is suitable aquatic breeding and non-breeding habitat present, the species has not been located within the locality for over 40 years. Recent studies have indicated that the amphibian chytrid fungus has caused the broad extinction of any populations of this species outside of near coastal area (<10 km from the coast). The exceptions to this are areas with unusual disturbance histories that leave chemical contaminants that attenuate the impacts of the fungus. There are no known such areas within the proposed WDR construction study area and so the species is highly unlikely to be present and so be impacted by the proposed works. It is highly unlikely to recover in the foreseeable future to the extent that it will re-inhabit the study area, if it ever was present. Offsets are not required for the GGBF.

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7. Appendix 1 – Curriculum Vitae – Dr. Frank Lemckert

Frank has been a professional scientist since 1992, specialising in understanding and managing the ecology and management of threatened species and particularly frogs. Frank has conducted ecological work throughout eastern Australia (NSW, Victoria, Queensland), establishing long-term research and monitoring programs into the management of fauna and developing strategies to mitigate the impacts of human disturbances. He has worked extensively with the NSW state and federal Governments on varying issues of fauna and flora management including the preparation of a draft NSW/National recovery plan for the Giant Burrowing Frog (*Heleioporus australiacus*) and is an accredited expert on the Green and Golden Bell Frog (*Litoria aurea*). Frank has prepared reports on endemism and representation in reserves of flora and fauna for the Commonwealth, represented the NSW Forestry Commission in license negotiations for the Comprehensive Regional Assessment process (2000) and provided expert ecological advice on illegal land clearing for the NSW and Commonwealth Governments. He has authored over 90 peer-reviewed publications. Frank is a research associate with the Australian Museum and University of Newcastle, convenor of the NSW Declining Frog Working Group and a member of the IUCN's Amphibian Specialist Group. He is a recognised expert in frog ecology and management, but has completed management related projects and works on a range of terrestrial vertebrate fauna.

Frank's primary role as a consultant has been to use his expertise and experience in technical writing and threatened species legislation to develop and maintain quality assurance in project reporting including:

- Two Species Impact Statements.
- >100 flora and fauna reports and assessments of significance using the EP&A Act and EPBC Act.
- Biodiversity Assessment Reports for Warragamba Dam Raising, Nowra Bridge, Golden Highway and Eurobodalla Dam.
- Manager for the Oxley Highway to Kempsey and Frederickton to Eungai ecological monitoring program.
- Construction and Environmental Management Plans, Monitoring Plans and Vegetation Management Plans for roads at Port Macquarie, Berry to Bomaderry and South Nowra.
- Nest Box, microbat and Green and Golden Bell Frog management plans for the Berry to Bomaderry and Oxley Highway to Kempsey Highway Upgrades.
- Review of monitoring strategies for the Woolgoolga to Ballina and Warrell Creek to Nambucca Heads programs for the Pacific Highway Upgrade.
- Review of two proposed Coal Seam Gas Impact Assessment methods for Matters of National Environmental Significance (contracted by the Commonwealth Government).
- Provision of species credit species expert reports for the Warragamba Dam raising project and Western Sydney Growth Centres Biocertification.

QUALIFICATIONS

- Bachelor of Science, University of Sydney, 1984 (Terrestrial Ecology and Marine Management)
- Master of Science, University of Sydney, 1991 (Population biology of the Common Froglet)
- PhD, University of Newcastle, 2009 (Management of forest frogs in timber production forests of NSW)

PROJECT EXPERIENCE

Ecological impact assessment

- Expert report on the green and golden bell frog for the western sydney growth areas biocertification project (2018-2019)
- Warragamba dam raising project target surveys, impact assessments, expert reporting (six species) and q/a for water nsw (2018-19)
- Shading impacts for proposed building works at homebush, nsw, piety pty ltd (2018)
- Granite hills windfarm bird and bat strike modelling and ecological impact assessment, nimmitabel, akuo energy (2018) and elysian windfarm, nimmitabel, akuo energy (2018)
- Vegetation removal and threatened frog management strategies, new intercity fleet management facility, john holland group (2018-19)
- Eurobodalla dam biodiversity assessment report, eurobodalla shire council (2017-18)
- Nowra bridge eis ecological assessments, nsw rms (2018)
- Heathcote road upgrade impact assessment and review of mitigation measures, nsw rms (2018-2019)
- Mona vale road threatened fauna expert survey and impact assessment, ecosure and nsw rms (2015-2016).

Government reviews/reports

- Biodiversity assessment method frog survey guidelines for species credit species (2019)
- Expert review of biodiversity impact assessment report for the hornsby quarry rehabilitation project (2019)
- Review of impact assessment pathways for two lpng projects, commonwealth government (2013)
- Expert advice on impacts of illegal land clearing at somersby, commonwealth government (2015)
- Expert advice on impacts of illegal land clearing at evans head, nsw state government (2016)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Review of monitoring strategies for the woolgoolga to ballina and warrell creek to nambucca heads programs for the pacific highway upgrade, nsw rms (2014)
- Hornsby council expert witness for development impacts at dural, hornsby shire council (2016)
- Expert representing forests nsw in the comprehensive reginal assessment program for the regional forest agreement program (1999-2001)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Flora and fauna representation in the australian reserve system, commonwealth government (2010)
- Flora and fauna endemism patterns across australia, commonwealth government (2009)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Expert review of fauna and flora impacts for 13 nsw forestry commission eis reports (1992-94).

EPBC referrals

- Green and golden bell frog (*litoria aurea*) referrals for the princes highway upgrade at south nowra, nsw rms
- Austen quarry (*eucalyptus pulverulenta*), hartley, hy-tec industries (2014-15)
- Marys mount koala (*phascolarctos cinereus*) referral, gunnedah quarry products (2015).

Monitoring programs

- Oxley highway to kempsey threatened biodiversity monitoring, nsw rms (2013-2017)
- Green and golden bell frog baseline monitoring program at meroo lakes, nsw oeh (2016-17)
- Fcnsw statewide ecological monitoring program, forestry corporation of nsw (2009-10)
- Threatened fauna monitoring hume highway, kapooka, nsw rms (2018).

Plans of management / strategies

- Commonwealth/nsw giant burrowing frog recovery plan, dewha/decc (2012)
- Eastern bentwing-bat management plan, gerringong, nsw rms (2014)
- Nestbox, microbat and green and golden bell frog management plans, berry to bomaderry upgrade of the princes highway, nsw rms (2017)
- Green and golden bell frog surveys and monitoring, princes highway upgrades at south nowra and berry to bomaderry, nsw rms (2012-2017)
- Green and golden bell frog management strategy, princes highway upgrade, nsw rms (2012-2014)
- Green and golden bell frog pre-clearing works kooragang island (daracon 2016 & current)
- Microbat management plan for clarencetown bridge, nsw rms (2016)
- Expert review of threatened frog management plan - woolgoolga to ballina upgrade, nsw rms (2014)
- Threatened microbat management plan for warringah mall, northern beaches council (2014)
- Threatened frog modelled habitat requirements, hornsby shire council (2016).

Training

- Lead instructor > 50 wildlife training schools run in nsw, act and victoria providing presentations on the survey, identification and management of all flora and fauna. This included detailed instruction on the management of threatened wading and aquatic birds and other aquatic species presented to queensland, victorian, nsw and commonwealth government staff (1993-2017)
- Private forestry survey requirements, victorian timber (2016).

Publications

Book Chapters

Hecnar S. J., & Lemckert, F.L. 2012. Habitat Protection: Refuges and Reserves. Pp 3636-3675 In Biology of the Amphibia Volume 10 - Conservation and Decline of Amphibians: Ecology, Effects of Humans, and Management. H. Heatwole (Ed.). Surrey-Beatty and Sons, Sydney.

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Hero, J-M, Richards, S, Alford, R., Allison, A., Bishop, P., Gunther, R., Iskandar, D., Kraus, F., Lemckert, F., Menzies, J., Roberts, D. & Tyler, M. 2008. Amphibians of the Australasian Realm. Pp 65-73 In: Threatened Amphibians of the World. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani & B. E. Young (Eds.). Lynx Edicions, Barcelona.

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Scientific Papers

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Goldingay, R., Daly, G. & Lemckert, F. 1996. Assessing the impacts of logging on reptiles and frogs in the montane forests of southern New South Wales. Wildlife Research 23:495-510.

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Lemckert, F.L. & Shine, R. 1992. Costs of reproduction in a population of the frog *Crinia signifera* (Anura: Myobatrachidae) from southeastern Australia. Journal of Herpetology 27:420-425.

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Lemckert F. 2004. The biology and conservation status of the heath frog (*Litoria littlejohni*). Herpetofauna 34:99-104.

Lemckert, F.L. 2000. Observations on the effects of fire on the Hip-pocket Frog, *Assa darlingtoni*. Herpetofauna 30:51-52.

Lemckert, F.L., Brassil, T. & McCray, K. 1998. Recent records of the giant burrowing frog (*Heleioporus australiacus*) from the far south coast of NSW. Herpetofauna 28:32-39.

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Unpublished reports

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Appendix J Expert Report: Littlejohn's Frog

Member of the Surbana Jurong Group

Warragamba Dam Raising Construction Area

Expert report – Littlejohn's Frog

Prepared for: Water for NSW

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Abbreviations and acronyms

Term	Definition
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
DOEE	Commonwealth Department of the Environment and Energy
DPIE	Department of Planning, Industry and Environment
EMP	Environmental Management Plan
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FBA	Framework for Biodiversity Assessment
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature
LGA	Local Government Authority
MNES	Matters of National Environmental Significance
OEH	Office of Environment and Heritage
PMST	Protected Matters Search Tool
TPZ	Technical Advisor
WNSW	Water for New South Wales

1. Introduction

1.1. Background

SMEC has been engaged by Water NSW to undertake and complete an assessment of the impacts of the proposed Warragamba Dam Raising project on threatened Biodiversity.

This expert report will assess the impacts that are predicted to occur as a result of the construction activities that are planned to take place in order to raise the wall of Warragamba Dam. This will Involve direct effects such as clearing of vegetation for roads and material lay-down areas as well as indirect effects including increased levels of dust and noise. These impacts are being assessed using the Framework for Biodiversity Assessment (FBA) as directed by the SEARs provided by OEH on 30 June 2017 and reissued 13 March 2018.

1.2. Reasons for the Expert Report

An expert report may be prepared under section 6.6 of the FBA where it states:

> *Using expert reports instead of undertaking a survey*
>
> *6.6.2.1 An expert report may be obtained instead of undertaking a threatened species survey at a development site.*
>
> *6.6.2.2 An expert report must only be prepared by a person who is accredited by the Chief Executive of OEH under section 142B(1)(b) of the TSC Act, or a person who, in the opinion of the Chief Executive of OEH possesses specialised knowledge based on training, study or experience to provide an expert opinion in relation to the biodiversity values to which an expert report relates.*
>
> *6.6.2.3 The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report.*
>
> *6.6.2.4 An expert report can only be used instead of a survey for species to which species credits apply.*
>
> *6.6.2.5 An expert report must set out whether:*
>
> *(a) for development sites – the species is unlikely to be present on the development site – in this case no further assessment of the species is required, or*
>
> *(b) for all development sites – the species is likely to be present on the site – in this case the expert report must provide an estimate of the number of individuals or area of habitat to be impacted by the development or the management actions (according to the unit of measurement identified for the species in the Threatened Species Profile Database).*

An expert report may only be used for those threatened species and populations to which species credits apply, not for any threatened species to which ecosystems apply.

In this case, an expert report has been provided in relation to the Littlejohn's Frog (*Litoria littlejohni)*, which is listed as vulnerable under the BC Act, and under the EPBC Act, and is a species credit species. An expert report has been prepared due to the difficulty in meeting the survey requirements set out in the FBA. The area to be covered was too inaccessible, especially during the necessary wet conditions for surveys, necessitating that an expert report be produced to consider the potential for this species to be present and extent of any possible occurrence.

1.3. Species Expert

Dr Francis Lemckert

Dr Lemckert is an Ecologist that has been undertaking studies into the ecology and management of frogs since 1986 and has been a principal ecological consultant since 2011. His skills include survey design/ implementation/ targeted species surveys, data handling, analysis and interpretation and the production of high level reports including papers published in international peer-reviewed journals and technical reports and recovery plans for the Commonwealth and NSW Governments. He has also been an expert witness in regards to considerations of the impacts of potentially illegal clearing for the Commonwealth, NSW and Local Governments (Hornsby Council) and provided expert advice to NSW DPI in regards to court considerations over the potential for forestry operations to impact on rock outcrop dependent species. Dr Lemckert represented Forests NSW (now Forestry Corporation NSW) as a reptile and amphibian expert in the Comprehensive Regional Assessments and Regional Forest Agreement Process carried out between 2000 and 2002 and as an expert in fauna management for negotiations over a new Threatened Species License for harvesting operations in 2014. He provided an expert review of the developed assessment process for impacts on Matters of National Environmental Significance for two proposed Coal Seam Gas Developments in Queensland and has completed two rounds of expert review of the status of Australia's amphibians for the IUCN, the latest being in 2016.

Dr Lemckert is an acknowledged expert on eastern Australian frogs having completed his Master of Science degree and PhD on the ecology and management of frogs in this region and has published over 70 papers (or book chapters) in Australian and International peer-reviewed journals. He has been used by both the NSW and Commonwealth Governments as an expert witness in court cases assessing the impacts of land clearing on threatened frogs. He is member of the Amphibian Specialist Group of the IUCN, secretary of the NSW Declining Frog Working Group of NSW and past president of the Australian Society of Herpetologists. He has been the co-supervisor of two PhD, a Master of Applied Science and three Bachelor of Science (Honours) students who completed theses addressing issues of frog conservation.

In regards to Littlejohn's Frog, Dr Lemckert can demonstrate his expertise through the following scientific publications and reports that include this species:

Lemckert, F.L. & Penman, T. 2012. Climate Change and Australia's frogs: how much do we need to worry? Pp 92-98 In: Wildlife and Climate Change: towards robust conservation strategies for Australian fauna. D. Lunney & P. Hutchings (Eds.). Royal Zoological Society of NSW, Mosman, NSW, Australia.

Lemckert, F. 2010. Habitat relationships and presence of the threatened heath frog *Litoria littlejohni* (Anura: Hylidae) in central New South Wales, Australia. Endangered Species Research 11:271-278.

Lemckert, F.L. & Mahony, M.J. 2008. Core calling periods of the frogs of temperate New South Wales, Australia. Herpetological Conservation and Biology 3:71-76.

Penman, T. D. and Lemckert, F. L. 2010. Predicted impact of climate change on threatened amphibians. Unpublished report to the Department of the Environment, Climate Change and Water, Hurstville.

Hero, J-M, Richards, S, Alford, R., Allison, A., Bishop, P., Gunther, R., Iskandar, D., Kraus, F., Lemckert, F., Menzies, J., Roberts, D. & Tyler, M. 2008. Amphibians of the Australasian Realm. Pp 65-73 In: Threatened Amphibians of the World. S.N. Stuart, M. Hoffman, J.S., Chanson, N.A. Cox, R.J. Berridge, P.J. Ramani & B.E. Young (Eds.). Lynx Edicions, Barcelona.

Gillespie, G., Lemckert, F. & Robertson, P. 2004. *Litoria littlejohni*. The IUCN Red List of Threatened Species. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T41036A10391959.en. Downloaded on 17 May 2018

Lemckert F. 2004. The biology and conservation status of the heath frog (*Litoria littlejohni*). Herpetofauna 34:99-104.

Dr Lemckert has also undertaken the following actions as a result of his recognised expertise in this species:

- Contracted by OEH to collect genetic samples from Littlejohn's Frogs to assist in determining the potential for two species to be present within the current recognised taxa. The data collected has indicated that two species may be present, but this needs further confirmation.
- Provided expert opinion on the habitat requirements, sub-population status and reservation requirements for Littlejohn's Frog during the NSW Government's Comprehensive Regional Assessment program completed in 2000-2001.

Dr Lemckert full CV is provided as Appendix A.

2. Species Information

2.1. Abundance and Distribution

Littlejohn's Tree Frog has a distribution that includes the plateaus and eastern slopes of the Great Dividing Range from Watagan State Forest (90 kilometres north of Sydney) south to Buchan in Victoria (White et al., 1994) in an altitude range from 100 to 950 metres above sea level (White & Ehmann 1997). The majority of the limited records available for this species have been obtained from within the Sydney Basin Bioregion (Figure 1; Bionet 2018). There are only scattered records in southern NSW, nearly all of which are more than 10 years old, and the species has only been very recently rediscovered in Victoria (Gillespie et al. 2016) where the population looks to be extremely small. AmphibiaWeb (2004) records an estimated extent of occurrence of approximately 65200 km^2.

The number of individuals of Littlejohn's Tree Frog is thought to be only as most known populations recorded contain four or fewer calling males. Only two of 47 records looked at by Lemckert (2004) reported 10 or more calling males, with (Daly & Craven 2007) observing more than 10 frogs on five occasions over a five-year study.

2.2. Life Cycle

Littlejohn's Tree Frog is recorded to have two distinct breeding patterns. The majority of records of calling and breeding come from areas of still water (dams, swamps or temporary pools with longer hydroperiods) located in forests (Lemckert 2004). However, records from coastal southern NSW between approximately Nowra and Darkes Forest appear to mainly be associated with permanently flowing rocky creeks where larger pools with relatively slow water flows are used for breeding (Daly & Craven 2007; F. Lemckert, Pers. Obs.). The calling seasons are similarly disparate. The pond breeding frogs in the Watagan Mountains, have been recorded calling throughout the year, with activity being triggered by heavier rain events (Lemckert 2004), with a more elevated chance of calling occurring from late summer to early spring (Lemckert and Mahony 2008). The rocky stream breeding frogs however are listed by Daly & Craven (2007) as typically calling in late winter and spring and little calling activity outside of this time. The pattern followed in the Warragamba area is unknown.

In both cases males have been recorded calling from low vegetation or on the ground close to the breeding pools. Clutches of up to 60 eggs are attached to submerged twigs, stems or branches, often near the banks of still pools in clear, slowly flowing streams. Hatching occurs seven to eight days after laying and larval life span of a group of captive tadpoles was 124 days (Anstis 2013). Littlejohn's Tree Frog Tadpoles are black or very dark grey with dark grey bellies. Tadpoles grow to 65 mm in length (Anstis 2013). The eggs and tadpoles are mostly found in areas of water that receive extended exposure to sunlight and the tadpoles are notable for their very dark colouration that may assist in thermoregulation.

2.3. Ecology and Habitat Requirements

As noted above, breeding habitat for this species is broad. It has been to use rocky streams and semi-permanent dams (Barker et al. 1995), still water in dams, ditches, isolated pools and flooded hollows (Hero et al. 1991), dams, creeks and lagoons (Griffiths 1997), semi-permanent or permanent dams, ponds and creeks (Anstis 2002) and temporary pools when sufficient run-off water was available (White et al. 1994).

Littlejohn's Tree Frog is known to inhabit forest, coastal woodland and heath, but the species was not considered to be associated with any specific vegetation types (Lemckert 2004).

Non-breeding habitat is heath based forests and woodlands and the species has been recorded sheltering under leaf litter and low vegetation (Lemckert 2010) or under rocks on ridges distant from breeding sites. They have well-developed suckers on their toes which suggests that the species is also a capable climber (Hero et al. 2002).

Lemckert (2010) undertook a GIS based assessment of the species and found that the species is more likely to occur in grass-free, moist and sunny areas that are relatively flat (Lemckert 2010), but these variables were too broad to accurately predict where Littlejohn's Tree Frog would occur and the species was absent from many apparently suitable sites (Lemckert 2010).

Adult Littlejohn's Tree Frog presumably eat invertebrates, but their diet has not been investigated (Hero et al. 2002).

2.4. BioMetric Vegetation Types

In this Sydney Basin Region the Red-crowned Toadlet is listed to be associated with the following vegetation formations and classes:

Dry sclerophyll forests (shrub/grass sub-formation)

- Central Gorge Dry Sclerophyll Forests
- Cumberland Dry Sclerophyll Forests
- Southern Hinterland Dry Sclerophyll Forests

Dry sclerophyll forests (shrubby sub-formation)

- Coastal Dune Dry Sclerophyll Forests
- South Coast Wet Sclerophyll Forests
- South East Dry Sclerophyll Forests
- Southern Tableland Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Montane Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests
- Western Slopes Dry Sclerophyll Forests

Dry sclerophyll forests (shrubby sub-formation)

- South East Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Montane Dry Sclerophyll Forests
- Western Slopes Dry Sclerophyll Forests

Forested wetlands

- Eastern Riverine Forests

Freshwater wetlands

- Coastal Heath Swamps
- Montane Bogs and Fens

Grassy woodlands

- Tableland Clay Grassy Woodlands

Heathlands

- South Coast Heaths
- Sydney Coastal Heaths

- Sydney Montane Heaths

Miscellaneous ecosystems

- Water bodies, rivers, lakes, streams (not wetlands)

Rainforests

- Northern Warm Temperate Rainforests
- Southern Warm Temperate Rainforests

Wet sclerophyll forests (grassy sub-formation)

- Northern Hinterland Wet Sclerophyll Forests
- Southern Lowland Wet Sclerophyll Forests

Wet sclerophyll forests (shrubby sub-formation)

- North Coast Wet Sclerophyll Forests
- Southern Escarpment Wet Sclerophyll Forests

The wide range of predicted vegetation formations and vegetation types, as defined by DECCW (2011a), is likely to be a function of the cryptic nature of this species (i.e. adoption of the precautionary principle due to limited knowledge on definitive habitat characteristics). The presence of suitable breeding habitat with adjacent heath based native vegetation is the best determinant of the likelihood of Littlejohn's Frog being present in an area.

2.5. Status and Threats

Littlejohn's Tree Frog is currently listed as vulnerable under BC Act and under the EPBC Act, but is listed as of Least Concern under the IUCN redlist.

The OEH profile for this species lists the following threats to Littlejohn's Tree Frog:

- Loss of streamside vegetation through clearing or frequent burning.
- Changes to natural water flows and water quality.
- Predation of eggs and tadpoles by introduced fish.
- Infection by amphibian chytrid fungus.
- Disturbance to habitat and hydrology due to longwall mining.
- Climate change.
- Disturbance to forest and woodland breeding and non-breeding habitat by trail bike activity and other recreation.
- Poor knowledge of the current distribution and abundance of the species, particularly in the blue mountains, south coast and hinterland areas.
- Forest disturbance associated with forestry operations.
- Lack of understanding of taxonomy, particularly the status of southern populations

The IUCN Redlist profile lists only one major threat: "Logging might be a threat to the species' habitat. It has been found to persist in some logged areas but whether or not it can persist long-term is not known".

The SPRAT profile for this species (DoE 2018) raises the following as consideration of threats:

- White and Ehmann (1997) report Littlejohn's Tree Frog as dependent on relatively undisturbed forested areas and the species is sensitive to habitat changes.
- Lemckert (2004) noted sites in the Watagan Mountains being disturbed by logging and with limited land clearing adjacent to them, but the frog is absent from cleared lands and so land clearing is a threat.

- Daly & Craven (2007) state that the introduction of Mosquitofish (*Gambusia holbrooki*) and Yabby (*Cherax destructor*) into streams could reduce recruitment success.
- Chytridiomycosis is an unknown threat to this species.

In particular, the lack of records from coastal southern NSW and Victoria provide a reasonably strong suggestion that this disease may have impacted Littlejohn's Tree Frog.

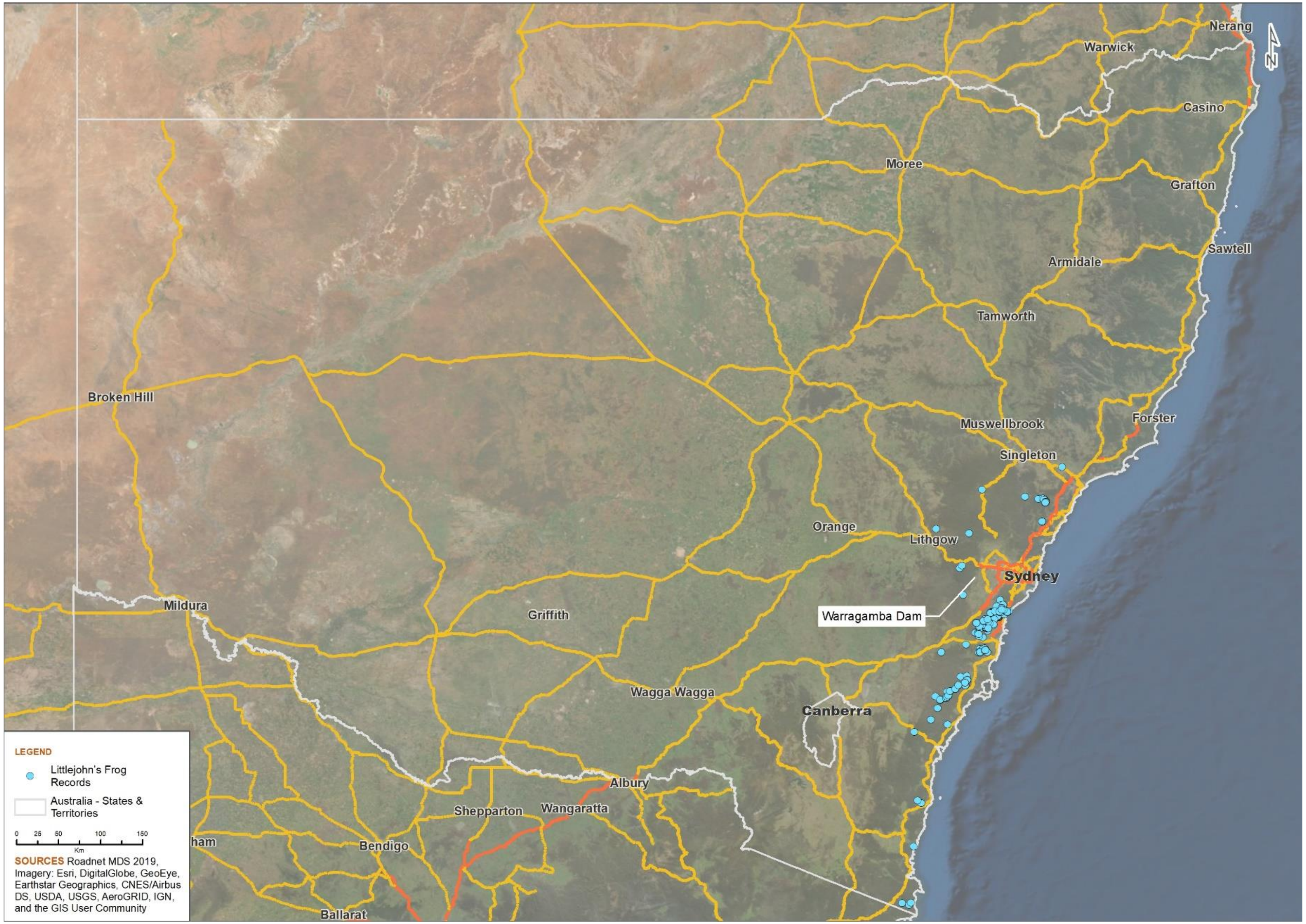

Figure 1 Records of Littlejohn's Frog in New South Wales.

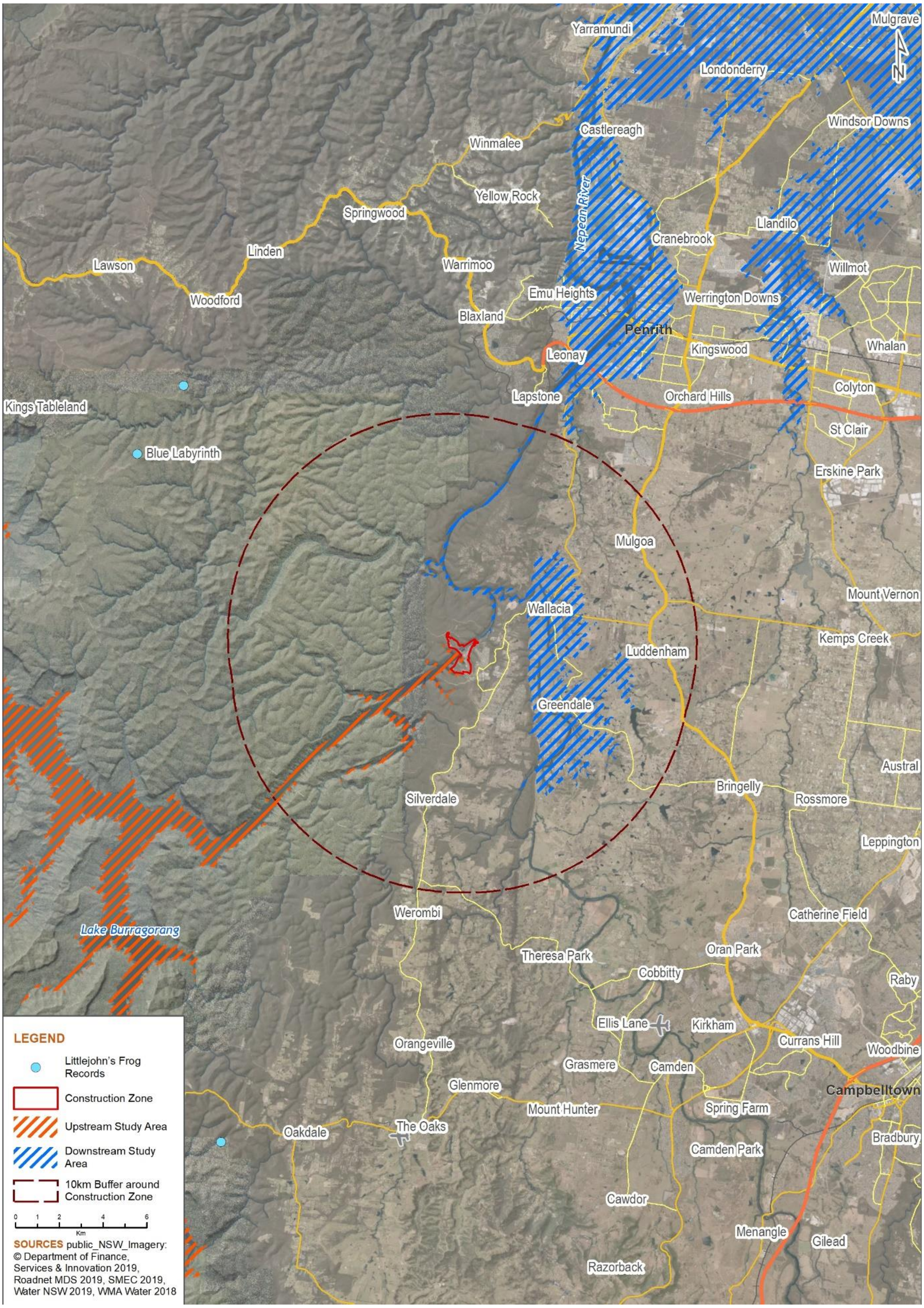

Figure 2 Records of Littlejohn's Frog in the locality

Figure 3. Construction footprint

3. Description of the Site

The footprint of the Warragamba Dam Raising development site is provided in Figure 2. The following information describing the development site and its surrounds is taken directly from the Warragamba Dam Raising Construction Biodiversity Assessment Report (SMEC 2010), unless otherwise acknowledged.

3.1. IBRA bioregions and IBRA subregions

The construction study area is located in the Interim Biogeographical Regionalisation of Australia Bioregion of the Sydney Basin and there are two subregions which are relevant to the assessment.

3.1.1. Bioregions

The development site and outer assessment circle are wholly located within the Sydney Basin Bioregion.

Development site: Sydney Basin Bioregion

Outer assessment circle: Sydney Basin Bioregion

OEH provides the following information on the Sydney Basin Bioregion:

The Sydney Basin Bioregion lies on the central east coast of NSW and covers an area of approximately 3.6 million hectares, which is the equivalent of 4.5 percent of NSW. The Sydney Basin Bioregion is one of two bioregions contained wholly within the state. It consists of a geological basin filled with near horizontal sandstones and shales of Permian to Triassic age that overlie older basement rocks of the Lachlan Fold Belt. The sedimentary rocks have been subject to uplift with gentle folding and minor faulting during the formation of the Great Dividing Range. Erosion by coastal streams has created a landscape of deep, cliffed gorges and remnant plateaus across which an east-west rainfall gradient and differences in soil control the vegetation of eucalypt forests, woodlands and heaths. The Sydney Basin Bioregion includes coastal landscapes of cliffs, beaches and estuaries.

The frontal slope of the Blue Mountains (where the site is located) is formed along the Lapstone monocline. A secondary flexure and similar escarpments occur at the coast forming the Hornsby Plateau and the Illawarra Escarpment. These structural features combine with different rock types and strong trends in joint patterns to control drainage patterns and the distribution of gorges and swamps.

3.1.2. Subregions

The development site is located across two IBRA subregions:

1. Wollemi subregion
2. Burragorang subregion.

Development site: Burragorang (19.59 hectares) and Wollemi (85.26 hectares).

Outer assessment circle: Burragorang (250.08 hectares), Wollemi (708.56 hectares), and Cumberland (40.48).

The outer assessment circle falls within both the Wollemi and Burragorang subregions, as well as within Cumberland subregion. The Wollemi, Burragorang, and Cumberland subregions are summarised in Table 1.

Table 1. Description of the subregions within Sydney Basin Bioregion occurring within the development site

SUBREGION	GEOLOGY	CHARACTERISTIC LANDFORMS	TYPICAL SOILS	VEGETATION
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. There are also a number of scattered volcanic necks distributed throughout the Wollemi subregion.	Characterised by the highest part of the Blue Mountains and other sandstone plateaus with benched rock outcrops.	Typically, soils are thin sands or deep yellow earths on plateaus, with thin texture contrast soils on shale benches. Organic sands in line swamps and joint crevices, while slope debris are found below cliffs, and sandy alluvium in pockets along the streams. On basalts, soils are red brown structured loams.	*Corymbia gummifera*, *Corymbia eximia*, *Angophora floribunda*, *Angophora costata*, *Eucalyptus sclerophylla*, and *Eucalyptus punctata* with diverse shrubs and heaths on plateau. Additionally, *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus agglomerata*, and *Syncarpia glomulifera* subsp. *glomulifera* and gully rainforests are present in gullies and canyon heads. *Eucalyptus vimilalis* and Blaxland's Stringybark on basalt. *Casuarina cunninghamiana* is found along main streams.
Burragorang	Comprised of Permian and Triassic sandstones and shales on the western edge of the Sydney Basin.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley	Typically, soils include rocky outcrops, texture contrast soils and uniform sands on sandstone. Cliff bases are generally pillowed with a sandy, clay matrix, alluviums contain rich loams.	Heath, shrubland and woodland with *Eucalyptus sieberi*, *Eucalyptus sclerophylla*, *Eucalyptus piperita* and *Corymbia gummifera* on sandstone similar to other parts of the Basin. *Eucalyptus deanei*, *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerata* immediately below escarpment passing to *Eucalyptus punctata*, *Eucalyptus crebra* and *Eucalyptus eugenoides* on rocky slopes. *Casuarina cunninghamiana* along main streams below the plateaus.
Cumberland	Triassic Wianamatta groups shales and sandstones, which are intruded by a small number of volcanic vents and partly covered by Tertiary river gravels and sands. There is quaternary alluvium along the mains streams.	Low rolling hills and wide valleys in a rain shadow area below the Blue Mountains. Volcanics from low hills in the shale landscapes. Swamps and lagoons on the floodplain of the Nepean River.	Typically, soils include a mixture of clays on volcanics, poor stony soils on older gravels, and high quality loams on floodplain alluvium.	*Eucalyptus moluccana, Eucalyptus tereticornis, Eucalyptus crebra* woodland with some *Corymbia macculata* on the shale hills. *Eucalyptus sclerophylla, Angophora floribunda*, and *Banksia serrata* on alluvial sands and gravels. *Angophora subvelutina, Eucalyptus amplifolia* and *Eucalyptus tereticornis* with abundant *Casuarina glauca* on river flats. Tall spike rush, and juncus with *Eucalyptus parramattensis* in lagoons and swamps.

3.2. NSW landscape regions (Mitchell Landscapes)

The development site is located across four landscape regions:

1. Kurrajong Fault Scarp
2. Lapstone Slopes
3. Burragorang Valley and Gorges
4. Nattai Plateau.

Development site: Kurrajong Fault Scarp (92.95 hectares); Lapstone Slopes (10.31 hectares); Burragorang Valley and Gorges (1.56 hectares); and Nattai Plateau (0.03 hectares)

Outer assessment circle: Kurrajong Fault Scarp (611.99 hectares); Lapstone Slopes (97.60 hectares); Burragorang Valley and Gorges (127.69 hectares); Silverdale Slopes (120.36 hectares); and Nattai Plateau (42.37 hectares)

Kurrajong Fault Scarp occurs over the majority of the development site (as measured by area) followed by Lapstone Slopes, Burragorang Valley and Gorges, and Nattai Plateau. Descriptions of each Mitchell Landscape are provided in Table 2.

Table 2. Description of the Mitchell Landscape

MITCHELL LANDSCAPE	DESCRIPTION
Kurrajong Fault Scarp	Dissected and broken slopes on Triassic Quartz sandstone and shale across the Lapstone monocline and Kurrajong fault scarp. Local dips on the sedimentary rocks up to 300 m, general elevation 100 to 250 m, local relief 100 m. Abundant rock outcrop with pockets of yellow-brown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of: *Eucalyptus agglomerata*, *Syncarpia glomulifera* subsp. *glomulifera*, Red *Corymbia gummifera*. *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus radiata*, *Eucalyptus punctata*, *Eucalyptus pilularis* and *Allocasuarina* sp. Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered *Eucalyptus tereticornis*, *Angophora floribunda* and *Eucalyptus globoidea* on the margins.
Lapstone Slopes	The frontal slope of the Blue Mountains formed by folding and faulting of Triassic quartz sandstone and shale with a veneer of Tertiary river gravels. A southern extension of the Kurrajong Fault Scarp landscape. Larger streams cut through the structural ridge in deep gorges, but smaller streams have accumulated organic sands in swamps and lagoons on the western side of the flexure. General elevation 50 to 300 m, local relief 180 m, steep dip slopes on the eastern face and benched faulted slopes on the west. Extensive rock outcrop, thin sandy soils with gravel and occasional white or yellow clay subsoils. Pockets of deep sand in some streams. *Corymbia gummifera*, *Corymbia eximia*, *Eucalyptus punctata*, *Allocasuarina torulosa*, *Eucalyptus sieberi*, *Eucalyptus radiata* with diverse shrubby understorey.

MITCHELL LANDSCAPE	DESCRIPTION
Burragorang Valley and Gorges	Deep steep sided benched slopes and gorge of the Wollondilly and Coxs Rivers incised into mostly horizontal Triassic quartz sandstone conglomerate, siltstone, and shale, cliffs to 150m high with waterfalls, general elevation 50 to 220 m, local relief 150 m. The gorge widens upstream and exposes underlying Permian chest, mudstones and conglomerate. Very extensive rock outcrop, thin yellow to yellow-brown silty sand and gravel with occasional white clay layers forming either shallow yellow earths or gleyed texture-contrast profiles. *Corymbia gummifera*, *Syncarpia glomulifera*, and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliffs upstream with *Eucalyptus tereticornis*, *Eucalyptus macrorhyncha*, *Eucalyptus crebra*, and *Eucalyptus mannifera*. Moist protected environments with *Eucalyptus saligna*, *Eucalyptus cypellocarpa*, *Eucalyptus muelleriana* and *Eucalyptus smithii*. Gallery forest of *Casuarina cunninghamiana* with *Eucalyptus deanei* and *Eucalyptus benthamii* along the main streams.
Nattai Plateau	Steeply dissected plateau remnants on lower Triassic lithic sandstone, shale and tuff, abundant rock outcrop and cliffs, steep debris slopes, general elevation 600 to 700 m, local relief 80 m. Shallow sand and occasional yellow texture-contrast soils. Forests of *Eucalyptus eugenioides*, *Eucalyptus fibrosa* subsp. *fibrosa*, *Callitris rhomboidea*, *Eucalyptus sieberi*, *Eucalyptus blaxlandii*, *Eucalyptus fastigata* and *Eucalyptus viminalis*.
Silverdale Slopes	Moderately undulating slopes descending to the east on gently dipping Triassic shales and sandstones. General elevation 230 to 630m, local relief 200m. Brown to yellow-brown texture-contrast soils. Woodland to forest with a shrubby understorey, common species; *Eucalyptus punctata*, *Eucalyptus albens*, *Eucalyptus paniculata*, *Eucalyptus crebra*, *Eucalyptus fibrosa*, *Eucalyptus moluccana*, *Allocasuarina torulosa*, *Eucalyptus eugenioides*, and occasional *Syncarpia glomulifera*.

3.3. Rivers and streams

The development site falls within the Warragamba catchment. Bordered on the west by the Great Dividing Range, the catchment stretches from north of Lithgow at the head of the Coxs River in the Blue Mountains, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River.

The proposed construction area includes areas of Lake Burragorang, the dam wall spillway and Warragamba River. Up until the dam wall, Lake Burragorang is considered to be a 9th order stream in accordance with the Strahler stream ordering method. The current geomorphological condition at the dam is characterised by altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplains.

3.4. Wetlands

One wetland (Lake Burragorang) has been mapped within the construction study area within the NSW Wetland shapefile. No important or local wetlands occur within the development site or outer assessment circle. There are a number of smaller dams mapped to the east of the development site, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 km of the development site.

3.5. Native vegetation

The development site is centred around Warragamba Dam, which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, the vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation. Instead much of the development site is comprised of vegetation typical of ridgetops on skeletal soils. The majority of the development site supports dry sclerophyll forest of shrubby sub-formation, as well as an area of wet sclerophyll forest. To the west of Warragamba Dam, to both the north and south of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenoides*, *Eucalyptus sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest which extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest Critically Endangered Ecological Community.

The development site is 104.85 hectares in size. A total of 54.37 ha of native vegetation has been mapped within the site with Table 3 providing a summary of the PCTs mapped as occurring, including vegetation formation, percent cleared within the Hawkesbury-Nepean catchment and extent within the development site. All of this vegetation is suitable for Littlejohn's Frog to use as shelter and feeding habitat.

Table 3. Summary of PCTs occurring within the development site

PCT CODE/ BVT CODE	PCT NAME	VEGETATION FORMATION	VEGETATION CLASS	% CLEARED WITHIN HN CATCHMENT	AREA WITHIN SITE (HA)
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	40	16.96
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	25	24.78
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	20	8.69
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Wet Sclerophyll Forests (Grassy sub-formation)	Northern Hinterland Wet Sclerophyll Forests	90	4.94

3.6. Landform, geology and soils

The study area is approximate 104.85 hectares and is located at and adjacent to Warragamba Dam. The elevation within the study area is varied, ranging between 21 metres AHD at its lowest point to 195 metres AHD at its highest point. The study area slopes from the top of the gorge down to the dam and Warragamba River.

The Soil Landscapes of Penrith 1:100,000 soil landscape sheet has mapped four soil landscapes within the outer assessment circle as outlined in Table 4 below.

Table 4. Soil landscape description

NAME	LANDSCAPE	SOILS	LIMITATIONS
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 meters, slopes 10-15%. Rock outcrop 25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop with broken scarps.	Shallow to moderately deep (30-100 cm) yellow earths and earthy sands on crests and on insides of benches; shallow siliceous sands on leading edges of benches; localised gleyed podzolic soils and yellow podzolic soils on shale lenses; shallow to moderately deep (<100 cm) siliceous sands and leached sands along drainage lines.	Steep slopes, water erosion hazard, rock outcrop, localised rockfall hazard, localised non-cohesive soils, shallow highly permeable soil, very low soil fertility.
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces on Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop.	Shallow (<50 cm) earthy sands and yellow earths; some siliceous sands / lithosols associated with rock outcrop.	Shallow, highly permeable soil, localised non-cohesive soils, very low soil fertility, localised water erosion hazard, localised rick outcrop.
Hawkesbury	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200 m, slopes >25%. Rock outcrop >50%. Narrow crests and ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders.	Shallow (<30 cm) discontinuous lithosols / siliceous sands, associated with rock outcrop; earthy sands, yellow earths and some locally deep sands on inside of benches and along joins and fractures; localised yellow and red podzolic soils associated with shale lenses, siliceous sands and secondary yellow earths along drainage lines.	Steep slopes, mass movement hazard, rockfall hazard, water erosion hazard, shallow soils, rock outcrop, non-cohesive soils (localised), stony, highly permeable soils of low fertility.
Blacktown	Gently undulating rises on Wianamatta Group shales. Local relief to 30 m, slopes usually >5%. Broad rounded crests and ridges with gently inclined slopes.	Shallow to moderately deep (>100 cm) hardsetting mottled texture contrast soils, red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and drainage lines.	Localised seasonal waterlogging, localised water erosion hazard, moderately reactive highly plastic subsoil, localised surface movement potential.

3.7. Hydrology

Lake Burragorang is the dominant hydrological feature of the study area. Created by damming the Warragamba River and flooding the Burragorang Valley, Lake Burragorang is four times the size of Sydney Harbour and is currently managed as Sydney's water supply dam.

Downstream of the dam is the Warragamba River. Water is discharged into Warragamba River when the dam spills. Water is also released into the Warragamba River (downstream of the Warragamba Weir) to provide a secure water supply to the population of North Richmond. Warragamba River is a 9th order Strahler stream and there are several small, unnamed ephemeral tributaries within study area.

3.8. Climate

There are no weather stations within the construction area, but Table 5 provides summaries of the weather conditions for stations located around the area. The climate for the area is mild with moderate rainfalls.

Table 5. Key climatic statistics for weather stations near the survey area.

WEATHER STATION	MEAN ANNUAL RAINFALL (MM)	MEAN MAXIMUM TEMPERATURE (°C)	MEAN MINIMUM TEMPERATURE (°C)
Jenolan Caves (1895-) (24 km W, 690 m higher)	970.6	25.6	0.2
Penrith Lakes AWS (1995-) (20 km NNE, 90 m lower)	718.6	31.0	5.3
Springwood (1883-) (21 km N, 250 m higher)	1082.1	29.0	6.5
Katoomba (1885-) (15 km N, 890 m higher)	1399.6	23.4	2.6
Picton Council Depot (1880-) (15 km SE, 60 m higher)	794.3	29.3	1.7

3.9. Land uses

The development footprint is located on land zoned as SP2 Infrastructure (Water Supply) under the *Wollondilly Local Environmental Plan (LEP) 2011* (Figure 4). This land around the dam serves as operational support for the existing dam and consists of cleared and vegetated areas, dam support facilities, access roads and parks. The proposed works would be permissible within this land zone type and construction activities would be contained within this zone.

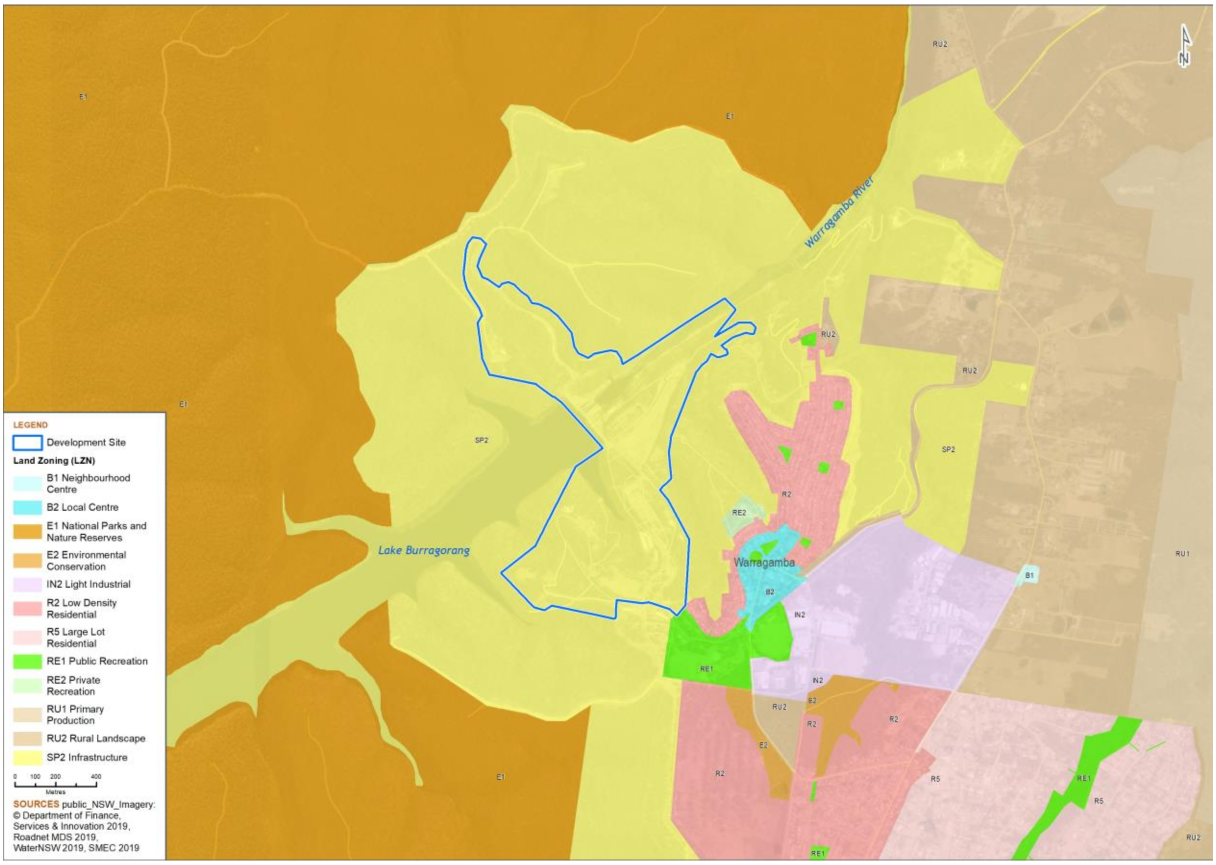

Figure 4. Land use zones

3.10. Habitat

The construction area (Figure 5) is comprised mainly of areas of sclerophyll woodland growing on the slopes of a steeply incised river valley. Rock outcrops are present broadly across the construction study area and there are several gully lines with ephemeral water courses located on both sides of the Warragamba River valley (Figure 6).

The vegetation present around the dam wall on the slopes of the valley is generally intact due to the prohibited access to the Warragamba Dam catchment. Hence the vegetation represents suitable habitat for the Littlejohn's Frog and the water quality of the ephemeral creeks feeding into the Warragamba River and the dam itself should not have been affected by surrounding urbanisation.

The Warragamba River directly below the dam wall has a highly modified flow and exists only as a series of large pools and sometimes stagnant pools. This is a result of the outflow pipe being situated not on the other side of the wall but instead approximately 1.7 km downstream of the wall. The vegetation lining the river up to the outflow pipe is a disturbed community with a significant presence of weeds.

Some vegetation has been historically cleared to provide infrastructure for the dam that includes the dam itself as well as the ancillary roads, buildings and areas for tourism (e.g. picnic areas) (Figure 5).

The study site retains full connectivity with large undisturbed tracts of wet/ mesic/ dry/ swamp sclerophyll forests that are retained in the catchment and the impacts of roads and the effects of rural land uses (i.e. managed midstorey) are minimal.

The site was visited and viewed by myself on the days of the 12th and 13th of December 2017.

Figure 5. Construction footprint

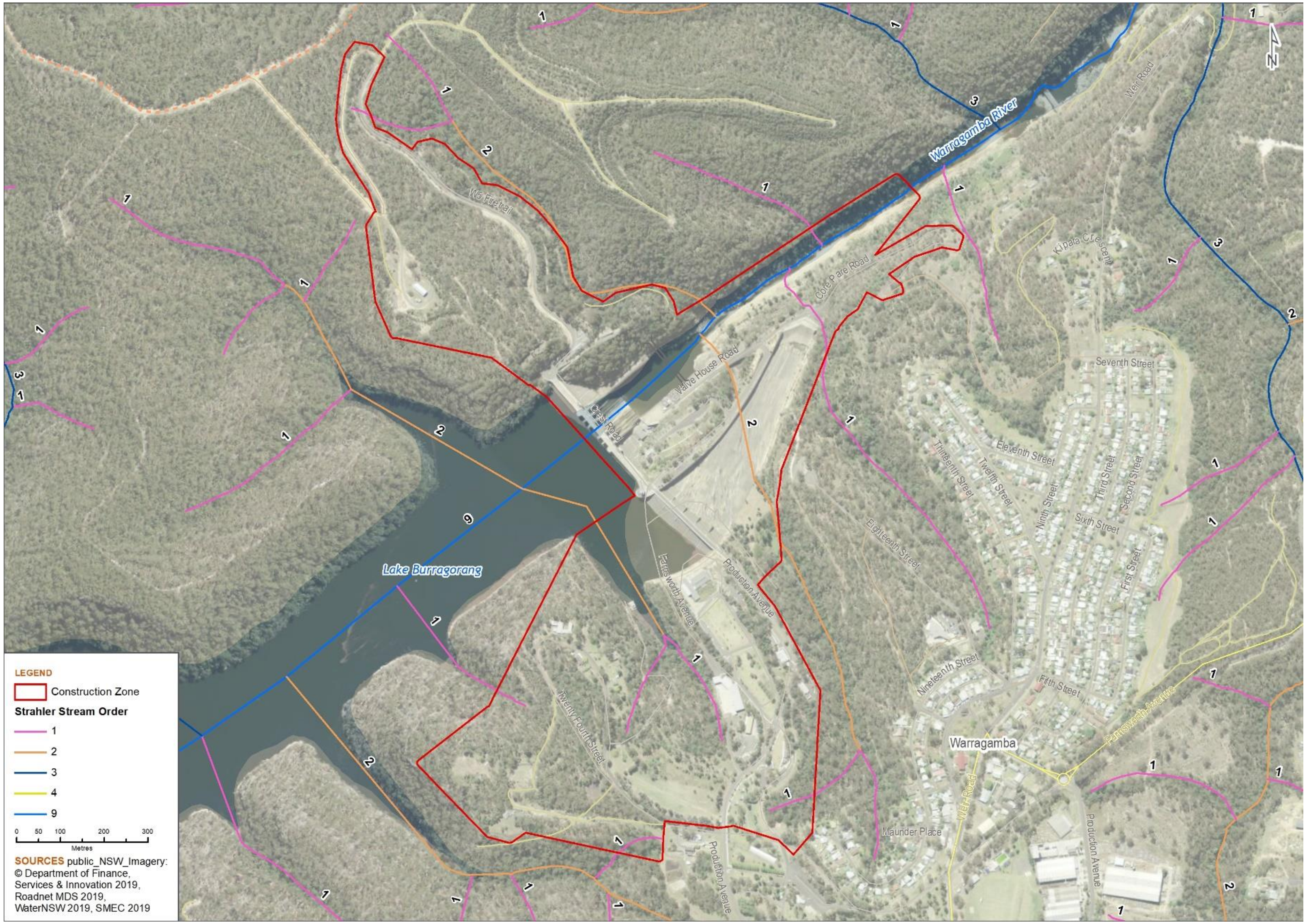

Figure 6. Stream order

4. Expert Assessment of Impacts

4.1.1. Local records

There are no Wildlife Atlas database records of the Littlejohn's Frog from within the construction area and none available within a 10 km radius of the site (Figure 2).

4.1.2. Breeding Habitat

Littlejohn's Frog is reliant for breeding on permanently flowing shallow rocky creeks (as occurs to the south of Sydney) or in dams or pools within areas of taller forest (typical of sites to the north of Sydney). Both types of breeding habitat contain few or no fish and sites around the Sydney Basin are all associated with Triassic Sandstones.

Streams present in the study area are either the ephemeral streams on the sides of valley or the Warragamba River immediately below the dam wall, which rarely flows and consists of a series of large still pools with deep water and fish. There are no dams present in the study area.

Therefore, the study area does contain breeding habitat suitable for this species.

4.1.3. Shelter Habitat

Littlejohn's Frog shelters under logs, rocks and leaf litter or is thought to shelter in tree hollows. Radio-tracking completed by myself has found them staying within 50 m of the breeding sites up to a month after breeding, but there are records of Littlejohn's Frogs moving 100-200 m from streams to seek shelter under rocks. They only known to be present at sites within native vegetation that has not been significantly impacted by weeds.

All of the remaining areas of intact native vegetation on the valley sides represents suitable non-breeding shelter habitat. The disturbed vegetation lining the Warragamba River immediately below the dam wall is considered to be unsuitable for Littlejohn's Frog as the vegetation is disturbed and contains a significant cover of weeds.

4.1.4. Foraging Habitat

Littlejohn's Frog has no known specific dietary requirements that might limit its distribution across the landscape and it is assumed that this species is foraging in the same area as it the sheltering habitat.

4.1.5. Total area of habitat impacted

No area of habitat for this species is considered to be potentially impacted by the proposed works as the absence of breeding habitat would prevent the species using the site for any activities. This is consistent with the lack of records for the species from the locality.

5. Conclusion

The Littlejohn's Frog is not known to be present within the WDR construction area and, in my expert opinion, it is not present within that area. There is not suitable breeding habitat within the development site as there are no permanent dams or ponds with suitable water quality and that are fish free that are located within the development site. There is also no suitable breeding habitat evident that is close enough to the construction area to result enable non-breeding frogs migrating to the area to use it as non-breeding habitat. On that basis there will be no impact on Littlejohn's Frog and no offsets are required for this species. A species polygon does not need to be prepared.

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7. Appendix A. CV – Dr. Frank Lemckert

Frank has been a professional scientist since 1992, specialising in understanding and managing the ecology and management of threatened species and particularly frogs. Frank has conducted ecological work throughout eastern Australia (NSW, Victoria, Queensland), establishing long-term research and monitoring programs into the management of fauna and developing strategies to mitigate the impacts of human disturbances. He has worked extensively with the NSW state and federal Governments on varying issues of fauna and flora management including the preparation of a draft NSW/National recovery plan for the Giant Burrowing Frog (*Heleioporus australiacus*) and is an accredited expert on the Green and Golden Bell Frog (*Litoria aurea*). Frank has prepared reports on endemism and representation in reserves of flora and fauna for the Commonwealth, represented the NSW Forestry Commission in license negotiations for the Comprehensive Regional Assessment process (2000) and provided expert ecological advice on illegal land clearing for the NSW and Commonwealth Governments. He has authored over 90 peer-reviewed publications. Frank is a research associate with the Australian Museum and University of Newcastle, convenor of the NSW Declining Frog Working Group and a member of the IUCN's Amphibian Specialist Group. He is a recognised expert in frog ecology and management, but has completed management related projects and works on a range of terrestrial vertebrate fauna.

Frank's primary role as a consultant has been to use his expertise and experience in technical writing and threatened species legislation to develop and maintain quality assurance in project reporting including:

- Two Species Impact Statements.
- >100 flora and fauna reports and assessments of significance using the EP&A Act and EPBC Act.
- Biodiversity Assessment Reports for Warragamba Dam Raising, Nowra Bridge, Golden Highway and Eurobodalla Dam.
- Manager for the Oxley Highway to Kempsey and Frederickton to Eungai ecological monitoring program.
- Construction and Environmental Management Plans, Monitoring Plans and Vegetation Management Plans for roads at Port Macquarie, Berry to Bomaderry and South Nowra.
- Nest Box, microbat and Green and Golden Bell Frog management plans for the Berry to Bomaderry and Oxley Highway to Kempsey Highway Upgrades.
- Review of monitoring strategies for the Woolgoolga to Ballina and Warrell Creek to Nambucca Heads programs for the Pacific Highway Upgrade.
- Review of two proposed Coal Seam Gas Impact Assessment methods for Matters of National Environmental Significance (contracted by the Commonwealth Government).
- Provision of species credit species expert reports for the Warragamba Dam raising project and Western Sydney Growth Centres Biocertification.

QUALIFICATIONS

- Bachelor of Science, University of Sydney, 1984 (Terrestrial Ecology and Marine Management)
- Master of Science, University of Sydney, 1991 (Population biology of the Common Froglet)
- PhD, University of Newcastle, 2009 (Management of forest frogs in timber production forests of NSW)

PROJECT EXPERIENCE

Ecological impact assessment

- Expert report on the green and golden bell frog for the western sydney growth areas biocertification project (2018-2019)
- Warragamba dam raising project target surveys, impact assessments, expert reporting (six species) and q/a for water nsw (2018-19)
- Shading impacts for proposed building works at homebush, nsw, piety pty ltd (2018)
- Granite hills windfarm bird and bat strike modelling and ecological impact assessment, nimmitabel, akuo energy (2018) and elysian windfarm, nimmitabel, akuo energy (2018)
- Vegetation removal and threatened frog management strategies, new intercity fleet management facility, john holland group (2018-19)
- Eurobodalla dam biodiversity assessment report, eurobodalla shire council (2017-18)
- Nowra bridge eis ecological assessments, nsw rms (2018)
- Heathcote road upgrade impact assessment and review of mitigation measures, nsw rms (2018-2019)
- Mona vale road threatened fauna expert survey and impact assessment, ecosure and nsw rms (2015-2016).

Government reviews/reports

- Biodiversity assessment method frog survey guidelines for species credit species (2019)
- Expert review of biodiversity impact assessment report for the hornsby quarry rehabilitation project (2019)
- Review of impact assessment pathways for two lpng projects, commonwealth government (2013)
- Expert advice on impacts of illegal land clearing at somersby, commonwealth government (2015)
- Expert advice on impacts of illegal land clearing at evans head, nsw state government (2016)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Review of monitoring strategies for the woolgoolga to ballina and warrell creek to nambucca heads programs for the pacific highway upgrade, nsw rms (2014)
- Hornsby council expert witness for development impacts at dural, hornsby shire council (2016)
- Expert representing forests nsw in the comprehensive reginal assessment program for the regional forest agreement program (1999-2001)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Flora and fauna representation in the australian reserve system, commonwealth government (2010)
- Flora and fauna endemism patterns across australia, commonwealth government (2009)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Expert review of fauna and flora impacts for 13 nsw forestry commission eis reports (1992-94).

EPBC referrals

- Green and golden bell frog (*litoria aurea*) referrals for the princes highway upgrade at south nowra, nsw rms
- Austen quarry (*eucalyptus pulverulenta*), hartley, hy-tec industries (2014-15)
- Marys mount koala (*phascolarctos cinereus*) referral, gunnedah quarry products (2015).

Monitoring programs

- Oxley highway to kempsey threatened biodiversity monitoring, nsw rms (2013-2017)
- Green and golden bell frog baseline monitoring program at meroo lakes, nsw oeh (2016-17)
- Fcnsw statewide ecological monitoring program, forestry corporation of nsw (2009-10)
- Threatened fauna monitoring hume highway, kapooka, nsw rms (2018).

Plans of management / strategies

- Commonwealth/nsw giant burrowing frog recovery plan, dewha/decc (2012)
- Eastern bentwing-bat management plan, gerringong, nsw rms (2014)
- Nestbox, microbat and green and golden bell frog management plans, berry to bomaderry upgrade of the princes highway, nsw rms (2017)
- Green and golden bell frog surveys and monitoring, princes highway upgrades at south nowra and berry to bomaderry, nsw rms (2012-2017)
- Green and golden bell frog management strategy, princes highway upgrade, nsw rms (2012-2014)
- Green and golden bell frog pre-clearing works kooragang island (daracon 2016 & current)
- Microbat management plan for clarencetown bridge, nsw rms (2016)
- Expert review of threatened frog management plan - woolgoolga to ballina upgrade, nsw rms (2014)
- Threatened microbat management plan for warringah mall, northern beaches council (2014)
- Threatened frog modelled habitat requirements, hornsby shire council (2016).

Training

- Lead instructor > 50 wildlife training schools run in nsw, act and victoria providing presentations on the survey, identification and management of all flora and fauna. This included detailed instruction on the management of threatened wading and aquatic birds and other aquatic species presented to queensland, victorian, nsw and commonwealth government staff (1993-2017)
- Private forestry survey requirements, victorian timber (2016).

Publications

Book Chapters

Hecnar S. J., & Lemckert, F.L. 2012. Habitat Protection: Refuges and Reserves. Pp 3636-3675 In Biology of the Amphibia Volume 10 - Conservation and Decline of Amphibians: Ecology, Effects of Humans, and Management. H. Heatwole (Ed.). Surrey-Beatty and Sons, Sydney.

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Appendix K Expert Report: Stuttering Frog

Member of the Surbana Jurong Group

Warragamba Dam Raising Construction Area

Expert report – Stuttering Frog

Prepared for: Water for NSW
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SMEC Australia

This report is confidential and is provided solely for the purposes of providing an expert report to assess the expected distribution and abundance of the Stuttering Frog in the area to be impacted by the construction works being completed to raise the wall of Warragamba Dam. This report is provided pursuant to a Consultancy Agreement between SMEC Australia Pty Limited ("SMEC") and Water NSW under which SMEC undertook to perform a specific and limited task for Water NSW. This report is strictly limited to the matters stated in it and subject to the various assumptions, qualifications and limitations in it and does not apply by implication to other matters. SMEC makes no representation that the scope, assumptions, qualifications and exclusions set out in this report will be suitable or sufficient for other purposes nor that the content of the report covers all matters which you may regard as material for your purposes.

This report must be read as a whole. The executive summary is not a substitute for this. Any subsequent report must be read in conjunction with this report.

The report supersedes all previous draft or interim reports, whether written or presented orally, before the date of this report. This report has not and will not be updated for events or transactions occurring after the date of the report or any other matters which might have a material effect on its contents or which come to light after the date of the report. SMEC is not obliged to inform you of any such event, transaction or matter nor to update the report for anything that occurs, or of which SMEC becomes aware, after the date of this report.

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Abbreviations and acronyms

Term	Definition
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
DOEE	Commonwealth Department of the Environment and Energy
DPIE	Department of Planning, Industry and Environment
EMP	Environmental Management Plan
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FBA	Framework for Biodiversity Assessment
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature
LGA	Local Government Authority
MNES	Matters of National Environmental Significance
OEH	Office of Environment and Heritage
PMST	Protected Matters Search Tool
TPZ	Technical Advisor
WNSW	Water for New South Wales

1. Introduction

1.1. Background

SMEC has been engaged by Water NSW to undertake and complete an assessment of the impacts of the proposed Warragamba Dam Raising project on threatened Biodiversity.

This expert report will assess the impacts that are predicted to occur as a result of the construction activities that are planned to take place in order to raise the wall of Warragamba Dam. This will Involve direct effects such as clearing of vegetation for roads and material lay-down areas as well as indirect effects including increased levels of dust and noise. These impacts are being assessed using the Framework for Biodiversity Assessment (FBA) as directed by the SEARs provided by OEH on 30 June 2017 and reissued 13 March 2018.

1.2. Reasons for the Expert Report

An expert report may be prepared under section 6.6 of the FBA where it states:

Using expert reports instead of undertaking a survey

6.6.2.1 An expert report may be obtained instead of undertaking a threatened species survey at a development site.

6.6.2.2 An expert report must only be prepared by a person who is accredited by the Chief Executive of OEH under section 142B(1)(b) of the TSC Act, or a person who, in the opinion of the Chief Executive of OEH possesses specialised knowledge based on training, study or experience to provide an expert opinion in relation to the biodiversity values to which an expert report relates.

6.6.2.3 The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report.

6.6.2.4 An expert report can only be used instead of a survey for species to which species credits apply.

6.6.2.5 An expert report must set out whether:

(a) for development sites – the species is unlikely to be present on the development site – in this case no further assessment of the species is required, or

(b) for all development sites – the species is likely to be present on the site – in this case the expert report must provide an estimate of the number of individuals or area of habitat to be impacted by the development or the management actions (according to the unit of measurement identified for the species in the Threatened Species Profile Database).

An expert report may only be used for those threatened species and populations to which species credits apply, not for any threatened species to which ecosystems apply.

In this case, an expert report has been provided in relation to the Stuttering Frog (*Mixophyes balbus)*, which is listed as vulnerable under the BC Act, and under the EPBC Act, and is a species credit species. An expert report has been prepared due to the difficulty in meeting the survey requirements set out in the FBA. The area to be covered is inaccessible as a water catchment area, especially during the necessary wet conditions for surveys, necessitating that an expert report be produced to consider the potential for this species to be present and extent of any possible occurrence.

1.3. Species Expert

Dr Francis Lemckert

Dr Lemckert is an Ecologist that has been undertaking studies into the ecology and management of frogs since 1986 and has been a principal ecological consultant since 2011. His skills include survey design/ implementation/ targeted species surveys, data handling, analysis and interpretation and the production of high level reports including papers published in international peer-reviewed journals and technical reports and recovery plans for the Commonwealth and NSW Governments. He has also been an expert witness in regards to considerations of the impacts of potentially illegal clearing for the Commonwealth, NSW and Local Governments (Hornsby Council) and provided expert advice to NSW DPI in regards to court considerations over the potential for forestry operations to impact on rock outcrop dependent species. Dr Lemckert represented Forests NSW (now Forestry Corporation NSW) as a reptile and amphibian expert in the Comprehensive Regional Assessments and Regional Forest Agreement Process carried out between 2000 and 2002 and as an expert in fauna management for negotiations over a new Threatened Species License for harvesting operations in 2014. He provided an expert review of the developed assessment process for impacts on Matters of National Environmental Significance for two proposed Coal Seam Gas Developments in Queensland and has completed two rounds of expert review of the status of Australia's amphibians for the IUCN.

Dr Lemckert is an acknowledged expert on eastern Australian frogs having completed his MSc & PhD studies researching the ecology and management of frogs and has published over 70 papers (or book chapters) on frog ecology and management in peer-reviewed journals. He has been engaged by both the NSW and Commonwealth Governments as an expert witness in court cases assessing the impacts of land clearing on threatened frogs, is a member of the Amphibian Specialist Group of the IUCN, secretary of the NSW Declining Frog Working Group of NSW and past president of the Australian Society of Herpetologists. He has been the co-supervisor of two PhD students and a Master of Applied Science Student who completed theses addressing frog conservation and management in NSW.

In regards to the Stuttering Frog (*Mixophyes balbus*), Dr Lemckert can demonstrate his expertise through the following publications that include this species:

Gillespie, G., Robertson, P., Hines, H., Lemckert, F. & Hero, J.-M. 2009. *Mixophyes balbus*. The IUCN Red List of Threatened Species 2009: e.T13595A4220629. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T13595A4220629.en. Downloaded on 17 May 2018.

Gillespie, G., Roberston, P., Hines, H., Lemckert, F. & Hero, J-M. 2008. *Mixophyes balbus*. Pp 422 In: Threatened Amphibians of the World. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani & B. E. Young (Eds). Lynx Edicions, Barcelona, Spain.

Lemckert, F.L. & Mahony, M.J. 2008. Core calling periods of the frogs of temperate New South Wales, Australia. Herpetological Conservation and Biology 3:71-76.

Slatyer, C., Rosauer, D. & Lemckert, F. 2007. An assessment of endemism and species richness patterns in the Australian Anura. Journal of Biogeography 34:583-596.

Hero, J-M., Morrison, C., Gillespie, G., Roberts, J.D., Newell, D., Meyer, E., McDonald, K., Lemckert, F., Mahony, M., Osborne, W., Hines, H., Richards, S., Hoskin, C., Clarke, J., Doak, N. & Shoo, L. 2006. Overview of the conservation status of Australian Frogs. Pacific Conservation Biology 12:313-320.

Green, M., Thompson, M.B. & Lemckert, F.L. 2004. The effects of suspended sediments on the tadpoles of two stream-breeding and forest dwelling frogs, *Mixophyes balbus* and *Heleioporus* *australiacus*. Pp 713-720 In: Conservation of Australia's Forest Fauna II. D. Lunney (Ed). Royal Zoological Society of NSW, Sydney.

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Lemckert, F. and Morse, R. (1999). Frogs of the timber production forests of the Dorrigo escarpment in northern New South Wales: an inventory of species present and the conservation of threatened species. In: A. Campbell, ed. Declines and Disappearances of Australian Frogs. Pages 72-80. Environment Australia, Canberra.

Lemckert, F. & Shoulder, J. (2007). The diets of three sympatric barred river frogs (Anura: Myobatrachidae) from southeastern Australia. Herpetological Review 38:152-154.

Lemckert, F., Potter, M., Smith, B. & Bruest, T. (1997). Recent records of the southern barred frog (*Mixophyes balbus*) from the south coast of NSW. Herpetofauna 27:60-62.

Dr Lemckert has also undertaken the following actions as a result of his recognised expertise in this species:

- Was invited to provide a profile for this species for the Arkive online fauna database: See http://www.arkive.org/species/GES/amphibians
- Was asked to advise in the preparation of the recovery plan for stream frogs of south-east Queensland 2001-2005 (Hines et al. 2002).
- Provided expert opinion on the habitat requirements, sub-population status and reservation requirements for the Stuttering Frog during the NSW Government's Comprehensive Regional Assessment program completed in 2000-2001.

Dr Lemckert full CV is provided as Appendix A.

2. Species Information

2.1. Description

The Stuttering Frog is a relatively large (females grow up 8 cm in length) ground dwelling frog of the Australian frog family Myobatrachidae. Individuals have vertical pupils, well developed webbing on the feet, broad barring on the hind legs and a black line from the snout, through the eye and above the 'ear'. The colour on the dorsum is brown to olive-green and may be broken into irregular blotches. The underside is creamy-white and the upper lip is also creamy, but with interruptions of darker markings. Adults have a pale-blue crescent across the upper half of the eye whereas juveniles have orange gold upper eyes.

2.2. Distribution and Abundance

The Stuttering Frog has a historic distribution that includes the plateaus and eastern slopes of the Great Dividing Range from the Cann River catchment in far East Gippsland, Victoria, to tributaries of the Timbarra River near Drake, New South Wales (Figure 1). There appears to be altitude related cline in its distribution with the species found at lower altitudes in the south (down to as low as 20 m ASL) to being only located at higher altitudes (up to 1400 m) in the far north. This may indicate it has a preferred specific temperature range that limits the areas it inhabits. The historic extent of occurrence for the Stuttering Frog is approximately 110 000 km^2 (Mahony et al. 1997).

The majority of records for this species are from the northern half of NSW and particularly north of the Hunter River. The species was never known to be common in the southern half of its range and has only been found in Victoria on three occasions (Tennyson Creek, Cann River and Jones Creek). It is now thought to be extinct in that state (Gillespie & Hines 1999). The species has been recorded to also have declined and disappeared from a number of locations in New South Wales where it was once considered to be common (Anstis 2013; Mahony 1993). Records from the southern half of NSW have declined notably since the 1970s and surveys in south-east New South Wales post 1990 located individuals at only a few sites (Daly 1998; Lemckert et al. 1997). The last population known south of Sydney was discovered in 2000 at Macquarie Pass National Park. A captive population was established from tadpoles from the population, but the wild now looks to be extinct and so the Stuttering Frog has now not been recorded in the wild south of the Sydney Basin within the last decade.

In regards to the Sydney Basin and immediate surrounds (see Figure 2), the records available are concentrated in the Watagan Mountains, where the species is still present, and around Macquarie Pass, where it is now extinct. The only records of the species from the Blue Mountains are to the west with a population at Ruby Creek being recorded into the early 2000s, but there are no sightings in the last 10 years and the current status of that population is not known. There are no other recent records south of the Hawkesbury River. North of the Hawkesbury there are records from the Watagan Mountains including in Ourimbah and Olney State Forests and the species remains present at these sites with apparently stable populations. Further north past the Hunter River the species has maintained or recovered to relatively normal numbers in most areas and can be easily detected through most of that range.

Of importance in regard to longer term management considerations is the genetic evidence that suggests the Stuttering Frog is probably a composite of two species, with the divide being in the Barrington Region. Any population in the study area would form part of the rarer southern species.

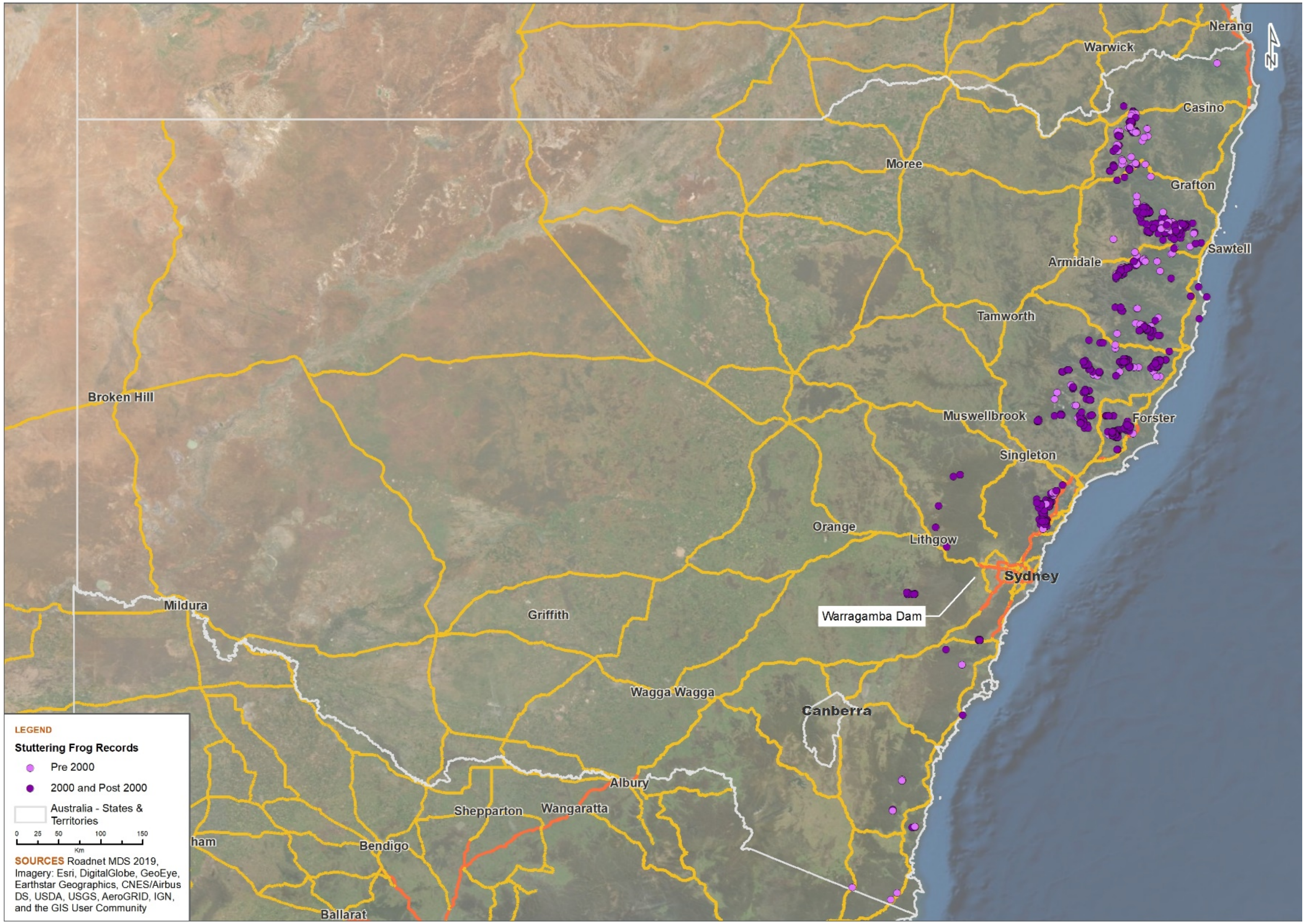

Figure 1. Location of Stuttering Frog records in NSW. Note the difference in records pre and post-2000.

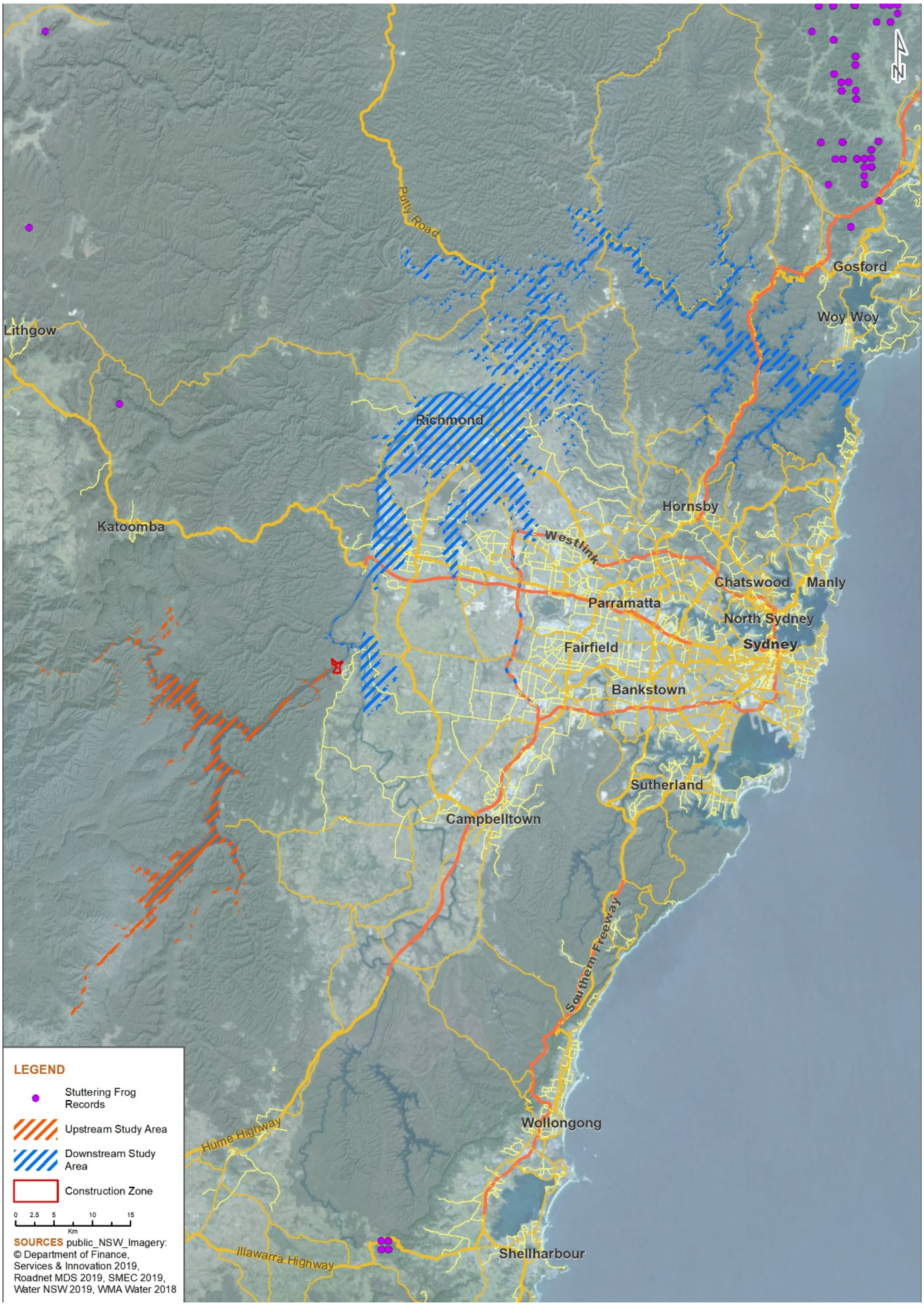

Figure 2 Location of Stuttering Frog records in the Sydney Basin.

2.3. Life Cycle

The Stuttering Frog is a species that is known to breed along streams with permanent or near permanent water flows, typically 3rd-4th order streams, located within areas of wetter forests. Breeding is triggered by heavy rain and can potentially occur all year, but much more typically occurs from late summer to early spring. Breeding does not occur in conjunction with rainfall, but rather several days afterwards when creek flows have returned to a steady normal flow. This presumably provides a relatively certain water level and flow during egg development.

Males call from close to slow flowing pools, often buried under leaf litter or under logs or low vegetation, but also in exposed positions when the environment is warm and wet. The call is a relatively soft grating 'wuh uh uh uh'. In the southern species that is the entire call, but north of the Barrington Region they include multiple o, o, o sounds as a second part of the call, which may be the obvious distinguishing feature between the two putative species. The stuttering call gives the species its common name.

Females construct a nest in an area of shallow running water that occurs between pools in relatively wide, flat sections of mountain streams (Knowles et al. 1998). They create a nest by rotating in loose material to excavate out a circular cavity where approximately 500 to 550 pigmented eggs (2.8 mm diameter) are deposited as a single layer either onto the loose substrate or directly onto bed rock (Knowles et al. 1998; Watson & Martin 1973). The eggs hatch after several days and the tadpoles stay within the nest until they are either strong enough to swim free or are washed out by water flows. Laying eggs into shallow areas of water is likely an adaptation to keep tadpoles away from fish until they have developed further and are more capable swimmers.

The tadpoles are dark in colouration with obvious spotting along the dorsal surface and particularly the tail fins. The develop within pools in the stream with the aquatic phase of the life cycle lasting up to a year (Anstis 2013).

2.4. Ecology and Habitat Requirements

The Stuttering Frog is typically found in association with streams located in temperate and sub-tropical rainforest and wet sclerophyll forest, but has also been recorded in tableland riparian vegetation and moist gullies in dryer forests (Mahony et al. 1997; Gillespie & Hines 1999; Lemckert and Morse 1999). In north-east New South Wales, statistical modelling was used to investigate the relationship of the Stuttering Frog with 24 environmental predictors (Gillespie & Hines 1999). The species showed a preference for the interiors of large forest tracts in areas with relatively cool mean annual temperatures. These sites are typically free from any disturbance with a thick canopy and relatively simple understorey. South of the Hunter River the sites historically inhabited by the Stuttering Frog were larger permanent flowing streams in large tracts of tall wet sclerophyll forest or rainforest and the species did not appear to be associated with dry forests in any way. The species is not associated with isolated ponds (e.g., forest dams) or ephemeral pools.

During periods of breeding activity adults typically shelter under leaf litter and logs close to the breeding stream. Outside of breeding times individuals have often been found on roads at more than 100 m away from the nearest waterbody indicating that individuals move widely through the forest when moist conditions prevail (Mahony 1993; Lemckert & Morse 1999). A limited radio-tracking study of individuals of both sexes conducted near Dorrigo found frogs regularly sheltering in deep (>10 cm) leaf litter immediately adjacent to the roads that they were caught on (F. Lemckert Unpubl. Data). This contrasts strongly with the behaviour of the Giant Barred Frog that has consistently been found to rarely move more than 30 m from its breeding stream.

As noted before, tadpoles develop in clear permanent streams where they are thought to feed on any organic material present in the stream bed. Tadpoles do occur with several species of native fish

(Mahony et al. 1997), but the effects of introduced fish such as trout, whilst potentially serious, are not clear (Hunter and Gillespie 2011).

Adult frogs feed on a wide range of invertebrates and small vertebrates (Lemckert and Shoulder 2007) and do not appear to have any specific dietary requirements.

2.5. BioMetric Vegetation Types

In this Sydney Basin Region the Stuttering Frog is listed to be associated with the following vegetation formations and classes:

Dry sclerophyll forests (shrub/grass sub-formation)

- Central Gorge Dry Sclerophyll Forests
- New England Dry Sclerophyll Forests
- Northern Gorge Dry Sclerophyll Forests
- Upper Riverina Dry Sclerophyll Forests

Dry sclerophyll forests (shrubby sub-formation)

- Northern Escarpment Dry Sclerophyll Forests
- Northern Tableland Dry Sclerophyll Forests
- South Coast Wet Sclerophyll Forests
- South East Dry Sclerophyll Forests
- Southern Tableland Dry Sclerophyll Forests
- Sydney Coastal Dry Sclerophyll Forests
- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Montane Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests
- Western Slopes Dry Sclerophyll Forests

Forested wetlands

- Coastal Floodplain Wetlands
- Eastern Riverine Forests

Freshwater wetlands

- Coastal Freshwater Lagoons
- Coastal Heath Swamps

Grassy woodlands

- New England Grassy Woodlands
- Southern Tableland Grassy Woodlands
- Tableland Clay Grassy Woodlands
- Western Slopes Grassy Woodlands

Heathlands

- Sydney Coastal Heaths
- Sydney Montane Heaths

Miscellaneous ecosystems

- Water bodies, rivers, lakes, streams (not wetlands) Water bodies, rivers, lakes, streams (not wetlands)

Rainforests

- Cool Temperate Rainforests
- Dry Rainforests Black Bean
- Littoral Rainforests
- Northern Warm Temperate Rainforests
- Southern Warm Temperate Rainforests
- Subtropical Rainforests

Wet sclerophyll forests (grassy sub-formation)

- Northern Hinterland Wet Sclerophyll Forests
- Northern Tableland Wet Sclerophyll Forests
- Southern Lowland Wet Sclerophyll Forests
- Southern Tableland Wet Sclerophyll Forests

Wet sclerophyll forests (shrubby sub-formation)

- North Coast Wet Sclerophyll Forests
- Northern Escarpment Wet Sclerophyll Forests
- Southern Escarpment Wet Sclerophyll Forests.

This broad range of types indicates, as for most Australian frogs, the lack of any clear relationships with particular vegetation types beyond that of dry vs wetter forests. This species is predominantly associated with wetter forest types.

2.6. Threatening Processes

The Stuttering Frog is currently listed as vulnerable under both the EPBC and BC Acts and also under the IUCN red list. The IUCN has classified this species as vulnerable because of “a population decline, estimated to be more than 30% over the last ten years, inferred from an observed decline in numbers, and from habitat destruction and degradation”.

The species is now recognised to almost certainly be extinct south of the Sydney Basin.

The OEH profile for this species lists the following threats to the Stuttering Frog:

- Modification and loss of habitat.
- Disease - chytrid fungus.
- Changes to natural water flows and water quality.
- Predation of eggs and tadpoles by introduced fish.
- Damage to habitat and impacts on water quality from forestry activities.
- Damage (vegetation removal, disturbance, turbidity) to habitat by domestic stock, feral cattle and pigs.
- Poor knowledge of the species' distribution, taxonomy and history of local extinction.

The Australian Department of Environment and Energy provides the following on its profile in regards to threats for this species:

> *Several potentially threatening processes have operated upstream of, or at, sites where the Stuttering Frog was formerly found, but, as populations of this species have also disappeared in catchments with seemingly minimal disturbance, it is not clear how much influence these processes have had. Logging and associated forest management practices have been carried out in some catchments where the Stuttering Frog historically occurred or currently occurs. The health and stability of extant populations in these disturbed catchments is unknown. Upstream forest grazing and land clearance for pasture have also occurred in some catchments. The species*

is not known from any localities with disturbed riparian vegetation or significant human impacts upstream, which may indicate that the species is highly sensitive to perturbations in the environment (Mahony et al. 1997).

The role of chytrid fungus in the decline of the Stuttering Frog has not been explicitly demonstrated, but it is highly likely that this is the primary cause of the major declines and extinction of this species south of Sydney and potentially now within the western Sydney Basin given that many historic areas appear to be unaffected by other factors.

Other impacts noted by DoEE include:

- Trampling by domestic stock (Knowles et al. 1998).
- Introduced fish, such as Eastern Gambusia (*Gambusia holbrooki*), Carp (*Cyprinus spp.*) and salmonids (Gillespie & Hines 1999).
- Sustained increased levels of sedimentation and changes to water pH (Green et al. 2004).

Of the above potential threats, the ones likely to be of a significant consideration in the construction area of Warragamba Dam Raising project are the presence of that amphibian Chytrid Fungus, modification and loss of habitat, changes to natural water flows and water quality and predation of eggs and tadpoles by introduced fish.

Figure 3. Construction footprint

3. Description of the Site

The footprint of the Warragamba Dam Raising development site is provided in Figure 3 and represents the subject site. The following information describing the subject site and its surrounds is taken directly from the Warragamba Dam Raising Construction Biodiversity Assessment Report (SMEC 2019).

3.1. IBRA bioregions and IBRA subregions

The construction study area is located in the Interim Biogeographical Regionalisation of Australia (IBRA) Bioregion of the Sydney Basin and there are two subregions which are relevant to the assessment.

3.1.1. Bioregions

The development site and outer assessment circle are wholly located within the Sydney Basin Bioregion.

Development site: Sydney Basin Bioregion

Outer assessment circle: Sydney Basin Bioregion

OEH provides the following information on the Sydney Basin Bioregion:

The Sydney Basin Bioregion lies on the central east coast of NSW and covers an area of approximately 3.6 million hectares, which is the equivalent of 4.5 percent of NSW. The Sydney Basin Bioregion is one of two bioregions contained wholly within the state. It consists of a geological basin filled with near horizontal sandstones and shales of Permian to Triassic age that overlie older basement rocks of the Lachlan Fold Belt. The sedimentary rocks have been subject to uplift with gentle folding and minor faulting during the formation of the Great Dividing Range. Erosion by coastal streams has created a landscape of deep, cliffed gorges and remnant plateaus across which an east-west rainfall gradient and differences in soil control the vegetation of eucalypt forests, woodlands and heaths. The Sydney Basin Bioregion includes coastal landscapes of cliffs, beaches and estuaries.

The frontal slope of the Blue Mountains (where the site is located) is formed along the Lapstone monocline. A secondary flexure and similar escarpments occur at the coast forming the Hornsby Plateau and the Illawarra Escarpment. These structural features combine with different rock types and strong trends in joint patterns to control drainage patterns and the distribution of gorges and swamps.

3.1.2. Subregions

The development site is located across two IBRA subregions:

- Wollemi subregion
- Burragorang subregion.

Development site: Burragorang (19.59 hectares) and Wollemi (85.26 hectares).

Outer assessment circle: Burragorang (250.08 hectares), Wollemi (708.56 hectares), and Cumberland (40.48).

The outer assessment circle falls within both the Wollemi and Burragorang subregions, as well as within Cumberland subregion. The Wollemi, Burragorang, and Cumberland subregions are described in Table 1.

Table 1. Description of the subregions within Sydney Basin Bioregion occurring within the development site

SUBREGION	GEOLOGY	CHARACTERISTIC LANDFORMS	TYPICAL SOILS	VEGETATION
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. There are also a number of scattered volcanic necks distributed throughout the Wollemi subregion.	Characterised by the highest part of the Blue Mountains and other sandstone plateaus with benched rock outcrops.	Typically, soils are thin sands or deep yellow earths on plateaus, with thin texture contrast soils on shale benches. Organic sands in line swamps and joint crevices, while slope debris are found below cliffs, and sandy alluvium in pockets along the streams. On basalts, soils are red brown structured loams.	*Corymbia gummifera*, *Corymbia eximia*, *Angophora floribunda*, *Angophora costata*, *Eucalyptus sclerophylla*, and *Eucalyptus punctata* with diverse shrubs and heaths on plateau. Additionally, *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus agglomerata*, and *Syncarpia glomulifera* subsp. *glomulifera* and gully rainforests are present in gullies and canyon heads. *Eucalyptus viminalis* and Blaxland's Stringybark on basalt. *Casuarina cunninghamiana* is found along main streams.
Burragorang	Comprised of Permian and Triassic sandstones and shales on the western edge of the Sydney Basin.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley	Typically, soils include rocky outcrops, texture contrast soils and uniform sands on sandstone. Cliff bases are generally pillowed with a sandy, clay matrix, alluviums contain rich loams.	Heath, shrubland and woodland with *Eucalyptus sieberi*, *Eucalyptus sclerophylla*, *Eucalyptus piperita* and *Corymbia gummifera* on sandstone similar to other parts of the Basin. *Eucalyptus deanei*, *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerata* immediately below escarpment passing to *Eucalyptus punctata*, *Eucalyptus crebra* and *Eucalyptus eugenoides* on rocky slopes. *Casuarina cunninghamiana* along main streams below the plateaus.
Cumberland	Triassic Wianamatta groups shales and sandstones, which are intruded by a small number of volcanic vents and partly covered by Tertiary river gravels and sands. There is quaternary alluvium along the mains streams.	Low rolling hills and wide valleys in a rain shadow area below the Blue Mountains. Volcanics from low hills in the shale landscapes. Swamps and lagoons on the floodplain of the Nepean River.	Typically, soils include a mixture of clays on volcanics, poor stony soils on older gravels, and high quality loams on floodplain alluvium.	*Eucalyptus moluccana, Eucalyptus tereticornis, Eucalyptus crebra* woodland with some *Corymbia maculata* on the shale hills. *Eucalyptus sclerophylla, Angophora floribunda*, and *Banksia serrata* on alluvial sands and gravels. *Angophora subvelutina, Eucalyptus amplifolia* and *Eucalyptus tereticornis* with abundant *Casuarina glauca* on river flats. Tall spike rush, and juncus with *Eucalyptus parramattensis* in lagoons and swamps.

3.2. NSW landscape regions (Mitchell Landscapes)

The development site is located across four landscape regions:

- Kurrajong Fault Scarp
- Lapstone Slopes
- Burragorang Valley and Gorges
- Nattai Plateau.

Development site: Kurrajong Fault Scarp (92.95 hectares); Lapstone Slopes (10.31 hectares); Burragorang Valley and Gorges (1.56 hectares); and Nattai Plateau (0.03 hectares)

Outer assessment circle: Kurrajong Fault Scarp (611.99 hectares); Lapstone Slopes (97.60 hectares); Burragorang Valley and Gorges (127.69 hectares); Silverdale Slopes (120.36 hectares); and Nattai Plateau (42.37 hectares)

Kurrajong Fault Scarp occurs over the majority of the development site (as measured by area) followed by Lapstone Slopes, Burragorang Valley and Gorges, and Nattai Plateau. Descriptions of each Mitchell Landscape are provided in *Table 2*.

Table 2. Description of the Mitchell Landscape

MITCHELL LANDSCAPE	DESCRIPTION
Kurrajong Fault Scarp	Dissected and broken slopes on Triassic Quartz sandstone and shale across the Lapstone monocline and Kurrajong fault scarp. Local dips on the sedimentary rocks up to 300 m, general elevation 100 to 250 m, local relief 100 m. Abundant rock outcrop with pockets of yellow-brown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of: *Eucalyptus agglomerata*, *Syncarpia glomulifera* subsp. *glomulifera*, Red *Corymbia gummifera*. *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus radiata*, *Eucalyptus punctata*, *Eucalyptus pilularis* and *Allocasuarina* sp. Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered *Eucalyptus tereticornis*, *Angophora floribunda* and *Eucalyptus globoidea* on the margins.
Lapstone Slopes	The frontal slope of the Blue Mountains formed by folding and faulting of Triassic quartz sandstone and shale with a veneer of Tertiary river gravels. A southern extension of the Kurrajong Fault Scarp landscape. Larger streams cut through the structural ridge in deep gorges, but smaller streams have accumulated organic sands in swamps and lagoons on the western side of the flexure. General elevation 50 to 300 m, local relief 180 m, steep dip slopes on the eastern face and benched faulted slopes on the west. Extensive rock outcrop, thin sandy soils with gravel and occasional white or yellow clay subsoils. Pockets of deep sand in some streams. *Corymbia gummifera*, *Corymbia eximia*, *Eucalyptus punctata*, *Allocasuarina torulosa*, *Eucalyptus sieberi*, *Eucalyptus radiata* with diverse shrubby understorey.

MITCHELL LANDSCAPE	DESCRIPTION
Burragorang Valley and Gorges	Deep steep sided benched slopes and gorge of the Wollondilly and Coxs Rivers incised into mostly horizontal Triassic quartz sandstone conglomerate, siltstone, and shale, cliffs to 150m high with waterfalls, general elevation 50 to 220 m, local relief 150 m. The gorge widens upstream and exposes underlying Permian chest, mudstones and conglomerate. Very extensive rock outcrop, thin yellow to yellow-brown silty sand and gravel with occasional white clay layers forming either shallow yellow earths or gleyed texture-contrast profiles. *Corymbia gummifera*, *Syncarpia glomulifera*, and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliffs upstream with *Eucalyptus tereticornis*, *Eucalyptus macrorhyncha*, *Eucalyptus crebra*, and *Eucalyptus mannifera*. Moist protected environments with *Eucalyptus saligna*, *Eucalyptus cypellocarpa*, *Eucalyptus muelleriana* and *Eucalyptus smithii*. Gallery forest of *Casuarina cunninghamiana* with *Eucalyptus deanei* and *Eucalyptus benthamii* along the main streams.
Nattai Plateau	Steeply dissected plateau remnants on lower Triassic lithic sandstone, shale and tuff, abundant rock outcrop and cliffs, steep debris slopes, general elevation 600 to 700 m, local relief 80 m. Shallow sand and occasional yellow texture-contrast soils. Forests of *Eucalyptus eugenioides*, *Eucalyptus fibrosa* subsp. *fibrosa*, *Callitris rhomboidea*, *Eucalyptus sieberi*, *Eucalyptus blaxlandii*, *Eucalyptus fastigata* and *Eucalyptus viminalis*.
Silverdale Slopes	Moderately undulating slopes descending to the east on gently dipping Triassic shales and sandstones. General elevation 230 to 630 m, local relief 200 m. Brown to yellow-brown texture-contrast soils. Woodland to forest with a shrubby understorey, common species; *Eucalyptus punctata*, *Eucalyptus albens*, *Eucalyptus paniculata*, *Eucalyptus crebra*, *Eucalyptus fibrosa*, *Eucalyptus moluccana*, *Allocasuarina torulosa*, *Eucalyptus eugenioides*, and occasional *Syncarpia glomulifera*.

3.3. Rivers and streams

The development site falls within the Warragamba catchment. Bordered on the west by the Great Dividing Range, the catchment stretches from north of Lithgow at the head of the Coxs River in the Blue Mountains, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River.

The proposed construction area includes areas of Lake Burragorang, the dam wall spillway and Warragamba River. Up until the dam wall, Lake Burragorang is considered to be a 9th order stream in accordance with the Strahler stream ordering method. The current geomorphological condition at the dam is characterised by altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplains.

3.4. Wetlands

One wetland (Lake Burragorang) has been mapped within the construction study area within the NSW Wetland shapefile. No important or local wetlands occur within the development site or outer assessment circle. There are a number of smaller dams mapped to the east of the development site, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 km of the development site.

3.5. Native vegetation

The development site is centred around Warragamba Dam, which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, the vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation. Instead much of the development site is comprised of vegetation typical of ridgetops on skeletal soils. The majority of the development site supports dry sclerophyll forest of shrubby sub-formation, as well as an area of wet sclerophyll forest. To the west of Warragamba Dam, to both the north and south of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenoides*, *Eucalyptus sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest which extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest Critically Endangered Ecological Community.

The development site is 104.85 hectares in size. A total of 54.37 ha of native vegetation has been mapped within the site with Table 3 providing a summary of the PCTs mapped as occurring, including vegetation formation, percent cleared within the Hawkesbury-Nepean catchment and extent within the development site. None of this vegetation is particularly suitable for the Stuttering Frog to use as shelter and feeding habitat.

Table 3. Summary of PCTs occurring within the development site

PCT CODE/ BVT CODE	PCT NAME	VEGETATION FORMATION	VEGETATION CLASS	% CLEARED WITHIN HN CATCHMENT	AREA WITHIN SITE (HA)
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	40	16.96
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	25	24.78
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	20	8.69
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	Wet Sclerophyll Forests (Grassy sub-formation)	Northern Hinterland Wet Sclerophyll Forests	90	4.94

3.6. Landform, geology and soils

The study area is approximate 104.85 hectares and is located at and adjacent to Warragamba Dam. The elevation within the study area is varied, ranging between 21 metres AHD at its lowest point to 195 metres AHD at its highest point. The study area slopes from the top of the gorge down to the dam and Warragamba River.

The Soil Landscapes of Penrith 1:100,000 soil landscape sheet has mapped four soil landscapes within the outer assessment circle as outlined in *Table 4* below.

Table 4. Soil landscape description

NAME	LANDSCAPE	SOILS	LIMITATIONS
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 meters, slopes 10-15%. Rock outcrop 25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop with broken scarps.	Shallow to moderately deep (30-100 cm) yellow earths and earthy sands on crests and on insides of benches; shallow siliceous sands on leading edges of benches; localised gleyed podzolic soils and yellow podzolic soils on shale lenses; shallow to moderately deep (<100 cm) siliceous sands and leached sands along drainage lines.	Steep slopes, water erosion hazard, rock outcrop, localised rockfall hazard, localised non-cohesive soils, shallow highly permeable soil, very low soil fertility.
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces on Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop.	Shallow (<50 cm) earthy sands and yellow earths; some siliceous sands / lithosols associated with rock outcrop.	Shallow, highly permeable soil, localised non-cohesive soils, very low soil fertility, localised water erosion hazard, localised rick outcrop.
Hawkesbury	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200 m, slopes >25%. Rock outcrop >50%. Narrow crests and ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders.	Shallow (<30 cm) discontinuous lithosols / siliceous sands, associated with rock outcrop; earthy sands, yellow earths and some locally deep sands on inside of benches and along joins and fractures; localised yellow and red podzolic soils associated with shale lenses, siliceous sands and secondary yellow earths along drainage lines.	Steep slopes, mass movement hazard, rockfall hazard, water erosion hazard, shallow soils, rock outcrop, non-cohesive soils (localised), stony, highly permeable soils of low fertility.
Blacktown	Gently undulating rises on Wianamatta Group shales. Local relief to 30 m, slopes usually >5%. Broad rounded crests and ridges with gently inclined slopes.	Shallow to moderately deep (>100 cm) hardsetting mottled texture contrast soils, red and brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and drainage lines.	Localised seasonal waterlogging, localised water erosion hazard, moderately reactive highly plastic subsoil, localised surface movement potential.

3.7. Hydrology

Lake Burragorang is the dominant hydrological feature of the study area. Created by damming the Warragamba River and flooding the Burragorang Valley, Lake Burragorang is four times the size of Sydney Harbour and is currently managed as Sydney's water supply dam.

Downstream of the dam is the Warragamba River. Water is discharged into Warragamba River when the dam spills. Water is also released into the Warragamba River (downstream of the Warragamba Weir) to provide a secure water supply to the population of North Richmond. Warragamba River is a 9th order Strahler stream and there are several small, unnamed ephemeral tributaries within study area.

3.8. Climate

There are no weather stations within the construction area, but Table 5 provides summaries of the weather conditions for stations located around the area. The climate for the area is mild with moderate rainfalls.

Table 5. Key climatic statistics for weather stations near the survey area.

WEATHER STATION	MEAN ANNUAL RAINFALL (MM)	MEAN MAXIMUM TEMPERATURE (°C)	MEAN MINIMUM TEMPERATURE (°C)
Jenolan Caves (1895-) (24 km W, 690 m higher)	970.6	25.6	0.2
Penrith Lakes AWS (1995-) (20 km NNE, 90 m lower)	718.6	31.0	5.3
Springwood (1883-) (21 km N, 250 m higher)	1082.1	29.0	6.5
Katoomba (1885-) (15 km N, 890 m higher)	1399.6	23.4	2.6
Picton Council Depot (1880-) (15 km SE, 60 m higher)	794.3	29.3	1.7

3.9. Land uses

The development footprint is located on land zoned as SP2 Infrastructure (Water Supply) under the *Wollondilly Local Environmental Plan (LEP) 2011* (Figure 4). This land around the dam serves as operational support for the existing dam and consists of cleared and vegetated areas, dam support facilities, access roads and parks. The proposed works would be permissible within this land zone type and construction activities would be contained within this zone.

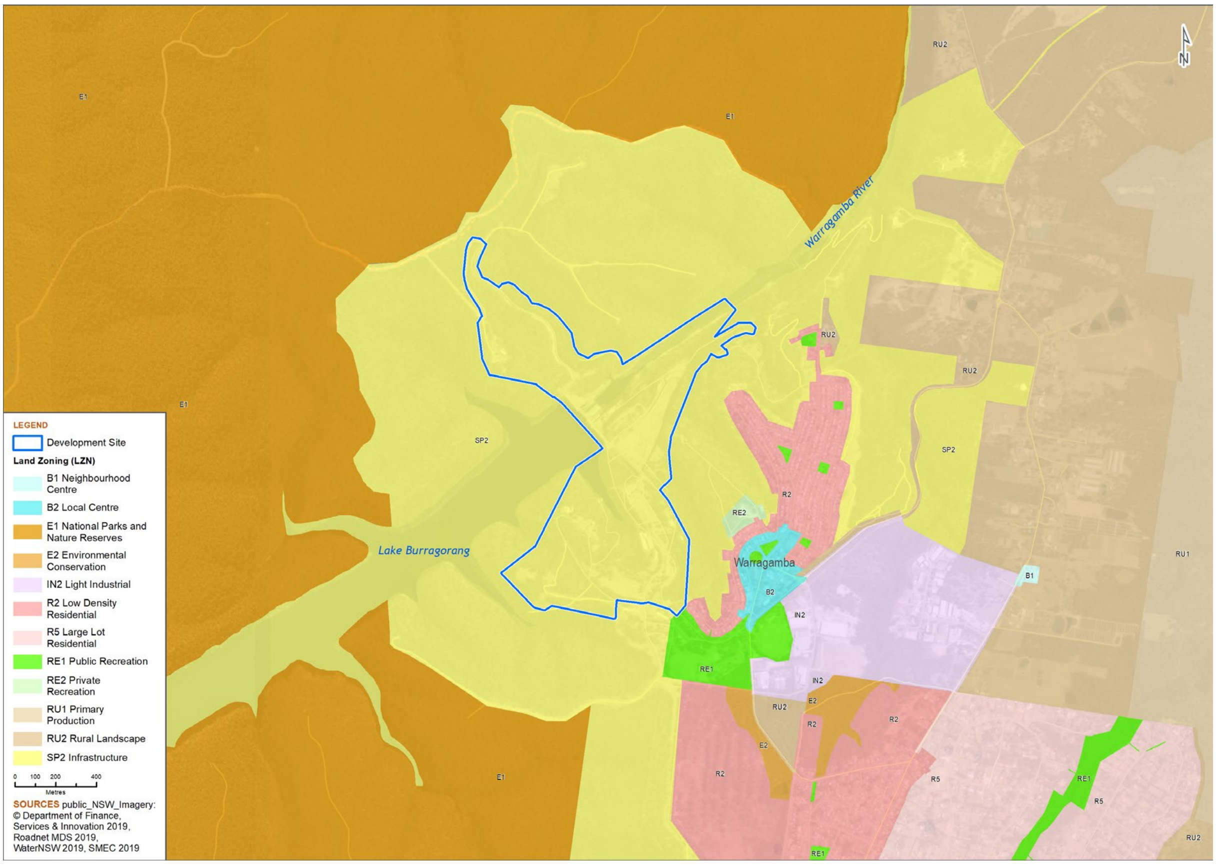

Figure 4. Land use zones

3.10. Habitat for the Stuttering Frog

The construction area is comprised mainly of areas of sclerophyll woodland growing on the slopes of a steeply incised river valley. Rock outcrops are present broadly across the construction study area and there are several gully lines that hold ephemeral water courses that occur on both sides of the main river valley and feed into it at the level of the dam or the Warragamba River (Figure 5).

The vegetation present around the dam wall on the slopes of the valley is generally intact due to the prohibited access to the Warragamba Dam catchment. Hence the vegetation represents suitable habitat for the Stuttering Frog and the water quality of the ephemeral creeks feeding into the Warragamba River and the dam itself should not have been affected by surrounding urbanisation.

The Warragamba River directly below the dam wall has a highly modified flow and exists only as a series of large pools and sometimes stagnant pools. This is a result of the outflow pipe being situated not on the other side of the wall but instead approximately 1.7 km downstream of the wall. The vegetation lining the river up to the outflow pipe is a disturbed community with a significant presence of weeds.

Some vegetation has been historically cleared to provide infrastructure for the dam that includes the dam itself as well as the ancillary roads, buildings and areas for tourism (e.g., picnic areas) (Figure 3).

The study site retains full connectivity with large undisturbed tracts of native sclerophyll forests that are retained in the catchment and the impacts of roads and the effects of rural land uses (i.e. managed midstorey) are minimal.

The site was visited and viewed by myself on the days of the 12 and 13 of February 2017.

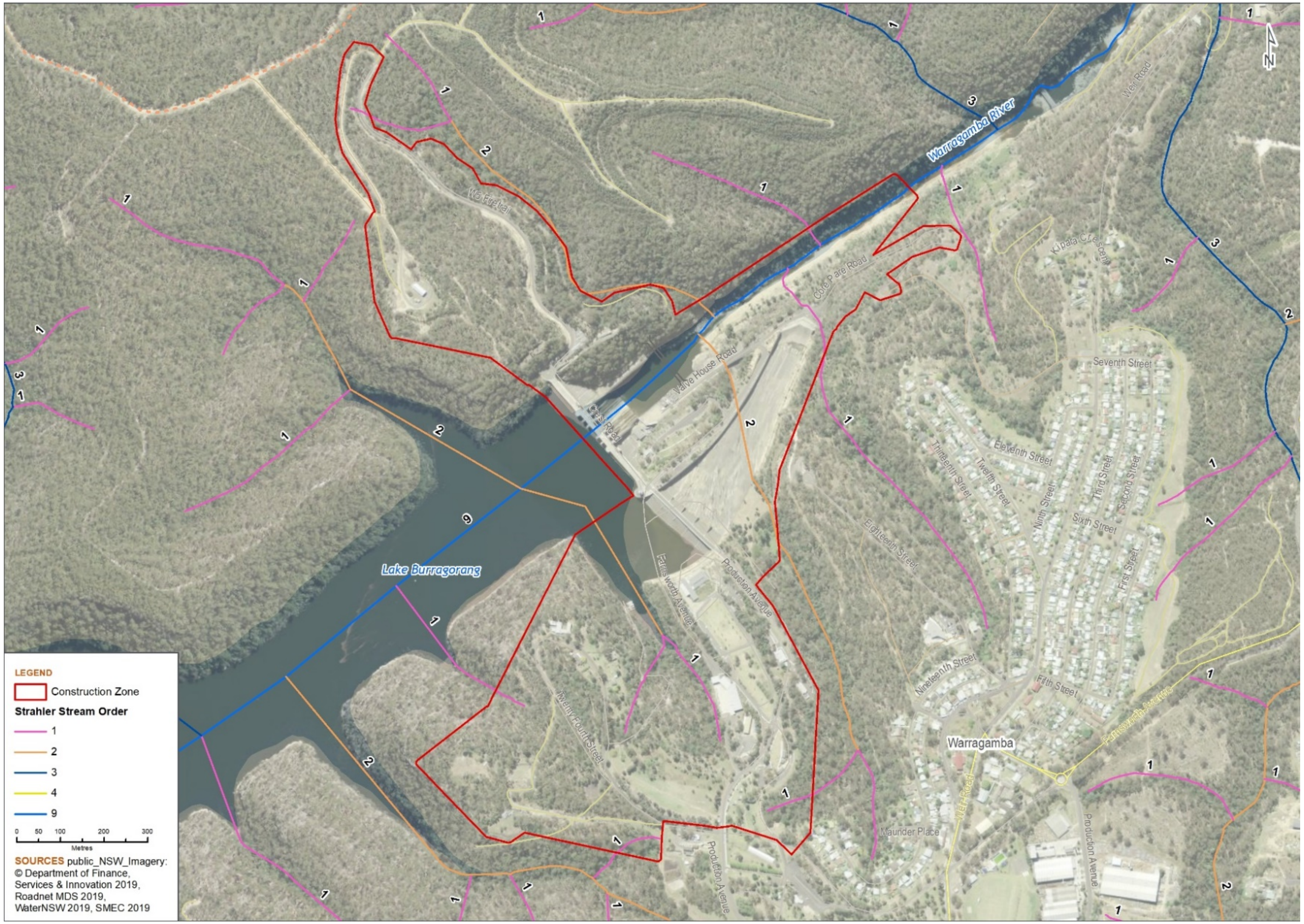

Figure 5. Stream order

4. Description of the Site

4.1 Local records

There are no Bionet (2018) database records of the Stuttering Frog within the subject or within a 10 km radius of the site (Figure 2).

4.2 Breeding Habitat

The sputtering Frog in the Sydney Basin historically used for breeding permanent streams located in large tracts of wet sclerophyll or rainforest and did not use rainforest lined creeks in dry forests at all. They can use streams that very occasionally stop flowing but retain large pools, but these need to still be located within wetter forests that extend more than 100 m from the edge of bank to provide areas of deep leaf litter and moist environments for shelter and foraging.

4.3 Shelter Habitat

The Stuttering Frog shelters under logs and in low vegetation but mainly under thick leaf litter. Stuttering frogs have been recorded more than 300 m away from the breeding site and appear to regularly disperse long distances from water. However, in the Sydney Basin this will be within broader areas of wetter forest. The species is not known to seek shelter within areas cleared of native vegetation or that are significantly disturbed.

The streamside vegetation of the Warragamba River is generally in poor condition and is not made up of wet forest types. At best the riparian vegetation extends only 10-20 m from the edge of the bank. Hence it provides poor shelter habitat for frogs as there is very limited leaf litter for cover and would not provide the broad areas of wet forest habitat this species needs.

4.4 Foraging Habitat

The Stuttering Frog has no known specific dietary requirements that might limit its distribution across the landscape and it is assumed that this species is foraging in the same area as it the sheltering habitat. As this habitat does not provide suitable shelter it is also not likely to be used for foraging.

4.5 Total area of habitat impacted

There is no suitable habitat for this species within the study area.

5 Conclusion

The Stuttering Frog is not known to be present within the WDR construction study area, but surveys have not been able to be carried out effectively to determine the presence or absence of the species. The Warragamba River in the study area provides permanent water, but not permanent flowing water as is used for breeding by the Stuttering Frog. There are no other potentially suitable breeding streams present. The vegetation present is not a suitable wet forest habitat that is used by this species in the Sydney Basin and the vegetation around the Warragamba River is also in poor condition.

On this basis I consider that the Stuttering Frog is not present within the Warragamba Dam raising construction area and it needs no consideration in regards to be impacted by the proposed works.

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7 Appendix A. CV – Dr. Frank Lemckert

Frank has been a professional scientist since 1992, specialising in understanding and managing the ecology and management of threatened species and particularly frogs. Frank has conducted ecological work throughout eastern Australia (NSW, Victoria, Queensland), establishing long-term research and monitoring programs into the management of fauna and developing strategies to mitigate the impacts of human disturbances. He has worked extensively with the NSW state and federal Governments on varying issues of fauna and flora management including the preparation of a draft NSW/National recovery plan for the Giant Burrowing Frog (*Heleioporus australiacus*) and is an accredited expert on the Green and Golden Bell Frog (*Litoria aurea*). Frank has prepared reports on endemism and representation in reserves of flora and fauna for the Commonwealth, represented the NSW Forestry Commission in license negotiations for the Comprehensive Regional Assessment process (2000) and provided expert ecological advice on illegal land clearing for the NSW and Commonwealth Governments. He has authored over 90 peer-reviewed publications. Frank is a research associate with the Australian Museum and University of Newcastle, convenor of the NSW Declining Frog Working Group and a member of the IUCN's Amphibian Specialist Group. He is a recognised expert in frog ecology and management, but has completed management related projects and works on a range of terrestrial vertebrate fauna.

Frank's primary role as a consultant has been to use his expertise and experience in technical writing and threatened species legislation to develop and maintain quality assurance in project reporting including:

- Two Species Impact Statements.
- >100 flora and fauna reports and assessments of significance using the EP&A Act and EPBC Act.
- Biodiversity Assessment Reports for Warragamba Dam Raising, Nowra Bridge, Golden Highway and Eurobodalla Dam.
- Manager for the Oxley Highway to Kempsey and Frederickton to Eungai ecological monitoring program.
- Construction and Environmental Management Plans, Monitoring Plans and Vegetation Management Plans for roads at Port Macquarie, Berry to Bomaderry and South Nowra.
- Nest Box, microbat and Green and Golden Bell Frog management plans for the Berry to Bomaderry and Oxley Highway to Kempsey Highway Upgrades.
- Review of monitoring strategies for the Woolgoolga to Ballina and Warrell Creek to Nambucca Heads programs for the Pacific Highway Upgrade.
- Review of two proposed Coal Seam Gas Impact Assessment methods for Matters of National Environmental Significance (contracted by the Commonwealth Government).
- Provision of species credit species expert reports for the Warragamba Dam raising project and Western Sydney Growth Centres Biocertification.

QUALIFICATIONS

- Bachelor of Science, University of Sydney, 1984 (Terrestrial Ecology and Marine Management)
- Master of Science, University of Sydney, 1991 (Population biology of the Common Froglet)
- PhD, University of Newcastle, 2009 (Management of forest frogs in timber production forests of NSW)

PROJECT EXPERIENCE

Ecological impact assessment

- Expert report on the green and golden bell frog for the western sydney growth areas biocertification project (2018-2019)
- Warragamba dam raising project target surveys, impact assessments, expert reporting (six species) and q/a for water nsw (2018-19)
- Shading impacts for proposed building works at homebush, nsw, piety pty ltd (2018)
- Granite hills windfarm bird and bat strike modelling and ecological impact assessment, nimmitabel, akuo energy (2018) and elysian windfarm, nimmitabel, akuo energy (2018)
- Vegetation removal and threatened frog management strategies, new intercity fleet management facility, john holland group (2018-19)
- Eurobodalla dam biodiversity assessment report, eurobodalla shire council (2017-18)
- Nowra bridge eis ecological assessments, nsw rms (2018)
- Heathcote road upgrade impact assessment and review of mitigation measures, nsw rms (2018-2019)
- Mona vale road threatened fauna expert survey and impact assessment, ecosure and nsw rms (2015-2016).

Government reviews/reports

- Biodiversity assessment method frog survey guidelines for species credit species (2019)
- Expert review of biodiversity impact assessment report for the hornsby quarry rehabilitation project (2019)
- Review of impact assessment pathways for two lpng projects, commonwealth government (2013)
- Expert advice on impacts of illegal land clearing at somersby, commonwealth government (2015)
- Expert advice on impacts of illegal land clearing at evans head, nsw state government (2016)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Review of monitoring strategies for the woolgoolga to ballina and warrell creek to nambucca heads programs for the pacific highway upgrade, nsw rms (2014)
- Hornsby council expert witness for development impacts at dural, hornsby shire council (2016)
- Expert representing forests nsw in the comprehensive reginal assessment program for the regional forest agreement program (1999-2001)
- Review of threatened species modelling in forestry areas, vic forests (2012)
- Flora and fauna representation in the australian reserve system, commonwealth government (2010)
- Flora and fauna endemism patterns across australia, commonwealth government (2009)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for wps (2008)
- Expert review of fauna and flora impacts for 13 nsw forestry commission eis reports (1992-94).

EPBC referrals

- Green and golden bell frog (*litoria aurea*) referrals for the princes highway upgrade at south nowra, nsw rms
- Austen quarry (*eucalyptus pulverulenta*), hartley, hy-tec industries (2014-15)
- Marys mount koala (*phascolarctos cinereus*) referral, gunnedah quarry products (2015).

Monitoring programs

- Oxley highway to kempsey threatened biodiversity monitoring, nsw rms (2013-2017)
- Green and golden bell frog baseline monitoring program at meroo lakes, nsw oeh (2016-17)
- Fcnsw statewide ecological monitoring program, forestry corporation of nsw (2009-10)
- Threatened fauna monitoring hume highway, kapooka, nsw rms (2018).

Plans of management / strategies

- Commonwealth/nsw giant burrowing frog recovery plan, dewha/decc (2012)
- Eastern bentwing-bat management plan, gerringong, nsw rms (2014)
- Nestbox, microbat and green and golden bell frog management plans, berry to bomaderry upgrade of the princes highway, nsw rms (2017)

- Green and golden bell frog surveys and monitoring, princes highway upgrades at south nowra and berry to bomaderry, nsw rms (2012-2017)
- Green and golden bell frog management strategy, princes highway upgrade, nsw rms (2012-2014)
- Green and golden bell frog pre-clearing works kooragang island (daracon 2016 & current)
- Microbat management plan for clarencetown bridge, nsw rms (2016)
- Expert review of threatened frog management plan - woolgoolga to ballina upgrade, nsw rms (2014)
- Threatened microbat management plan for warringah mall, northern beaches council (2014)
- Threatened frog modelled habitat requirements, hornsby shire council (2016).

Training

- Lead instructor > 50 wildlife training schools run in nsw, act and victoria providing presentations on the survey, identification and management of all flora and fauna. This included detailed instruction on the management of threatened wading and aquatic birds and other aquatic species presented to queensland, victorian, nsw and commonwealth government staff (1993-2017)
- Private forestry survey requirements, victorian timber (2016).

Publications

Book Chapters

Hecnar S. J., & Lemckert, F.L. 2012. Habitat Protection: Refuges and Reserves. Pp 3636-3675 In Biology of the Amphibia Volume 10 - Conservation and Decline of Amphibians: Ecology, Effects of Humans, and Management. H. Heatwole (Ed.). Surrey-Beatty and Sons, Sydney.

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Appendix L Expert Report: Giant Barred Frog

Member of the Surbana Jurong Group

Warragamba Dam Raising Construction Area

Expert report – Giant Barred Frog

Prepared for: Water for NSW
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This report is confidential and is provided solely for the purposes of providing an expert report to assess the expected distribution and abundance of the Giant Barred Frog in the area to be impacted by the construction works being completed to raise the wall of Warragamba Dam. This report is provided pursuant to a Consultancy Agreement between SMEC Australia Pty Limited ("SMEC") and Water NSW under which SMEC undertook to perform a specific and limited task for Water NSW. This report is strictly limited to the matters stated in it and subject to the various assumptions, qualifications and limitations in it and does not apply by implication to other matters. SMEC makes no representation that the scope, assumptions, qualifications and exclusions set out in this report will be suitable or sufficient for other purposes nor that the content of the report covers all matters which you may regard as material for your purposes.

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Abbreviations and acronyms

Term	Definition
BAM	Biodiversity Assessment Method
BC Act	*Biodiversity Conservation Act 2016*
DOEE	Commonwealth Department of the Environment and Energy
DPIE	Department of Planning, Industry and Environment
EMP	Environmental Management Plan
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FBA	Framework for Biodiversity Assessment
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature
LGA	Local Government Authority
MNES	Matters of National Environmental Significance
OEH	Office of Environment and Heritage
PMST	Protected Matters Search Tool
TPZ	Technical Advisor
WNSW	Water for New South Wales

1. Introduction

1.1. Background

SMEC has been engaged by Water NSW to undertake and complete an assessment of the impacts of the proposed Warragamba Dam Raising project on threatened Biodiversity.

This expert report will assess the impacts that are predicted to occur as a result of the construction activities that are planned to take place in order to raise the wall of Warragamba Dam. This will involve direct effects such as clearing of vegetation for roads and material lay-down areas as well as indirect effects including increased levels of dust and noise. These impacts are being assessed using the Framework for Biodiversity Assessment (FBA) as directed by the SEARs provided by OEH on 30 June 2017 and reissued 13 March 2018.

1.2. Reasons for the Expert Report

An expert report may be prepared under section 6.6 of the FBA where it states:

> *Using expert reports instead of undertaking a survey*
>
> *6.6.2.1 An expert report may be obtained instead of undertaking a threatened species survey at a development site.*
>
> *6.6.2.2 An expert report must only be prepared by a person who is accredited by the Chief Executive of OEH under section 142B(1)(b) of the TSC Act, or a person who, in the opinion of the Chief Executive of OEH possesses specialised knowledge based on training, study or experience to provide an expert opinion in relation to the biodiversity values to which an expert report relates.*
>
> *6.6.2.3 The expert report must document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report.*
>
> *6.6.2.4 An expert report can only be used instead of a survey for species to which species credits apply.*
>
> *6.6.2.5 An expert report must set out whether:*
>
> *(a) for development sites – the species is unlikely to be present on the development site – in this case no further assessment of the species is required, or*
>
> *(b) for all development sites – the species is likely to be present on the site – in this case the expert report must provide an estimate of the number of individuals or area of habitat to be impacted by the development or the management actions (according to the unit of measurement identified for the species in the Threatened Species Profile Database).*

An expert report may only be used for those threatened species and populations to which species credits apply, not for any threatened species to which ecosystems apply.

In this case, an expert report has been provided in relation to the Giant Barred Frog (*Mixophyes iteratus)*, which is listed as endangered under both the BC Act and EPBC Act, and is a species credit species. An expert report has been prepared due to the difficulty in meeting the survey requirements set out in the FBA. The area to be covered is inaccessible as a water catchment area, especially during the necessary wet conditions for surveys, necessitating that an expert report be produced to consider the potential for this species to be present and extent of any possible occurrence.

1.3. Species Expert

Dr Francis Lemckert

Dr Lemckert is an Ecologist that has been undertaking studies into the ecology and management of frogs since 1986 and has been a principal ecological consultant since 2011. His skills include survey design/ implementation/ targeted species surveys, data handling, analysis and interpretation and the production of high level reports including papers published in international peer-reviewed journals and technical reports and recovery plans for the Commonwealth and NSW Governments. He has also been an expert witness in regards to considerations of the impacts of potentially illegal clearing for the Commonwealth, NSW and Local Governments (Hornsby Council) and provided expert advice to NSW DPI in regards to court considerations over the potential for forestry operations to impact on rock outcrop dependent species. Dr Lemckert represented Forests NSW (now Forestry Corporation NSW) as a reptile and amphibian expert in the Comprehensive Regional Assessments and Regional Forest Agreement Process carried out between 2000 and 2002 and as an expert in fauna management for negotiations over a new Threatened Species License for harvesting operations in 2014. He provided an expert review of the developed assessment process for impacts on Matters of National Environmental Significance for two proposed Coal Seam Gas Developments in Queensland and has completed two rounds of expert review of the status of Australia's amphibians for the IUCN.

Dr Lemckert is an acknowledged expert on eastern Australian frogs having completed his MSc & PhD studies researching the ecology and management of frogs and has published over 70 papers (or book chapters) on frog ecology and management in peer-reviewed journals. He has been engaged by both the NSW and Commonwealth Governments as an expert witness in court cases assessing the impacts of land clearing on threatened frogs, is a member of the Amphibian Specialist Group of the IUCN, secretary of the NSW Declining Frog Working Group of NSW and past president of the Australian Society of Herpetologists. He has been the co-supervisor of two PhD students and a Master of Applied Science Student who completed theses addressing frog conservation and management in NSW.

In regards to the Giant Barred Frog (*Mixophyes iteratus*), Dr Lemckert can demonstrate his expertise through the following publications that include this species:

Gillespie, G., Robertson, P., Hines, H., Lemckert, F. & Hero, J.-M. 2009. *Mixophyes iteratus*. The IUCN Red List of Threatened Species 2009: e.T13595A4220629. http://dx.doi.org/10.2305/IUCN.UK.2004.RLTS.T13595A4220629.en. Downloaded on 17 May 2018.

Gillespie, G., Roberston, P., Hines, H., Lemckert, F. & Hero, J-M. 2008. *Mixophyes iteratus*. Pp 422 In: Threatened Amphibians of the World. S. N. Stuart, M. Hoffman, J. S., Chanson, N. A. Cox, R. J. Berridge, P. J. Ramani & B. E. Young (Eds). Lynx Edicions, Barcelona, Spain.

Lemckert, F.L. & Brassil, T. 2000. Movements and habitat use of the endangered giant barred river frog, *Mixophyes iteratus*, and the implications for its conservation in timber production forests. Biological Conservation 96:177-184.

Lemckert, F. & Shoulder, J. (2007). The diets of three sympatric barred river frogs (Anura: Myobatrachidae) from southeastern Australia. Herpetological Review 38:152-154.

Lemckert, F.L. & Mahony, M.J. 2008. Core calling periods of the frogs of temperate New South Wales, Australia. Herpetological Conservation and Biology 3:71-76.

Slatyer, C., Rosauer, D. & Lemckert, F. 2007. An assessment of endemism and species richness patterns in the Australian Anura. Journal of Biogeography 34:583-596.

Hero, J-M., Morrison, C., Gillespie, G., Roberts, J.D., Newell, D., Meyer, E., McDonald, K., Lemckert, F., Mahony, M., Osborne, W., Hines, H., Richards, S., Hoskin, C., Clarke, J., Doak, N. & Shoo, L. 2006. Overview of the conservation status of Australian Frogs. Pacific Conservation Biology 12:313-320.

Lemckert, F.L. 1999. Impacts of selective logging on frogs in a forested area of northern New South Wales. Biological Conservation 89:321-328.

Lemckert, F.L. & Brassil, T. 2000. Movements and habitat use of the endangered giant barred river frog, *Mixophyes iteratus*, and the implications for its conservation in timber production forests. Biological Conservation 96:177-184.

Lemckert, F. & Shoulder, J. (2007). The diets of three sympatric barred river frogs (Anura: Myobatrachidae) from southeastern Australia. Herpetological Review 38:152-154.

Dr Lemckert has also undertaken the following actions as a result of his recognised expertise in this species:

- Was invited to provide a profile for this species for the Arkive online fauna database: See http://www.arkive.org/species/GES/amphibians/.
- Completed three years of monitoring of the Giant Barred Frog for the Oxley Highway to Kempsey Upgrade of the Princes Highway. NSW RMS 2015-2017.
- Was engaged to provide the expert technical review of the Threatened Frog Monitoring Plan for the Upgrade of the Pacific Highway between Woolgoolga and Ballina. NSW RMS 2014.
- Was engaged to provide the expert technical review of the Giant Barred Frog Monitoring Plan for the Upgrade of the Pacific Highway between Warrell Creek and Nambucca Heads. NSW RMS 2014.
- Was asked to advise in the preparation of the recovery plan for stream frogs of south-east Queensland 2001-2005 (Hines et al. 2002).
- Was commissioned by the CSIRO to provide expert advice on the Giant Barred Frog for an assessment of impacts by the proposed Traveston Crossing Dam in Queensland.
- Provided expert opinion on the habitat requirements, sub-population status and reservation requirements for the Giant Barred Frog during the NSW Government's Comprehensive Regional Assessment program completed in 2000-2001.

Dr Lemckert full CV is provided as Appendix A.

2. Species Information

2.1. Description

The Giant Barred Frog is the largest native ground frog (family Myobatrachidae) in Australia. Females reach a maximum length of 115 mm and weigh up to 200 g. Individuals have vertical pupils, very well developed webbing on the feet, broad barring on the hind legs and a narrow black line from the snout, through the eye and above the 'ear'. The colour on the dorsum is brown to olive-green and may be broken into irregular blotches or spots. The underside is creamy-white and the backs of the thighs are marked with distinctive black and yellow marbling. Adults have a brilliant golden upper half of the eye, which gives them an alternative common name of Golden-eyed Barred Frog, whereas juveniles have orange gold upper eyes as it typical of all of the Barred Frogs.

2.2. Distribution and Abundance

The Giant Barred Frog has a historic distribution that has been considered to include the coast and adjacent ranges of the Great Dividing Range from the Blue Mountains in NSW to Maryborough in southeast Queensland (Figure 1). The species is found at altitudinal ranges from sea level to around 600 m and is associated with large permanent flowing streams and rivers. The historic extent of occurrence for the Giant Barred Frog is approximately 110 000 km² (Hines et al. 1999).

Cogger (1975) originally indicated that the Giant Barred Frog was recorded as far south as Narooma on the south coast of NSW, but there is no evidence to indicate that this species ever occurred south of the Sydney Basin. There is also uncertainty as to the extent that this species inhabited the Sydney Basin with it being unclear if records attributed to this frog south of the Hawkesbury River actually represent this species. From at least the 1990s, the species appears only to have been present north of the Hawkesbury River with populations being recorded in the Watagan Mountains at places such as Ourimbah and McPherson State Forests and Jilliby. At the very least the Giant Barred Frog has not been recorded in the Sydney Basin for over 20 years (Hines and SEQ Frog Recovery Team 2002) despite some intensive searching (White 2000).

North of the Hawkesbury there are populations scattered along the NSW coast and into Queensland. There have been apparent declines and local extinctions of this species such as in the forests around Bulahdelah and in some parts of the Watagan Mountains and areas of southeast Queensland (Hines et al 1999). In the Dorrigo area the species remained widespread and common (Lemckert and Morse 1999).

The records available for the species across the state are provided in Figure 1 and from the Sydney Basin are provided in

Figure 1 They clearly show a lack of any confirmed records of this species from the area of Warragamba Dam or even the Sydney Basin. All records of this species available across its range from after 2000 are confined to areas north of the Hawkesbury River.

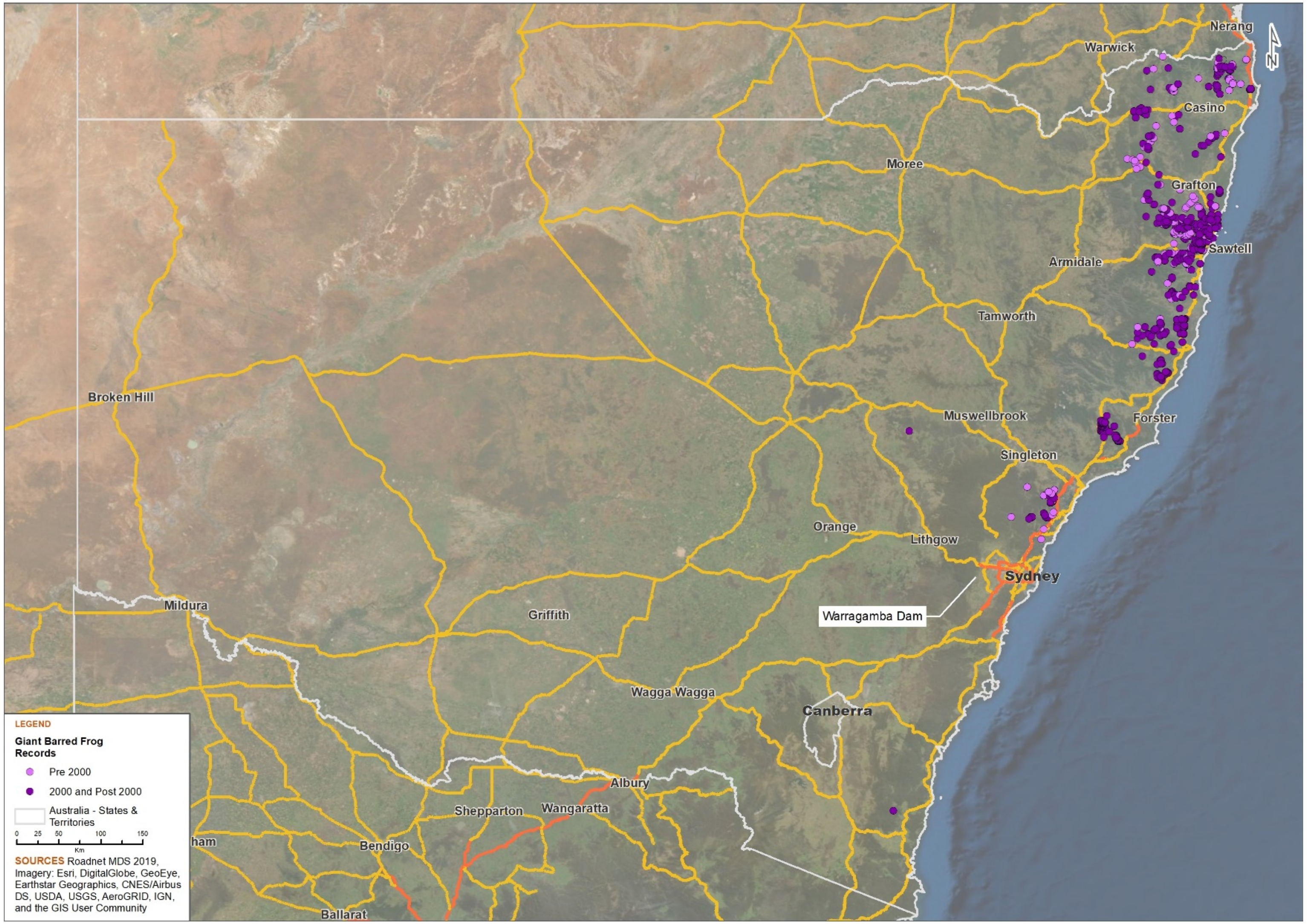

Figure 1. Location of Giant Barred Frog records in NSW. Note the difference in records pre and post-2000.

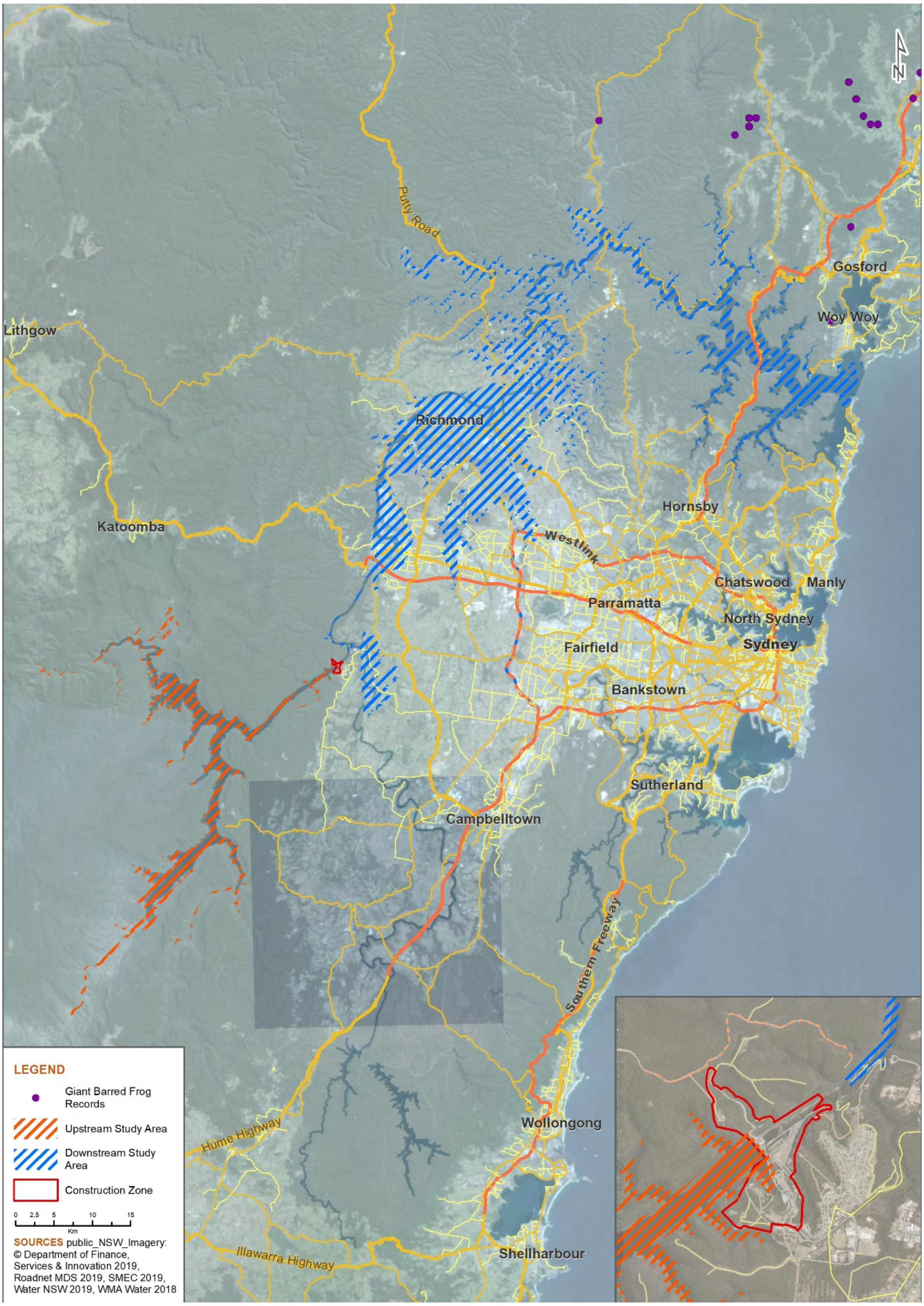

Figure 2 Location of Giant Barred Frog records in the Sydney Basin.

2.3. Life Cycle

Reproduction of the Giant Barred Frog is associated with large permanent pools within streams and rivers where there are cuttings into the bank that provide sheltered horizontal surfaces under the bank. Males call from the edges, or within 10 m of, still or slow flowing pools, often buried under cover (leaf litter or low vegetation). The species will also call from exposed above ground positions when the environment is warm and wet. The call is a relatively soft 'wart wart'. Calling can be heard mainly in the warmer summer months from December to February. There is no clear link between calling/breeding and rainfall, but rather activity is more linked to temperature (Koch and Hero 2007). Frogs tend to disperse away from the breeding sites during periods of flooding rainfall (Streatfield 1999; Lemckert Pers. Obs.).

Eggs are deposited out of the water under overhanging banks or on steep banks by the female flicking the eggs onto the chosen section of bank using her back feet. The eggs are sticky and generally adhere to the surface or other eggs (usually at most two layers of eggs) and start their development (Knowles et al. 1998). The locations where the eggs are deposited are dark and sheltered and maintain higher levels of humidity by being close to the water and eggs that stick in sub-optional locations usually desiccate. Such stream microhabitats are limited (Knowles et al. 1998) and so form a limiting resource for this species and not every part of every stream suits this species.

Hero and Fickling (1996) and Morrison and Hero (2002) reported clutch sizes for the species as 4184 (one clutch counted) and 1343–3471 (13 clutches counted) respectively, which is large by Australian frog standards, buy not really for a frog of this size. The eggs are around 1.7 mm in diameter and development to hatching takes several days. On reaching a suitable development stage (time taken is temperature dependent) the tadpoles hatch out and drop into the stream to continue development. This mechanism of laying eggs out of water is presumed to prevent fish and other aquatic predators present in permanent streams from easily accessing the vulnerable egg and early tadpole stages and tadpoles at hatching stage are capable swimmers.

The tadpoles are dark in colouration with obvious spotting along the dorsal surface and particularly the tail fins. They are large (up to 10 cm long) and very capable swimmers, which is probably a necessity in an environment with predatory fish. The develop within pools in the stream with the aquatic phase of the life cycle lasting up to a year (Anstis 2013).

2.4. Ecology and Habitat Requirements

The Giant Barred Frog is a stream breeding species and a true river frog. It is associated almost exclusively with large (>3rd order) permanent streams with flowing water and this includes large rives (> 50 m width). The Giant Barred Frog is typically found in association with streams located in temperate and sub-tropical rainforest and wet sclerophyll forest (Mahony et al. 1997; Gillespie & Hines 1999; Lemckert and Morse 1999). However, the critical element for the species is riparian vegetation of some type and it is not necessarily native vegetation with the species being well known for inhabiting areas of privet or lantana along creeks (Lemckert and Morse 1999; Lemckert Pers. Obs.) and for inhabiting creeks with only a fringing riparian vegetation in otherwise cleared agricultural lands (Lemckert Pers. Obs.). In north-east New South Wales, statistical modelling was used to investigate the relationship of the Giant Barred Frog with 24 environmental predictors (Gillespie & Hines 1999). The species showed a preference for the interiors of large forest tracts in areas with relatively cool mean annual temperatures. These sites are typically free from any disturbance with a thick canopy and relatively simple understorey. South of the Hunter River the sites historically inhabited by the Giant Barred Frog were larger permanent flowing streams in large tracts of tall wet sclerophyll forest or rainforest and the species did not appear to be associated with dry forests in any way. The species is not associated with isolated ponds (e.g., forest dams) or ephemeral pools.

During periods of breeding activity adults typically shelter under leaf litter and logs close to the breeding stream. Outside of breeding times individuals have often been found on roads at more than

100 m away from the nearest waterbody indicating that individuals move widely through the forest when moist conditions prevail (Mahony 1993; Lemckert & Morse 1999). A limited radio-tracking study of individuals of both sexes conducted near Dorrigo found frogs regularly sheltering in deep (>10 cm) leaf litter immediately adjacent to the roads that they were caught on (F. Lemckert Unpubl. Data). This contrasts strongly with the behaviour of the Giant Barred Frog that has consistently been found to rarely move more than 30 m from its breeding stream.

As noted before, tadpoles develop in clear permanent streams where they are thought to feed on any organic material present in the stream bed. Tadpoles do occur with several species of native fish (Mahony et al. 1997), but the effects of introduced fish such as trout, whilst potentially serious, are not clear (Hunter and Gillespie 2011).

Adult frogs feed on a wide range of invertebrates and small vertebrates (Lemckert and Shoulder 2007) and do not appear to have any specific dietary requirements.

2.5. BioMetric Vegetation Types

In the Sydney Basin Region the Giant Barred Frog is listed to be associated with the following vegetation formations and classes:

Dry sclerophyll forests (shrub/grass sub-formation)

- Northern Gorge Dry Sclerophyll Forests

Dry sclerophyll forests (shrubby sub-formation)

- Sydney Coastal Dry Sclerophyll Forests
- Sydney Hinterland Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests

Forested wetlands

- Coastal Floodplain Wetlands
- Coastal Swamp Forests
- Eastern Riverine Forests

Grassy woodlands

- Western Slopes Grassy Woodlands

Heathlands

- Sydney Coastal Heaths

Miscellaneous ecosystems

- Water bodies, rivers, lakes, streams (not wetlands)

Rainforests

- Cool Temperate Rainforests
- Dry Rainforests Black Bean
- Littoral Rainforests
- Northern Warm Temperate Rainforests
- Southern Warm Temperate Rainforests
- Subtropical Rainforests

Wet sclerophyll forests (grassy sub-formation)

- Northern Hinterland Wet Sclerophyll Forests
- Northern Tableland Wet Sclerophyll Forests
- Southern Tableland Wet Sclerophyll Forests

Wet sclerophyll forests (shrubby sub-formation)

- North Coast Wet Sclerophyll Forests
- Northern Escarpment Wet Sclerophyll Forests
- Southern Escarpment Wet Sclerophyll Forests.

This reasonably broad range of wetter vegetation types indicates, as for most Australian frogs, the lack of any clear relationships with particular vegetation types beyond that of dry vs wetter forests. This species is predominantly associated with wetter forest types.

2.6. Threatening Processes

The Giant Barred Frog is currently listed as endangered under both the EPBC and BC Acts and vulnerable under the IUCN red list.

The IUCN has classified this species as vulnerable because of "a population decline, estimated to be more than 30% over the last ten years, inferred from an observed decline in numbers, and from habitat destruction and degradation". It lists the following as threats to the Giant Barred Frog:

- Residential and commercial development
- Agriculture and aquaculture
- Transportation & service corridors
- Biological resource use
- Pollution

The species is now recognised to almost certainly be extinct south of the Sydney Basin.

The OEH profile for this species lists the following threats to the Giant Barred Frog:

- Modification and loss of habitat.
- Disease - chytrid fungus.
- Changes to natural water flows and water quality.
- Predation of eggs and tadpoles by introduced fish.
- Damage to habitat and impacts on water quality from forestry activities.
- Damage (vegetation removal, disturbance, turbidity) to habitat by domestic stock, feral cattle and pigs.
- Poor knowledge of the species' distribution, taxonomy and history of local extinction.

The Australian Department of Environment and Energy provides the following on its profile in regards to threats for this species:

Upstream clearing, changes in water flow regimes, degradation of water quality, disturbance to riparian vegetation, feral animals, domestic stock and weed invasion have been identified as potential threats to the Giant Barred Frog (Hines et al. 1999; Hines & SEQTFRT 2002).

Disturbance to riparian vegetation is particularly important as many populations of the Giant Barred Frog in south-east Queensland, and some populations in north-east NSW, such as the Tweed Valley, occur along narrow remnant riparian vegetation on private lands (H. Hines 2001, pers. comm.) which are readily exposed to such disturbances. Lemckert (1999) found that the Giant Barred Frog decreased in abundance in recently-logged areas and at sites where little undisturbed forest was available. Damage from Feral Pigs (Sus scrofa) increased greatly in the Conondale Range (Hines & SEQTFRT 2002) and possibly in other areas occupied by the species (H. Hines 2001, pers. comm.). While there is potential for direct predation by pigs, the greatest impact is likely to be from increased silt on embryos and tadpoles (H. Hines 2001, pers. comm.). Similarly, trampling by domestic stock is also likely to have deleterious impacts on oviposition sites of the species (Knowles et al. 1998).

Chytridiomycosis is a disease caused by infection with the chytrid fungus (Batrachochytrium dendrobatidis) affecting amphibians worldwide. The disease has been recorded in four regions of Australia, namely the east coast, south-west Western Australia, Adelaide and Tasmania. This highly virulent pathogen of amphibians is capable, at the minimum, of causing sporadic deaths in some populations, and 100% mortality in other populations (AGDEH 2006o). Chytrid fungus has been identified in individuals of the Giant Barred Frog (Speare & Berger 2000). The role played by chytrid fungus in the decline of the species is addressed in the Species Recovery Plan (Hines & SEQTFRT 2002).

Individuals of the Giant Barred Frog have sometimes been killed in the mistaken belief that they are the introduced Cane Toad (Bufo marinus) (Hines & SEQTFRT 2002).

Populations of the Giant Barred Frog now exist in small, isolated patches of forest. The effect that this may have on genetic variation within populations, the general health of individuals and the species' response to identified threats is unknown (J-M. Hero 2001, pers. comm.).

The role of chytrid fungus in the decline of the Giant Barred Frog has not been explicitly demonstrated, but it is highly likely that this is the primary cause of the major declines and extinction of this species south of Sydney and potentially now within the western Sydney Basin given that many historic areas appear to be unaffected by other factors.

Other impacts noted by DoEE include:

- Trampling by domestic stock
- Introduced fish, such as Eastern Gambusia (*Gambusia holbrooki*), Carp (*Cyprinus spp.*) and salmonids
- Sustained increased levels of sedimentation and changes to water pH

Of the above potential threats, the ones likely to be of a significant consideration in the construction area of Warragamba Dam Raising project are the presence of that amphibian Chytrid Fungus, modification and loss of habitat, changes to natural water flows and water quality and predation of eggs and tadpoles by introduced fish.

Figure 3. Construction footprint

3. Description of the Site

The footprint of the Warragamba Dam Raising development site is provided in Figure 3 and represents the subject site. The following information describing the subject site and its surrounds is taken directly from the Warragamba Dam Raising Construction Biodiversity Assessment Report (SMEC 2019).

3.1. IBRA bioregions and IBRA subregions

The construction study area is located in the Interim Biogeographical Regionalisation of Australia (IBRA) Bioregion of the Sydney Basin and there are two subregions which are relevant to the assessment.

3.1.1. Bioregions

The development site and outer assessment circle are wholly located within the Sydney Basin Bioregion.

Development site: Sydney Basin Bioregion

Outer assessment circle: Sydney Basin Bioregion

OEH provides the following information on the Sydney Basin Bioregion:

The Sydney Basin Bioregion lies on the central east coast of NSW and covers an area of approximately 3.6 million hectares, which is the equivalent of 4.5 percent of NSW. The Sydney Basin Bioregion is one of two bioregions contained wholly within the state. It consists of a geological basin filled with near horizontal sandstones and shales of Permian to Triassic age that overlie older basement rocks of the Lachlan Fold Belt. The sedimentary rocks have been subject to uplift with gentle folding and minor faulting during the formation of the Great Dividing Range. Erosion by coastal streams has created a landscape of deep, cliffed gorges and remnant plateaus across which an east-west rainfall gradient and differences in soil control the vegetation of eucalypt forests, woodlands and heaths. The Sydney Basin Bioregion includes coastal landscapes of cliffs, beaches and estuaries.

The frontal slope of the Blue Mountains (where the site is located) is formed along the Lapstone monocline. A secondary flexure and similar escarpments occur at the coast forming the Hornsby Plateau and the Illawarra Escarpment. These structural features combine with different rock types and strong trends in joint patterns to control drainage patterns and the distribution of gorges and swamps.

3.1.2. Subregions

The development site is located across two IBRA subregions:

- Wollemi subregion
- Burragorang subregion.

Development site: Burragorang (19.59 hectares) and Wollemi (85.26 hectares).

Outer assessment circle: Burragorang (250.08 hectares), Wollemi (708.56 hectares), and Cumberland (40.48).

The outer assessment circle falls within both the Wollemi and Burragorang subregions, as well as within Cumberland subregion. The Wollemi, Burragorang, and Cumberland subregions are described in Table 1.

Table 1. Description of the subregions within Sydney Basin Bioregion occurring within the development site

SUBREGION	GEOLOGY	CHARACTERISTIC LANDFORMS	TYPICAL SOILS	VEGETATION
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. There are also a number of scattered volcanic necks distributed throughout the Wollemi subregion.	Characterised by the highest part of the Blue Mountains and other sandstone plateaus with benched rock outcrops.	Typically, soils are thin sands or deep yellow earths on plateaus, with thin texture contrast soils on shale benches. Organic sands in line swamps and joint crevices, while slope debris are found below cliffs, and sandy alluvium in pockets along the streams. On basalts, soils are red brown structured loams.	*Corymbia gummifera*, *Corymbia eximia*, *Angophora floribunda*, *Angophora costata*, *Eucalyptus sclerophylla*, and *Eucalyptus punctata* with diverse shrubs and heaths on plateau. Additionally, *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus agglomerata*, and *Syncarpia glomulifera* subsp. *glomulifera* and gully rainforests are present in gullies and canyon heads. *Eucalyptus viminalis* and Blaxland's Stringybark on basalt. *Casuarina cunninghamiana* is found along main streams.
Burragorang	Comprised of Permian and Triassic sandstones and shales on the western edge of the Sydney Basin.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley	Typically, soils include rocky outcrops, texture contrast soils and uniform sands on sandstone. Cliff bases are generally pillowed with a sandy, clay matrix, alluviums contain rich loams.	Heath, shrubland and woodland with *Eucalyptus sieberi*, *Eucalyptus sclerophylla*, *Eucalyptus piperita* and *Corymbia gummifera* on sandstone similar to other parts of the Basin. *Eucalyptus deanei*, *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus agglomerata* immediately below escarpment passing to *Eucalyptus punctata*, *Eucalyptus crebra* and *Eucalyptus eugenoides* on rocky slopes. *Casuarina cunninghamiana* along main streams below the plateaus.
Cumberland	Triassic Wianamatta groups shales and sandstones, which are intruded by a small number of volcanic vents and partly covered by Tertiary river gravels and sands. There is quaternary alluvium along the mains streams.	Low rolling hills and wide valleys in a rain shadow area below the Blue Mountains. Volcanics from low hills in the shale landscapes. Swamps and lagoons on the floodplain of the Nepean River.	Typically, soils include a mixture of clays on volcanics, poor stony soils on older gravels, and high quality loams on floodplain alluvium.	*Eucalyptus moluccana, Eucalyptus tereticornis, Eucalyptus crebra* woodland with some *Corymbia maculata* on the shale hills. *Eucalyptus sclerophylla, Angophora floribunda*, and *Banksia serrata* on alluvial sands and gravels. *Angophora subvelutina, Eucalyptus amplifolia* and *Eucalyptus tereticornis* with abundant *Casuarina glauca* on river flats. Tall spike rush, and juncus with *Eucalyptus parramattensis* in lagoons and swamps.

3.2. NSW landscape regions (Mitchell Landscapes)

The development site is located across four landscape regions:

- Kurrajong Fault Scarp
- Lapstone Slopes
- Burragorang Valley and Gorges
- Nattai Plateau.

Development site: Kurrajong Fault Scarp (92.95 hectares); Lapstone Slopes (10.31 hectares); Burragorang Valley and Gorges (1.56 hectares); and Nattai Plateau (0.03 hectares)

Outer assessment circle: Kurrajong Fault Scarp (611.99 hectares); Lapstone Slopes (97.60 hectares); Burragorang Valley and Gorges (127.69 hectares); Silverdale Slopes (120.36 hectares); and Nattai Plateau (42.37 hectares)

Kurrajong Fault Scarp occurs over the majority of the development site (as measured by area) followed by Lapstone Slopes, Burragorang Valley and Gorges, and Nattai Plateau. Descriptions of each Mitchell Landscape are provided in Table 2.

Table 2. Description of the Mitchell Landscape

MITCHELL LANDSCAPE	DESCRIPTION
Kurrajong Fault Scarp	Dissected and broken slopes on Triassic Quartz sandstone and shale across the Lapstone monocline and Kurrajong fault scarp. Local dips on the sedimentary rocks up to 300 m, general elevation 100 to 250 m, local relief 100 m. Abundant rock outcrop with pockets of yellow-brown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of: *Eucalyptus agglomerata*, *Syncarpia glomulifera* subsp. *glomulifera*, *Corymbia gummifera*. *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus radiata*, *Eucalyptus punctata*, *Eucalyptus pilularis* and *Allocasuarina* sp. Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered *Eucalyptus tereticornis*, *Angophora floribunda* and *Eucalyptus globoidea* on the margins.
Lapstone Slopes	The frontal slope of the Blue Mountains formed by folding and faulting of Triassic quartz sandstone and shale with a veneer of Tertiary river gravels. A southern extension of the Kurrajong Fault Scarp landscape. Larger streams cut through the structural ridge in deep gorges, but smaller streams have accumulated organic sands in swamps and lagoons on the western side of the flexure. General elevation 50 to 300 m, local relief 180 m, steep dip slopes on the eastern face and benched faulted slopes on the west. Extensive rock outcrop, thin sandy soils with gravel and occasional white or yellow clay subsoils. Pockets of deep sand in some streams. *Corymbia gummifera*, *Corymbia eximia*, *Eucalyptus punctata*, *Allocasuarina torulosa*, *Eucalyptus sieberi*, *Eucalyptus radiata* with diverse shrubby understorey.

MITCHELL LANDSCAPE	DESCRIPTION
Burragorang Valley and Gorges	Deep steep sided benched slopes and gorge of the Wollondilly and Coxs Rivers incised into mostly horizontal Triassic quartz sandstone conglomerate, siltstone, and shale, cliffs to 150m high with waterfalls, general elevation 50 to 220 m, local relief 150 m. The gorge widens upstream and exposes underlying Permian chest, mudstones and conglomerate. Very extensive rock outcrop, thin yellow to yellow-brown silty sand and gravel with occasional white clay layers forming either shallow yellow earths or gleyed texture-contrast profiles. *Corymbia gummifera*, *Syncarpia glomulifera*, and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliffs upstream with *Eucalyptus tereticornis*, *Eucalyptus macrorhyncha*, *Eucalyptus crebra*, and *Eucalyptus mannifera*. Moist protected environments with *Eucalyptus saligna*, *Eucalyptus cypellocarpa*, *Eucalyptus muelleriana* and *Eucalyptus smithii*. Gallery forest of *Casuarina cunninghamiana* with *Eucalyptus deanei* and *Eucalyptus benthamii* along the main streams.
Nattai Plateau	Steeply dissected plateau remnants on lower Triassic lithic sandstone, shale and tuff, abundant rock outcrop and cliffs, steep debris slopes, general elevation 600 to 700 m, local relief 80 m. Shallow sand and occasional yellow texture-contrast soils. Forests of *Eucalyptus eugenioides*, *Eucalyptus fibrosa* subsp. *fibrosa*, *Callitris rhomboidea*, *Eucalyptus sieberi*, *Eucalyptus blaxlandii*, *Eucalyptus fastigata* and *Eucalyptus viminalis*.
Silverdale Slopes	Moderately undulating slopes descending to the east on gently dipping Triassic shales and sandstones. General elevation 230 to 630 m, local relief 200 m. Brown to yellow-brown texture-contrast soils. Woodland to forest with a shrubby understorey, common species; *Eucalyptus punctata*, *Eucalyptus albens*, *Eucalyptus paniculata*, *Eucalyptus crebra*, *Eucalyptus fibrosa*, *Eucalyptus moluccana*, *Allocasuarina torulosa*, *Eucalyptus eugenioides*, and occasional *Syncarpia glomulifera*.

3.3. Rivers and streams

The development site falls within the Warragamba catchment. Bordered on the west by the Great Dividing Range, the catchment stretches from north of Lithgow at the head of the Coxs River in the Blue Mountains, to the source of the Wollondilly River west of Crookwell, and south of Goulburn along the Mulwaree River.

The proposed construction area includes areas of Lake Burragorang, the dam wall spillway and Warragamba River. Up until the dam wall, Lake Burragorang is considered to be a 9^{th} order stream in accordance with the Strahler stream ordering method. The current geomorphological condition at the dam is characterised by altered hydrological and sediment transport regimes between the upstream catchment and downstream rivers and floodplains.

3.4. Wetlands

One wetland (Lake Burragorang) has been mapped within the construction study area within the NSW Wetland shapefile. No important or local wetlands occur within the development site or outer assessment circle. There are a number of smaller dams mapped to the east of the development site, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 km of the development site.

3.5. Native vegetation

The development site is centred around Warragamba Dam, which flooded Warragamba Gorge when it was constructed between 1948 and 1960. As such, the vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation. Instead much of the development site is comprised of vegetation typical of ridgetops on skeletal soils. The majority of the development site supports dry sclerophyll forest of shrubby sub-formation, as well as an area of wet sclerophyll forest. To the west of Warragamba Dam, to both the north and south of Lake Burragorang, the vegetation is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenoides*, *Eucalyptus sieberi* and *Corymbia gummifera*. To the north-east of Warragamba Dam there is an area of wet sclerophyll forest which extends through a drainage line from just below the ridge line down to the dam infrastructure at the base of the dam wall. The canopy in this area is dominated by *Eucalyptus pilularis*, *Syncarpia glomulifera*, *Eucalyptus punctata* and *Angophora costata*. This vegetation conforms to the Shale/Sandstone Transition Forest Critically Endangered Ecological Community under the BC Act and EPBC Act.

The development site is 104.85 hectares in size. A total of 54.37 ha of native vegetation has been mapped within the site with Table 3 providing a summary of the PCTs mapped as occurring, including vegetation formation, percent cleared within the Hawkesbury-Nepean catchment and extent within the development site. None of this vegetation is particularly suitable for the Giant Barred Frog to use as shelter and feeding habitat.

Table 3. Summary of PCTs occurring within the development site

PCT CODE/ BVT CODE	PCT NAME	VEGETATION FORMATION	VEGETATION CLASS	% CLEARED WITHIN HN CATCHMENT	AREA WITHIN SITE (HA)
HN564 (PCT ID 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	40	16.96
HN566 (PCT ID 1083)	Red Bloodwood - Scribbly Gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Coastal Dry Sclerophyll Forests	25	24.78
HN568 (PCT ID 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Dry Sclerophyll Forests (Shrubby sub-formation)	Sydney Hinterland Dry Sclerophyll Forests	20	8.69
HN604 (PCT ID 1281)	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains,	Wet Sclerophyll Forests (Grassy sub-formation)	Northern Hinterland Wet Sclerophyll Forests	90	4.94

PCT CODE/ BVT CODE	PCT NAME	VEGETATION FORMATION	VEGETATION CLASS	% CLEARED WITHIN HN CATCHMENT	AREA WITHIN SITE (HA)
	Sydney Basin Bioregion				

3.6. Landform, geology and soils

The study area is approximate 104.85 hectares and is located at and adjacent to Warragamba Dam. The elevation within the study area is varied, ranging between 21 metres AHD at its lowest point to 195 metres AHD at its highest point. The study area slopes from the top of the gorge down to the dam and Warragamba River.

The Soil Landscapes of Penrith 1:100,000 soil landscape sheet has mapped four soil landscapes within the outer assessment circle as outlined in Table 4 below.

Table 4. Soil landscape description

NAME	LANDSCAPE	SOILS	LIMITATIONS
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20-80 meters, slopes 10-15%. Rock outcrop 25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop with broken scarps.	Shallow to moderately deep (30-100 cm) yellow earths and earthy sands on crests and on insides of benches; shallow siliceous sands on leading edges of benches; localised gleyed podzolic soils and yellow podzolic soils on shale lenses; shallow to moderately deep (<100 cm) siliceous sands and leached sands along drainage lines.	Steep slopes, water erosion hazard, rock outcrop, localised rockfall hazard, localised non-cohesive soils, shallow highly permeable soil, very low soil fertility.
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces on Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop.	Shallow (<50 cm) earthy sands and yellow earths; some siliceous sands / lithosols associated with rock outcrop.	Shallow, highly permeable soil, localised non-cohesive soils, very low soil fertility, localised water erosion hazard, localised rick outcrop.
Hawkesbury	Rugged, rolling to very steep hills on Hawkesbury Sandstone. Local relief 40-200 m, slopes >25%. Rock outcrop >50%. Narrow crests and ridges, narrow incised valleys, steep sideslopes with rocky benches, broken scarps and boulders.	Shallow (<30 cm) discontinuous lithosols / siliceous sands, associated with rock outcrop; earthy sands, yellow earths and some locally deep sands on inside of benches and along joins and fractures; localised yellow and red podzolic soils associated with shale lenses, siliceous sands and secondary yellow earths along drainage lines.	Steep slopes, mass movement hazard, rockfall hazard, water erosion hazard, shallow soils, rock outcrop, non-cohesive soils (localised), stony, highly permeable soils of low fertility.
Blacktown	Gently undulating rises on Wianamatta Group shales. Local relief to 30	Shallow to moderately deep (>100 cm) hardsetting mottled texture contrast soils, red and	Localised seasonal waterlogging, localised water erosion hazard,

NAME	LANDSCAPE	SOILS	LIMITATIONS
	m, slopes usually >5%. Broad rounded crests and ridges with gently inclined slopes.	brown podzolic soils on crests grading to yellow podzolic soils on lower slopes and drainage lines.	moderately reactive highly plastic subsoil, localised surface movement potential.

3.7. Hydrology

Lake Burragorang is the dominant hydrological feature of the study area. Created by damming the Warragamba River and flooding the Burragorang Valley, Lake Burragorang is four times the size of Sydney Harbour and is currently managed as Sydney's water supply dam.

Downstream of the dam is the Warragamba River. Water is discharged into Warragamba River when the dam spills. Water is also released into the Warragamba River (downstream of the Warragamba Weir) to provide a secure water supply to the population of North Richmond. Warragamba River is a 9th order Strahler stream and there are several small, unnamed ephemeral tributaries within study area.

3.8. Climate

There are no weather stations within the construction area, but Table 5 provides summaries of the weather conditions for stations located around the area. The climate for the area is mild with moderate rainfalls.

Table 5. Key climatic statistics for weather stations near the survey area.

WEATHER STATION	MEAN ANNUAL RAINFALL (MM)	MEAN MAXIMUM TEMPERATURE (°C)	MEAN MINIMUM TEMPERATURE (°C)
Jenolan Caves (1895-) (24 km W, 690 m higher)	970.6	25.6	0.2
Penrith Lakes AWS (1995-) (20 km NNE, 90 m lower)	718.6	31.0	5.3
Springwood (1883-) (21 km N, 250 m higher)	1082.1	29.0	6.5
Katoomba (1885-) (15 km N, 890 m higher)	1399.6	23.4	2.6
Picton Council Depot (1880-) (15 km SE, 60 m higher)	794.3	29.3	1.7

3.9. Land uses

The development footprint is located on land zoned as SP2 Infrastructure (Water Supply) under the *Wollondilly Local Environmental Plan (LEP) 2011* (Figure 4). This land around the dam serves as operational support for the existing dam and consists of cleared and vegetated areas, dam support facilities, access roads and parks. The proposed works would be permissible within this land zone type and construction activities would be contained within this zone.

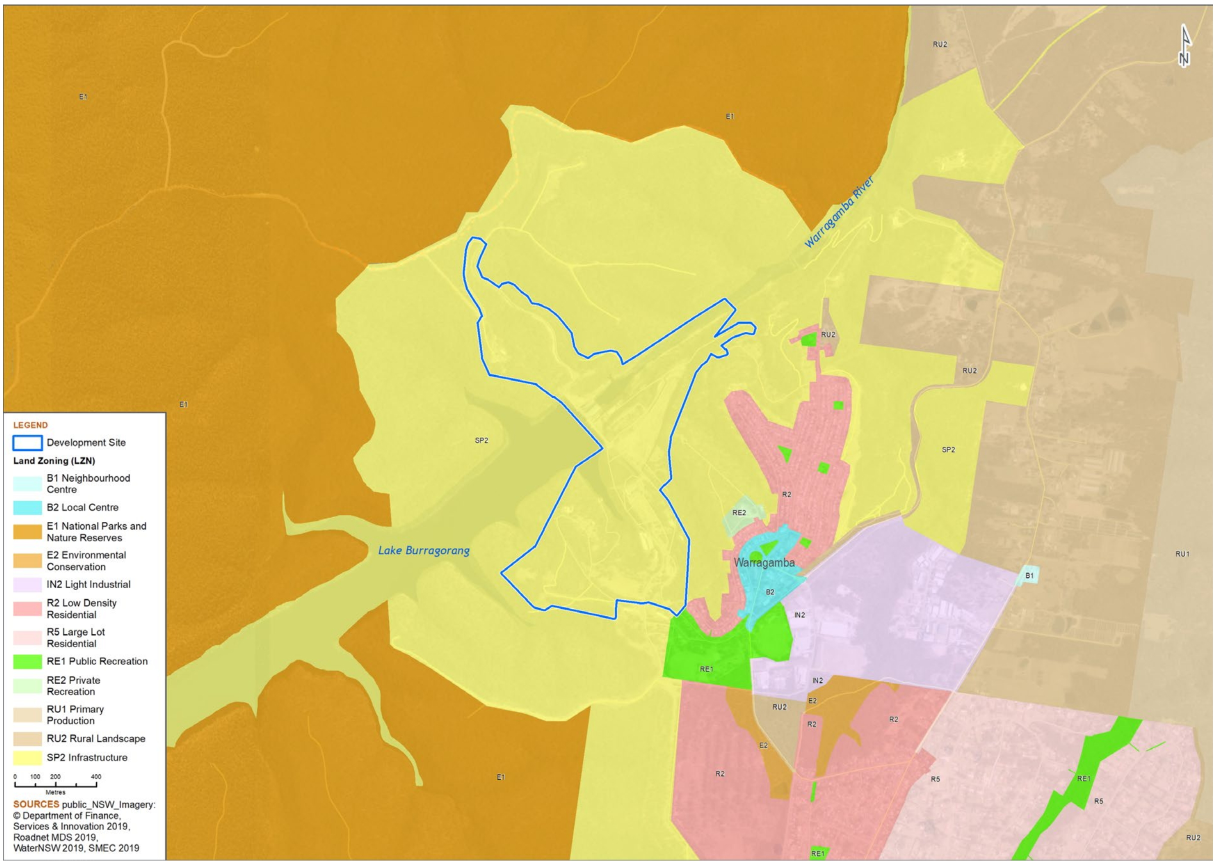

Figure 4. Land use zones

3.10. Habitat for the Giant Barred Frog

The construction area is comprised mainly of areas of sclerophyll woodland growing on the slopes of a steeply incised river valley. Rock outcrops are present broadly across the construction study area and there are several gully lines that hold ephemeral water courses that occur on both sides of the main river valley and feed into it at the level of the dam or the Warragamba River (Figure 5). The vegetation present around the dam wall on the slopes of the valley is generally intact due to the prohibited access to the Warragamba Dam catchment. Hence the vegetation represents suitable habitat for the Giant Barred Frog and the water quality of the ephemeral creeks feeding into the Warragamba River and the dam itself should not have been affected by surrounding urbanisation.

The Warragamba River directly below the dam wall has a highly modified flow and exists only as a series of large pools and sometimes stagnant pools. This is a result of the outflow pipe being situated not on the other side of the wall but instead approximately 1.7 km downstream of the wall. The vegetation lining the river up to the outflow pipe is a disturbed community with a significant presence of weeds.

Some vegetation has been historically cleared to provide infrastructure for the dam that includes the dam itself as well as the ancillary roads, buildings and areas for tourism (e.g., picnic areas) (Figure 3) .

The study site retains full connectivity with large undisturbed tracts of native sclerophyll forests that are retained in the catchment and the impacts of roads and the effects of rural land uses (i.e. managed midstorey) are minimal.

The site was visited and viewed by myself on the days of the 12 and 13 of February 2018.

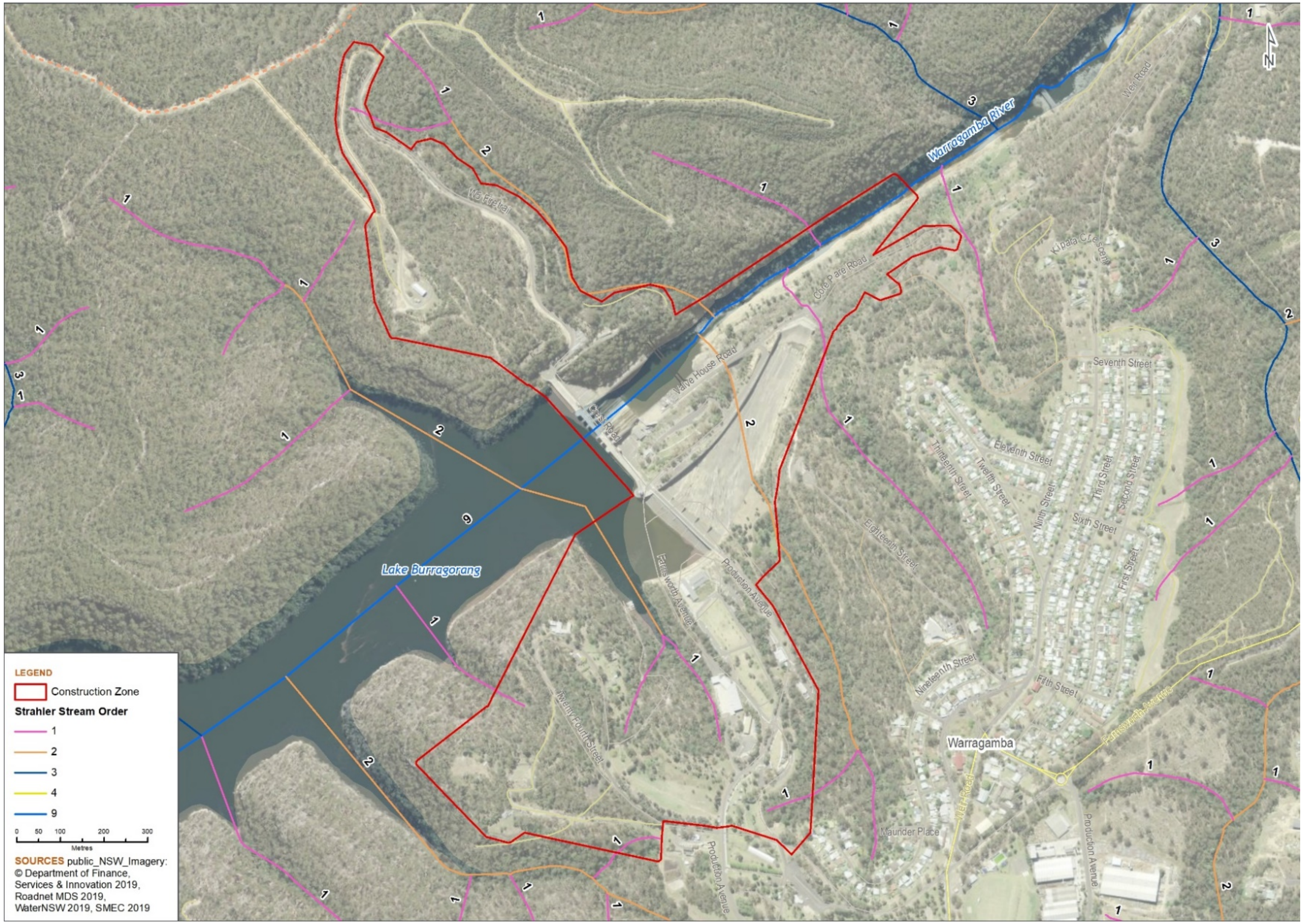

Figure 5. Stream order

4 Expert Assessment of Impacts

4.1 Local records

There are no BioNet (2018) database records of the Giant Barred Frog within the subject or within a 10 km radius of the site (Figure 2).

4.2 Breeding Habitat

The Giant Barred Frog in the Sydney Basin historically bred in permanent streams located in large tracts of wet sclerophyll or rainforest and did not use rainforest lined creeks in dry forests at all. They can use streams that very occasionally stop flowing but retain large pools.

2.6.1. Shelter Habitat

The Giant Barred Frog shelters under logs and in low vegetation but mainly under thick leaf litter. Giant Barred Frogs have rarely ever been recorded more than 20 m away from the breeding site and prefer to remain in close proximity to water. The species is not known to seek shelter within areas cleared of native vegetation or that are significantly disturbed.

The streamside vegetation of the Warragamba River is generally in poor condition and is not made up of wet forest types that extend 10-20 m from the edge of the bank. Hence it provides poor shelter habitat for frogs as there is very limited leaf litter for cover and would not provide the depth of litter cover in wet forest habitat this species needs.

2.6.2. Foraging Habitat

The Giant Barred Frog has no known specific dietary requirements that might limit its distribution across the landscape and it is assumed that this species is foraging in the same area as it the sheltering habitat. As this habitat does not provide suitable shelter it is also not likely to be used for foraging.

2.6.3. Total area of habitat impacted

There is no suitable habitat for this species within the study area.

5 Conclusion

The Giant Barred Frog is not known to be present within the WDR construction study area and there is little evidence to indicate that it has ever occurred in this area. However, surveys were not carried out effectively to determine the presence or absence of the species. The Warragamba River in the study area provides permanent water, but not permanent flowing water as is used for breeding by the Giant Barred Frog. There are no other potentially suitable breeding streams present. The vegetation present is not wet forest habitat that is used by this species in the Sydney Basin and the vegetation around the Warragamba River is also in poor condition.

On this basis I consider that, even in the unlikely situation that the species once occurred in the study area, the Giant Barred Frog is not present within the Warragamba Dam Raising construction area and it needs no consideration in regards to be impacted by the proposed works.

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19 Appendix A. CV – Dr. Frank Lemckert

Frank has been a professional scientist since 1992, specialising in understanding and managing the ecology and management of threatened species and particularly frogs. Frank has conducted ecological work throughout eastern Australia (NSW, Victoria, Queensland), establishing long-term research and monitoring programs into the management of fauna and developing strategies to mitigate the impacts of human disturbances. He has worked extensively with the NSW state and federal Governments on varying issues of fauna and flora management including the preparation of a draft NSW/National recovery plan for the Giant Burrowing Frog (*Heleioporus australiacus*) and is an accredited expert on the Green and Golden Bell Frog (*Litoria aurea*). Frank has prepared reports on endemism and representation in reserves of flora and fauna for the Commonwealth, represented the NSW Forestry Commission in license negotiations for the Comprehensive Regional Assessment process (2000) and provided expert ecological advice on illegal land clearing for the NSW and Commonwealth Governments. He has authored over 90 peer-reviewed publications. Frank is a research associate with the Australian Museum and University of Newcastle, convenor of the NSW Declining Frog Working Group and a member of the IUCN's Amphibian Specialist Group. He is a recognised expert in frog ecology and management, but has completed management related projects and works on a range of terrestrial vertebrate fauna.

Frank's primary role as a consultant has been to use his expertise and experience in technical writing and threatened species legislation to develop and maintain quality assurance in project reporting including:

- Two Species Impact Statements.
- >100 flora and fauna reports and assessments of significance using the EP&A Act and EPBC Act.
- Biodiversity Assessment Reports for Warragamba Dam Raising, Nowra Bridge, Golden Highway and Eurobodalla Dam.
- Manager for the Oxley Highway to Kempsey and Frederickton to Eungai ecological monitoring program.
- Construction and Environmental Management Plans, Monitoring Plans and Vegetation Management Plans for roads at Port Macquarie, Berry to Bomaderry and South Nowra.
- Nest Box, microbat and Green and Golden Bell Frog management plans for the Berry to Bomaderry and Oxley Highway to Kempsey Highway Upgrades.
- Review of monitoring strategies for the Woolgoolga to Ballina and Warrell Creek to Nambucca Heads programs for the Pacific Highway Upgrade.
- Review of two proposed Coal Seam Gas Impact Assessment methods for Matters of National Environmental Significance (contracted by the Commonwealth Government).
- Provision of species credit species expert reports for the Warragamba Dam raising project and Western Sydney Growth Centres Biocertification.

QUALIFICATIONS

- Bachelor of Science, University of Sydney, 1984 (Terrestrial Ecology and Marine Management)
- Master of Science, University of Sydney, 1991 (Population biology of the Common Froglet)
- PhD, University of Newcastle, 2009 (Management of forest frogs in timber production forests of NSW)

PROJECT EXPERIENCE

Ecological impact assessment

- Expert report on the green and golden bell frog for the western Sydney growth areas Biocertification project (2018-2019)
- Warragamba dam raising project target surveys, impact assessments, expert reporting (six species) and q/a for Water for NSW (2018-19)
- Shading impacts for proposed building works at Homebush, NSW. Piety Pty Ltd (2018)
- Granite hills windfarm bird and bat strike modelling and ecological impact assessment, Nimmitabel, Akuo Energy (2018) and Elysian Windfarm, Nimmitabel, Akuo Energy (2018)
- Vegetation removal and threatened frog management strategies, new intercity fleet management facility, John Holland Group (2018-19)
- Eurobodalla dam biodiversity assessment report, Eurobodalla Shire Council (2017-18)
- Nowra Bridge EIS ecological assessments, NSW RMS (2018)
- Heathcote road upgrade impact assessment and review of mitigation measures, NSW RMS (2018-2019)
- Mona vale road threatened fauna expert survey and impact assessment, Ecosure and NSW RMS (2015-2016).

Government reviews/reports

- Biodiversity assessment method frog survey guidelines for species credit species (2019)
- Expert review of biodiversity impact assessment report for the Hornsby quarry rehabilitation project (2019)
- Review of impact assessment pathways for two LNPG projects, Commonwealth government (2013)
- Expert advice on impacts of illegal land clearing at Somersby, Commonwealth government (2015)
- Expert advice on impacts of illegal land clearing at Evans Head, NSW state government (2016)
- Review of threatened species modelling in forestry areas, Vic forests (2012)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for WPS (2008)
- Review of monitoring strategies for the Woolgoolga to Ballina and Warrell Creek to Nambucca Heads programs for the Pacific Highway upgrade, NSW RMS (2014)
- Hornsby council expert witness for development impacts at Dural, Hornsby Shire Council (2016)
- Expert representing Forests NSW in the comprehensive reginal assessment program for the regional forest agreement program (1999-2001)
- Review of threatened species modelling in forestry areas, Vic Forests (2012)
- Flora and fauna representation in the Australian reserve system, commonwealth government (2010)
- Flora and fauna endemism patterns across australia, commonwealth government (2009)
- Review impacts to threatened reptiles and amphibians in the southern brigalow belt, for WPS (2008)
- Expert review of fauna and flora impacts for 13 NSW Forestry Commission EIS reports (1992-94).

EPBC referrals

- Green and golden bell frog (*Litoria aurea*) referrals for the princes highway upgrade at south Nowra, NSW RMS
- Austen quarry (*Eucalyptus pulverulenta*), Hartley, Hy-Tec Industries (2014-15)
- Marys Mount Koala (*Phascolarctos cinereus*) referral, Gunnedah Quarry Products (2015).

Monitoring programs

- Oxley Highway to Kempsey threatened biodiversity monitoring, NSW RMS (2013-2017)
- Green and golden bell frog baseline monitoring program at Meroo Lakes, NSW OEH (2016-17)
- FCNSW statewide ecological monitoring program, Forestry Corporation of NSW (2009-10)
- Threatened fauna monitoring Hume Highway, Kapooka, NSW RMS (2018).

Plans of management / strategies

- Commonwealth/NSW Giant Burrowing Frog recovery plan, DEWHA/DECC (2012)
- Eastern Bentwing-bat management plan, Gerringong, NSW RMS (2014)

- Nestbox, microbat and Green and Golden Bell Frog management plans, Berry to Bomaderry upgrade of the Princes Highway, NSW RMS (2017)
- Green and Golden Bell Frog surveys and monitoring, Princes Highway upgrades at South Nowra and Berry to Bomaderry, NSW RMS (2012-2017)
- Green and Golden Bell Frog management strategy, Princes Highway upgrade, NSW RMS (2012-2014)
- Green and Golden Bell Frog pre-clearing works, Kooragang Island (Daracon 2016 & current)
- Microbat management plan for Clarencetown bridge, NSW RMS (2016)
- Expert review of threatened frog management plan - Woolgoolga to Ballina upgrade of the Pacific Highway, NSW RMS (2014)
- Threatened microbat management plan for Warringah Mall, Northern Beaches Council (2014)
- Threatened frog modelled habitat requirements, Hornsby Shire Council (2016).

Training

- Lead instructor > 50 wildlife training schools run in NSW, ACT and Victoria providing presentations on the survey, identification and management of all flora and fauna. This included detailed instruction on the management of threatened wading and aquatic birds and other aquatic species presented to Queensland, Victorian, NSW and Commonwealth government staff (1993-2017)
- Private forestry survey requirements, Victorian timber (2016).

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Appendix M Expert Report: *Pterostylis saxicola*

Expert report on the Sydney Plains Greenhood, *Pterostylis saxicola* in the area predicted to be affected by the Warragamba Dam wall raising project. 2. Construction Footprint

[redacted]

15 November 2019

Table of Contents

1. Introduction

1.1 Project context

WaterNSW, a corporation owned by the State Government of New South Wales, is planning to raise the wall of Warragamba Dam by approximately 14 metres for the purpose of flood mitigation in the Hawkesbury Nepean River catchment ("the project"). This is a Major Project of State Significant Infrastructure for which WaterNSW must conduct an Environmental Assessment and prepare an Environmental Impact Statement (EIS), as directed by the Secretary's Environmental Assessment Requirements (SEARs) (where "the Secretary" is the Secretary of the Department of Planning and Environment). The EIS will determine the impact of raising the dam wall on threatened species and ecological communities upstream of, downstream of, and in the immediate vicinity of the dam wall. The EIS will also provide conservation measures to mitigate any impact, as specified by NSW and Commonwealth environmental legislation. The EIS must include plans for compensating for the damage caused by the project to native biodiversity, as specified in the State Government's NSW Biodiversity Offsets Policy for Major Projects. This policy requires WaterNSW to apply the Framework for Biodiversity Assessment (FBA) to assess impacts on biodiversity (NSW Office of Environment and Heritage 2014). The FBA specifies that each threatened species that is likely to be impacted by the project should be surveyed in the affected areas, or, if that is not feasible, that an export report be prepared to assess the presence, total area and geographic distribution of suitable habitat in the impacted areas, and to estimate the number of individuals likely to occur there if this and not area is the unit of measurement identified for the species in the Threatened Species Profile Database.

The FBA specifies that an expert report must:
6.6.2.3 … document the information that was considered, and/or rejected as unsuitable for consideration, to reach the determination made in the expert report.
6.6.2.5 … set out whether:
(a) for development sites – the species is unlikely to be present on the development site – in this case no further assessment of the species is required, or
(b) for all development sites – the species is likely to be present on the site – in this case the expert report must provide an estimate of the number of individuals or area of habitat to be impacted by the development or the management actions (according to the unit of measurement identified for the species in the Threatened Species Profile Database).

According to Section 6.5.2 of the Biodiversity Assessment Method (NSW Office of Environment and Heritage 2017), an expert report must also:

- identify the relevant species or population
- justify the use of an expert report
- indicate and justify the likelihood of presence of the species or population
- include a description of how the estimate [of the number of individuals or area of habitat] was made
- identify the expert and provide evidence of their expert credentials.

1.2 Purpose of the expert report

In March 2019 I was engaged by SMEC Australia on behalf of WaterNSW to produce three expert reports on the distribution and abundance of an endangered species of orchid, *Pterostylis saxicola*, within the area predicted to be impacted by the Warragamba Dam wall raising project. This report is the second of these and deals with impacts in the area directly affected by construction work on the dam wall itself (termed "the survey area" herein). The aim of this exercise is to assess whether *P.*

saxicola is native to the survey area and, if so, to assess where suitable habitat is located, and to estimate the area occupied by *P. saxicola* in the survey area (the unit of measurement identified for *Pterostylis saxicola* in the Threatened Species Profile Database is area).

Sections 1.5, 2, 4.1-4.6, 4.8.4, 5 and 6 are essentially the same as the comparable sections in my report on the upstream part of the Warragamba dam raising proposal (Weston unpublished c). They are repeated here to save readers the inconvenience of having to repeatedly refer to the other document.

1.3 Survey area

The survey area for this report is located within 1.1 km of the Warragamba Dam wall, west of the Sydney Metropolitan Area, between latitudes 33° 52′ 30″ S and 33° 53′ 32″ S and longitudes 150° 35′ 21″ E and 150° 36′ 28″ E (figure 1). It comprises 105 hectares of land, including the existing dam wall and abutment structures, auxiliary roads, associated operational buildings and adjacent bushland.

1.4 Reasons for use of expert report

Pterostylis saxicola has never been collected or observed within the survey area. However, sites at which the species has been collected or observed, according to the BioNet Wildlife Atlas, are known to the north, north east, east, south east and west of the survey area. The survey area is located within the extent of occupancy (EOO) of *P. saxicola*, suggesting that it is part of the distributional range of the orchid. Moreover, according to vegetation mapping by SMEC (2019), a plant community type (PCT) in which populations of *P. saxicola* are known to occur, PCT 1081 (Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain), is present in the survey area, raising the strong possibility that suitable habitat for *P. saxicola* might exist there. If this were so, *P. saxicola* might once have lived there, or still exist in the survey area as an unrecorded population.

Pterostylis saxicola is a perennial, deciduous herb that can only be identified with confidence when flowering in Spring (late September to early November). However, the cryptic coloration and small size of this plant render it a challenging subject for conventional surveying: aerial and “drive by” surveys are not feasible and even experienced orchid spotters need to be standing within a few metres of a flowering plant to notice it. In any case, plants may not flower if climatic conditions during the growing season from March to December (see section 2.2 below) are poor. These limitations and the possibility that *P. saxicola* might be native to the survey area triggered the need for an expert report.

An alternative surveying approach used here involves the construction of a general habitat model for *Pterostylis saxicola*, which can then be used, in conjunction with environmental maps, to identify suitable habitat across the survey area.

1.5 Credentials of expert

I prepared this report as an independent botanical consultant but I am also currently an Honorary Research Associate at the National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust (the New South Wales state herbarium). In 2016, I retired from my role as a Senior Principal Research Scientist at the state herbarium, having worked there since 1982 as a Systematic Botanist and as curator of the herbarium’s collections of specimens of Orchidaceae (including *Pterostylis saxicola*) (see my Curriculum Vitae, attached). I now work, part-time, at the National Herbarium of New South Wales as an Honorary Research Associate. I have published, either as sole author or as a co-author, 16 papers on the systematics and ecology of the Orchidaceae in the peer-reviewed scientific literature, including the most comprehensive phylogenetic analysis of the predominantly Australian subtribe Diurideae yet published (Weston et al. 2014). As curator of Orchidaceae at the state herbarium, I examined all specimens of P. saxicola incorporated into the collection between 1986 and 2016. I was invited to contribute to floristic treatments of the Orchidaceae for Flora of New South Wales, (see my Curriculum Vitae, attached). I was also asked to be lead author of the essay on the ecology of the Orchidaceae that accompanied the “Ecology of Sydney Plants” (Weston et al. 2005). Throughout my career I have participated in numerous collecting trips in the field, collecting specimens in all Australian states for the state herbarium. In documenting these specimens I had to describe the habitat at each collecting site, including associated plant species, substrate, aspect, degree and kind of disturbance. I have also cultivated numerous species of Pterostylis as an orchid enthusiast and advised horticulturalists at the Royal Botanic Gardens on appropriate techniques for cultivating species of Pterostylis and other orchids.

Figure 1. Map of the survey area (area enclosed within the blue line).

In 2018 I prepared expert reports on *Pterostylis saxicola* in the Greater Macarthur, Wilton, and Western Sydney Aerotropolis Growth Areas and in the Greater Penrith to Eastern Creek Urban Release Investigation Area for the N.S.W. Department of Planning and Environment (Weston unpublished a,b). In March 2019 I was contracted by SMEC to prepare three expert reports on *Pterostylis saxicola* for the Warragamba Dam raising project, the first of which (Weston unpublished c) was submitted to SMEC on 18 May 2019. During the preparation of these reports I characterised in detail the associated plant species and other ecological attributes of seven plots, each of 30 metre radius, centred on highly precise grid references of sites at which *P. saxicola* had previously been collected, at two of which I found flowering plants of *Pterostylis saxicola*. I am personally familiar with this taxon and the habitats in which it lives.

In November 2018 I was approved by the Office of Environment and Heritage as a species expert for *Pterostylis saxicola* under section 6.5.2 of the Biodiversity Assessment Method (see https://www.environment.nsw.gov.au/topics/animals-and-plants/biodiversity/biodiversity-offsets-scheme/experts). This approval is current for a period of six years.

2. Species information

2.1 Species description

The following morphological description of *Pterostylis saxicola* is a modified version of that published by Jones and Clements (1997), updated with data gathered from more recently collected specimens held by the National Herbarium of N.S.W (see figures 2, 3).

Tuberous, terrestrial herb. Tubers oblate, c. 15-20 mm wide. Leaves oblong-elliptical to ovate-elliptical or obovate, 10-45 mm long, 5-15 mm wide, 5-10 in a radical rosette, green, the margins entire, shortly petiolate, apex subacute to apiculate, often withered at anthesis. Inflorescence 10.5-35 cm tall, slender, with 3-6 ensheathing, lanceolate sterile bracts. Floral bracts lanceolate, 6-19 mm long, 3-4 mm wide, acuminate, closely sheathing. Pedicels 3-26 mm long, slender, straight or slightly curved. Ovary narrowly obovoid, 3-5 mm long, 1-2 mm wide, reddish brown. Flowers 1-10, porrect to semi-erect, 12-12 mm long, transparent with dark red-brown markings and suffusions in the galea, the lateral sepals wholly red-brown, shiny; galea gibbous at the base, curved medially, decurved suddenly to the apex; petal flanges poorly developed, not touching and not closing off the base of the galea. Dorsal sepal 11-13 mm long, cucullate, obliquely erect, abruptly decurved in distal quarter, apical point c. 3 mm long, filamentous, acuminate. Lateral sepals deflexed, ovate in outline when flattened, fused part 7-10 mm long, 9-11 mm wide, shallowly concave, the margins strongly incurved, glabrous; sinus narrow; free points filamentous, c. 5 mm long, curved forwards, divergent, 8-10 mm apart at the tips. Petals ovate-lanceolate, 11-14 mm long, 3.5-5 mm wide, nearly straight, transparent, with brown basal markings and two or three brown lines, dorsal margin brown, ciliate, proximal flange poorly developed. Labellum highly irritable, attached by a ligulate basal claw c. 2 mm long, c. 2 mm wide; lamina broadly obovate, 4.5-6 mm long, 2.5-3.5 mm wide, dark red-brown, constricted in the proximal quarter, adaxial surface shallowly concave to broadly grooved, apex obtuse; marginal trichomes 3-5 pairs, white, the longest pair c. 3.5 mm long, arising near the proximal constriction, basal lobe large, with 1-3 pairs of trichomes c. 0.7 mm long, abaxial surface with a narrow central channel extending from the basal lobe to the apex. Column porrect from the end of the ovary, 10-12 mm long, c. 2.5 mm wide; column wings c. 3.3 mm long, c. 2.5 mm wide, more or less rectangular, anterior margins ciliate. Stigma elliptical to broadly scutiform, c. 5 mm long, c. 2.5 mm wide, the upper margins irregular. Anther c. 1.2 mm long, obtuse. Pollinia linear-oblong to clavate, c. 2 mm long, yellow, mealy. Fruiting capsules obovoid, 7-8 mm long, c. 4-5 mm wide, brownish, erect.

2.2 Life cycle

Pterostylis saxicola is a perennial, deciduous, tuberous herb that germinates from a minute, dust-like seed. Like all other orchids, germination is reliant on invasion of the seed by the hyphae of a specific fungal associate, which, in the case of *P. saxicola*, is an unnamed species of *Ceratobasidium* (Basidiomycota: Cantharellales) (Sommerville et al. 2008). The first morphological change that an orchid seed undergoes during germination is swelling to form a protocorm, a rootless, shootless 'blob'. The orchid fungus forms an intracellular relationship with its host, usually in the roots and/or tubers and is thus classed as an endomycorrhiza. It forms hyphal coils, called pelotons, in the cells of its host, which are beneficial to the orchid in that they provide the host plant with nutrients such as

Figure 2. Flowering plant of *Pterostylis saxicola*, at Scheyville National Park, showing the basal rosette of crowded leaves lying flat on the ground and a terminal, erect inflorescence, bearing one open flower, seen from the side, and an unopened flower bud.

Figure 3. Inflorescence of *Pterostylis saxicola*, at Simmos Beach Reserve, Macquarie Fields, showing two flowers, the lower one in frontal view, the higher one in lateral view, showing galea, labellum and paired lateral sepals.

soluble sugars (Rasmussen 1995). The duration of the association varies according to the life history of the particular orchid species, with some species of orchids being completely dependent on their mycorrhizal fungi for life while other species are capable of living without their fungi from shortly after germination. The ease of cultivation of *Pterostylis* species and the green colour of almost all plant parts strongly suggest that adult plants are not obligately dependent on their mycorrhizal associates as adult plants.

Plants of *Pterostylis saxicola*, like those of most other species in Orchidaceae subfamily Orchidoideae, are deciduous, with the whole shoot system growing anew every year from a dormant tuber. The new shoot usually starts growing from an apical meristem on the tuber in late summer, with new shoots usually breaking the soil surface by March. The shoot develops into a "rosette" of crowded leaves just above ground level and in late winter a terminal raceme starts growing from the centre of the rosette, reaching anthesis in spring. While the shoot is growing above ground, a new replacement tuber is growing below ground, from the base of the shoot. Some species of *Pterostylis* multiply and spread vegetatively by producing additional new tubers on the ends of long roots but the subgenus to which *P. saxicola* belongs, *Oligochaetochilus*, does not share this attribute (Jones 2006).

Almost all species of *Pterostylis* are deceptively pollinated by male flies that attempt to copulate with the labellum of the flower. The labellum mimics a female fly of a particular species (or species group) in size, appearance and texture and by exuding an allomone that is identical to the pheromone released by the female flies (Phillips et al. 2013, Kuiter & Findlater-Smith 2017). In species of *Pterostylis* for which the pollination process has been studied and described, the labellum is highly motile ("irritable"), like that of *Pterostylis* saxicola, and a male fly that lands on it is tossed inside the hood (galea) formed by the dorsal sepal and lateral petals, and trapped there. The only escape route provided by the flower is a tunnel through which the male fly must squeeze in order to escape. In the process of negotiating its exit, the fly is forced to rub past the stigma of the flower, depositing on it any pollinia that it was already carrying. The fly is then forced to contact the anther, sticking a pollinarium on its thorax, before it can finally escape. The pollinator of *P. saxicola* is still unknown, but the pollinators of other species of *Pterostylis* subgenus *Oligochaetochilus*, where known, are males of unnamed species of *Orfelia* (Mycetophilidae) (Kuiter & Findlater-Smith 2017). Sexually deceptive pollination has evolved multiple times in the Australian terrestrial orchid flora, involving hundreds of species (Weston et al. 2014). Most of those for which pollinators have been identified are pollinated by the males of only one species of insect and *P. saxicola* is most likely pollinated by a single species of fly too.

Fruiting capsules of *Pterostylis saxicola* mature quickly, with the most proximal capsules sometimes dehiscing before the most distal flowers have withered. They split down six sutures to release thousands of minute, wind-dispersed seeds in November to early December.

2.3 Distribution and abundance

Records for *Pterostylis saxicola* are widely distributed across the Cumberland Plain and lower Blue Mountains in an area bounded by Scheyville, Freemans Reach, Euroka Campground, Douglas Park, Picnic Point, and Cattai, with two outlying records from the Gingra Range in Kanangra Boyd National Park and Anvil Hill in the Hunter Valley (BioNet Atlas, as held records received 22 February 2019; National Herbarium of New South Wales specimen database, accessed 8 April 2019) (figure 4). It has been recorded at altitudes ranging from 30 to 440 metres. It is very sporadically distributed, partly because much of this land has been cleared for agriculture and suburban development but large parts of the Warragamba catchment are remote and inaccessible. However, the outlying records suggest that any habitat model is unlikely to be a powerful predictor of the presence of populations at particular locations.

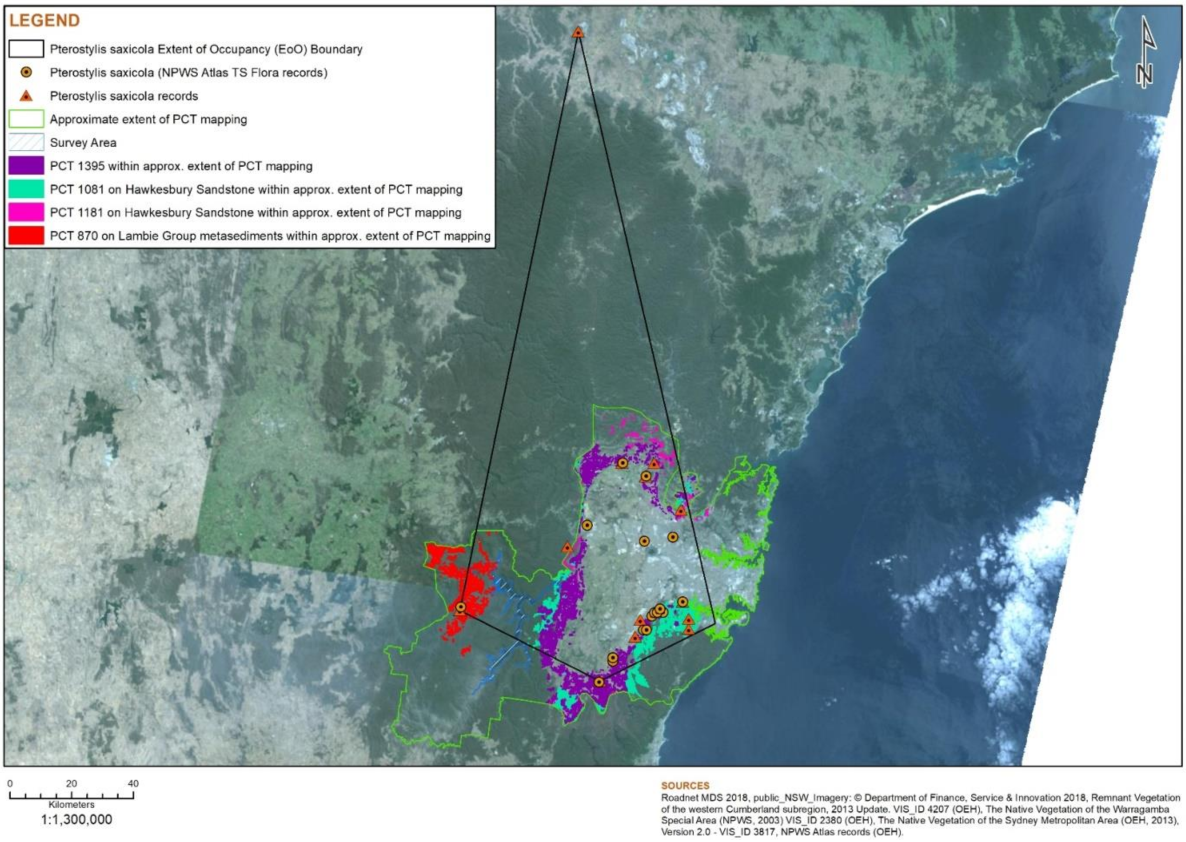

Figure 4. Map showing known records, extent of occupancy (EOO) and recorded habitats of *Pterostylis saxicola*.

Plants of *Pterostylis saxicola* are usually gregarious, with most collectors and observers noting multiple plants co-occurring together. Counts of the number of individual plants at sites vary from one to 280, with a mean population size of 82. As *P. saxicola* does not usually multiply vegetatively (Jones 2006, as *Oligochaetochilus saxicola*), these clusters are most likely the result of seeds germinating close to their parents.

2.4 Habitat requirements

The habitat model published in the endangered species profile for *Pterostylis saxicola* (NSW Office of Environment and Heritage 2018a) states that it is "most commonly found growing in small pockets of shallow soil in depressions on sandstone rock shelves above cliff lines. The vegetation communities above the shelves where *P. saxicola* occurs are sclerophyll forest or woodland on shale/sandstone transition soils or shale soils". This description applies accurately to the habitat associated with the type collection and with some other records in the southern half of the species' distribution but not to those found elsewhere. The distributional range and habitat requirements of *P. saxicola* can be subdivided into two main sub-populations and two outlying populations.

The northern sub-population is in an area bounded by Scheyville, Freemans Reach, The Ironbarks near Glenbrook, Toongabbie, Ryde, Glenhaven and Cattai. I have visited four sites with precise grid references at which *Pterostylis saxicola* has been observed or collected in this area and identified the plant community types found there (see section 4.4, appendix 1). The substrate underlying the sites at Scheyville and Freemans Reach, both of which I have visited, is deep Ashfield Shale (Wianamatta Group) and the Ryde record is also mapped to this substrate. I have also visited the Cattai and The

Ironbarks sites, which are on Mittagong Formation substrates (transition zones between Ashfield Shale and Hawkesbury Sandstone). The Toongabbie record also maps to this substrate. All of these sites are in elevated, well-drained but gently rolling country, not on rugged sandstone outcrops.

The plant communities that I identified at the four sites mentioned above are the following:

- 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain (see figure 5);
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain (see figure 6).

Most records from the southern sub-population, in an area bounded by Macquarie Fields, Minto, Douglas Park, Woronora River and Picnic Point differ in habitat from the northern records. Although a recent record from Menangle is from Ashfield Shale, in most cases where they have highly precise locality data and/or detailed habitat descriptions, collections and observations from this area have been made on Hawkesbury Sandstone, on the rims and sides of the gorges of the Nepean, Georges and Woronora Rivers. I have visited four precisely georeferenced sites at which *Pterostylis saxicola* has been observed or collected in this area and identified the plant community types found there (see appendix 1). Observers' notes repeatedly describe the soils as very shallow sands overlying sandstone rock shelves, as stated in the published habitat model (NSW Office of Environment and Heritage 2018a) and the four sites that I visited and characterised were consistent with this description. However, although all were elevated, well-drained sites, only some of them were recorded above cliff lines, contrary to the published model. All of these sites occur close to outcrops of Ashfield Shale, mostly downhill from them, but for some of these sites, the only evidence of shale influence on the environment seems to be associated plant community types. I identified the following plant community types at these sites:

- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain (see figure 7);
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney (see figure 8);
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain.

In addition to the two main sub-populations, there are also two outlying, precisely georeferenced, herbarium records. One of these is from the Gingra Range in Kanangra Boyd National Park. This site is on metasediments of the Devonian Lambie Formation, and was mapped by Tozer *et al.* (2010) to their map unit DSF p37 Kowmung-Wollondilly Grassy Gorge Woodland. According to the references cited in the BioNet Vegetation Classification, this is equivalent to the following PCT:

- 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges (see figure 9).

However, this site is so close to a mapped boundary between PCT 870 and PCT 1107 (River Peppermint - Narrow-leaved Peppermint open forest on sheltered escarpment slopes, Sydney Basin Bioregion and South East Corner Bioregion) that a field survey of the site was required in order to confidently identify the PCT or transition zone there. I visited this site on 2 April 2019 (see below) and confirmed that it is unequivocally located in PCT 870. The precise locality of the record occurs within an area mapped by Warragamba VIS map 2380 as the map unit Kanangra Gorge Sheltered Grey Gum Forest, which is a map unit that was assessed as equivalent to PCT 870 by SMEC in the Upstream Assessment BAR for the upstream survey area.

Figure 5. PCT 849 Grey Box – Forest Red Gum grassy woodland on flats of the Cumberland Plain, on Ashfield Shale at Scheyville National Park (my site PS1, appendix 1).

Figure 6. PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest of the edges of the Cumberland Plain, on Mittagong Formation at The Ironbarks (my site PS8, appendix 1).

Figure 7. PCT 1081 Red Bloodwood - grey gum woodland on the edges of the Cumberland Plain (my site PS3, appendix 1)

Figure 8. PCT 1181 Smooth-barked Apple – Red Bloodwood – Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, east of Appin.

Figure 9. PCT 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges, Gingra Range, Kanangra-Boyd National Park (my site PS 9, appendix 1).

The outlying population in the upper Hunter River Valley is represented by a specimen collected on the top of Anvil Hill, an isolated mesa composed of Narrabeen Group sandstone and conglomerate. This site is inaccessible, being surrounded by the Mangoola open-cut coal mine. However, the collectors' notes described the habitat as "Open woodland of *Eucalyptus crebra* with shrub layer dominated by *Notelaea microcarpa* and *Spartothamnella juncea*. Skeletal soils derived from Triassic sandstone and conglomerate". This is the only record of *Pterostylis saxicola* from a Narrabeen Group substrate. The plant community on Anvil Hill is not identifiable from the habitat description above but it is worth noting that *Eucalyptus crebra* is a co-dominant tree at three of the nine *P. saxicola* sites that I have characterised.

As well as identifying suitable habitats for *Pterostylis saxicola* it is also possible to identify habitats that are unequivocally unsuitable for this orchid. While many of these need not be listed because they are trivially obvious, such as perennially aquatic environments, some habitats are more subtly unsuitable. These include flood-prone habitats and areas on substrates of quarternary alluvium. *Pterostylis saxicola* has not been recorded in such environments nor have any of its close relatives. Moreover, these orchids are quite exacting in their horticultural requirements, especially with respect to watering. They require sufficient water to sustain growth when the shoots are actively growing or to prevent desiccation of the tubers during dormancy but not so much that the soil becomes soggy. Over-watering, especially when the plants are dormant, causes them to rot. Well-drained soils, combining course sand, loam and some organic matter, are recommended (Jones 2006).

Pterostylis saxicola has mostly been recorded growing in intact native vegetation but there is one notable exception: a plant described in a “Car Park growing through bitumen”, adjacent to a large area of bushland from which other substantiated records had been made. Several others have come from small patches of remnant urban bushland, in some cases less than a hectare in area, surrounded by highly disturbed land. However, no records mention heavily weed-infested habitats or evidence of heavy grazing by introduced herbivores. Sites with significant edge effects are probably not sustainable reserves for conserving this species.

3. Description of the survey area

3.1 Land use history

The first human inhabitants of the survey area were Aborigines who moved into the district many thousands of years ago. When the British first started to settle in the Sydney Region in 1788, the survey area lay within the traditional lands of the Mulgoa band of the Dharug language group (Kohen 1986). The Mulgoa people might have gathered molluscs and crustaceans or used traps or lines to catch fish from Warragamba River and its tributaries (Turbet 1989). Small mammals, reptiles and insects and edible plants such as tuberous ground orchids and nectar-bearing flowers would also have provided some food resources in the survey area. However, the rugged topography and infertile soils would have ensured that food resources were much sparser here than on the adjacent Cumberland Plain and would have strongly discouraged permanent occupation of the survey area.

The first European to explore the Warragamba River was George William Evans, then acting surveyor-general of New South Wales, who in 1804 ventured upstream as far as the present site of Warragamba Dam (Weatherburn 1966). Governor Lachlan Macquarie named the Warragamba River on advice from two Aboriginal guides when he visited the area in 1810, and by 1811, two horse trails had been formed from Bents Basin and Wallacia through the dense eucalypt forest on the ridge that separates the Warragamba Gorge from the Nepean River, now known as Silverdale (McClelland 1987). However, no land was released to settlers in this area until 1878 when the land between what are now the towns of Silverdale and Werombi was granted (McClelland 1987). The construction of a bridge across the Nepean River at Blaxlands Crossing in 1895 made the Mulgoa Forest accessible for gathering firewood and tan bark and also popular for hiking and camping, which encouraged the establishment of several guest houses in Wallacia and Silverdale in the early 20th century (McClelland 1987).

Economic exploitation of the survey area was negligible and it remained as undisturbed bushland until the early 20th century, when the Metropolitan Water Sewerage and Drainage Board (precursor to WaterNSW) began to take an interest in the Warragamba River as a water resource. The Warragamba River had been proposed as a suitable site for a dam as early as 1845 by Polish explorer Paul Strzelecki (Sydney Catchment Authority 2010) but it was not until 1934 that the first surveys of potential dam sites on the River were conducted by the Board (McClelland 1987). In response to a prolonged drought, a weir and pumping station were built on the Warragamba River and a 1.2 metre diameter pipeline was laid to Prospect Reservoir between 1937 and 1940. Planning of Warragamba Dam began in 1938 and construction finally commenced ten years later (Sydney Catchment Authority 2010). The dam was formally opened in 1960.

3.2 Landscape context

The Warragamba River gorge, where Warragamba Dam is sited, is oriented from south west to north east, cutting through strata of Hawkesbury Sandstone. Elevation varies from 21 m immediately downstream from the dam wall, to 195 m at the highest point, north west of the left side of the dam wall (SMEC 2019). Although the only exposed rock in the whole of the survey area is Hawkesbury Sandstone, immediately south of the survey area this grades into Mittagong Formation strata and a large cap of Ashfield Shale on slightly higher ground. Some shale colluvium is therefore likely to be present in the soils on the south eastern side of the dam.

The survey area is located just west of a step-like geological fold, the Lapstone Monocline (Martyn 2018), on rocks that were uplifted and tilted to the east as a result of two phases of mountain building over the past 120 million years (Czarnota et al. 2014). From 120 to 80 Ma, uplift of the eastern Australian highlands, including the Central Tablelands of New South Wales, was driven by the eastward motion of what is now eastern Australia's margin away from the sinking eastern Gondwana slab (Müller et al. 2016). From 80 to 10 Ma it coincided with Cenozoic volcanism as eastern Australia drifted over the edge of the large Pacific mantle upwelling (Czarnota et al. 2014; Müller et al. 2016). The pre-existing Warragamba River eroded a deep valley through the gently rising strata during this time, creating a rugged, steep-sided sandstone gorge. The land immediately adjacent to the gorge on its south eastern and north western flanks slopes gently towards the gorge.

Topography, as well as distance from the sea, influence climate. The survey area lies just over one km west of an easterly facing escarpment 150 m high, which may exert a mild orographic effect, slightly elevating rainfall on the survey area compared to the adjacent western edge of the coastal plain. The steeply incised Warragamba River gorge would channel any cold air drainage, probably making the river bed downstream of the dam wall the coldest part of the survey area.

The climate of the survey area is warm-temperate but subject to winter frosts. A map of variation in rainfall across the Warragamba Special Area is presented in NPWS (2003: 9, map 5). Although no methodology was provided to explain how that map was produced, it appears to be based on a predictive model, presumably produced by integrating data from surrounding weather stations and patterns of topographic variation. This map indicates that the survey area receives mean annual rainfall of between 701 and 900 mm.

3.3 Native vegetation communities

A vegetation map of the survey area has been produced for the draft Biodiversity Assessment Report (SMEC unpublished). According to that map, the native vegetation of the survey area consists of the plant community types listed in table 1 and mapped in figure 10.

PCT identification number	Descriptive name of PCT	Area occupied in survey area (ha)
1081	Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain	16.96
1083	Red Bloodwood - scribbly gum heathy woodland on sandstone plateaux, Sydney Basin	24.78
1086	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	8.69
1281	Turpentine - Grey Ironbark open forest on shale in the lower Blue Mountains, Sydney Basin Bioregion	4.94

Table 1. Plant community types mapped in the survey area (SMEC unpublished).

Red Bloodwood - scribbly gum heathy woodland (PCT 1083) is the most abundant plant community type in the survey area but is restricted to flat or gently sloping ground on the tops of plateaux, both north and south of the dam wall. Red Bloodwood – Grey Gum woodland on the edges of the

Cumberland Plain (PCT 1081) is the next most abundant plant community type, covering most of the (sometimes very steep) slopes of all aspects in the survey area. Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest (PCT 1086) also occurs on sloping ground, on similar sites to PCT 1081. Turpentine - Smooth-barked Apple moist shrubby forest (PCT 1284) is the least abundant plant community type in the survey area and is restricted to lower slopes of sheltered gullies.

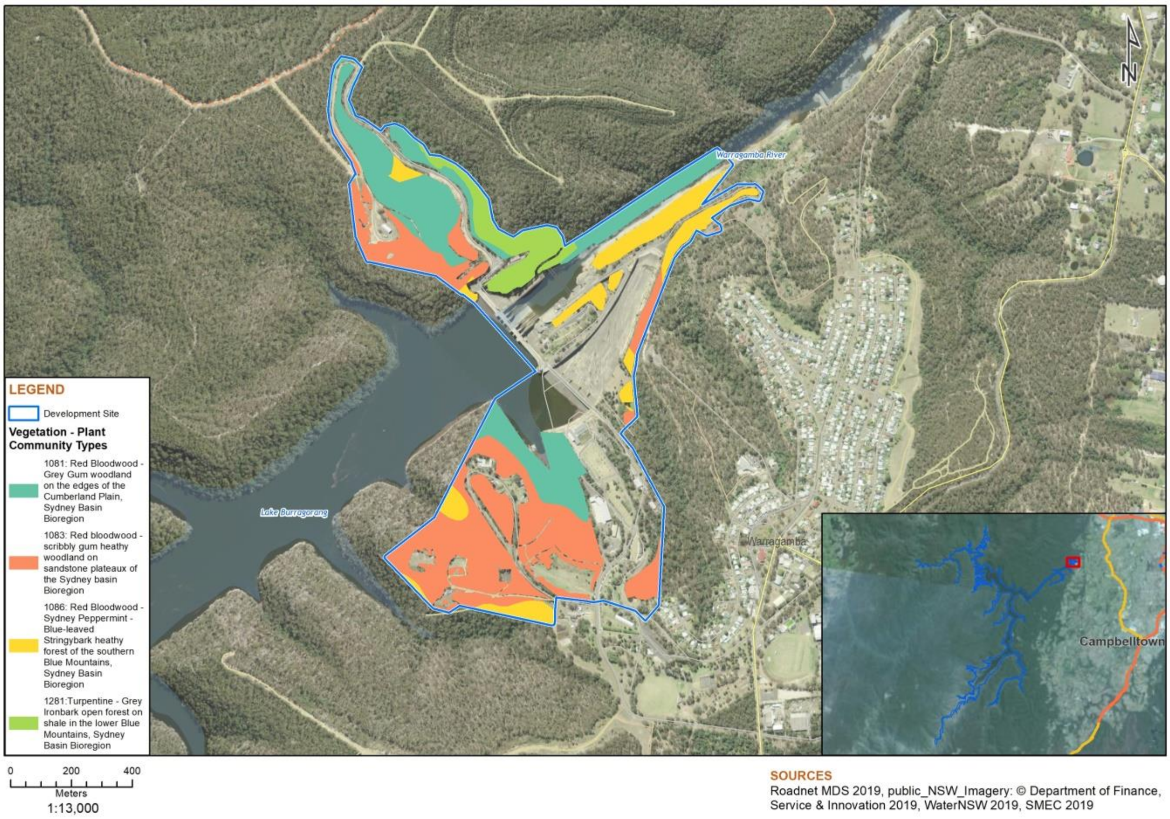

Figure 10. Map of plant community types found in the survey area.

4. Assessment of species presence and habitat

The approach that I took in assessing the presence or absence of *Pterostylis saxicola* in the survey area started with the construction of a general habitat model for *P. saxicola*, from existing records and my own surveys, outside the survey area but within the known geographical range of the orchid. I then used this model, in conjunction with environmental maps, to identify suitable habitat within the survey area. I then estimated the density of populations within each suitable habitat type and used these estimates, to calculate the expected number of populations of *Pterostylis saxicola* in the survey area as a whole.

4.1 Methodological limitations

Assessing the suitable habitat of *Pterostylis saxicola*, given the present state of knowledge of the biology of this species, has to be a largely descriptive exercise. The causal processes that constrain its distribution and abundance are largely unknown but probably include physiological limits to tolerance of temperature and humidity, the availability of mineral nutrients and water, soil drainage, factors limiting the distribution and abundance of its obligate symbionts – its pollinators and mycorrhizal associates, and the distribution and abundance of native herbivores, pathogens and parasites. Suitable habitat has to be estimated on the basis of associations between its distribution and environmental proxies such as substrate types and plant community types, and interactions between them. Multidimensional bioclimatic modelling would extend this approach to climatic variables but such analysis is beyond the scope of this report.

It could also be argued that predicting the presence of suitable habitat for *Pterostylis saxicola* in the survey area is based on questionable assumptions. The assumptions on which my predictions were based are as follows:

- Combinations of plant community type and substrate are reasonable indicators of environmental space. That is, they can be used to predict the distribution and abundance of species, such as *Pterostylis saxicola*, that did not figure prominently in the process by which the indicators were defined.
- Although *P. saxicola* is patchily distributed, the probability of its presence is equally spread across the geographic distribution of each combination of plant community type and substrate.
- The environmental preferences of *Pterostylis saxicola* do not vary across its distributional range.

These simplifying assumptions are testable in principle, although only the first one can be said to have been empirically tested to any extent. However, the fact that about 1500 plant community types have been recognised in New South Wales, but that *Pterostylis saxicola* has been recorded from only five of them suggests that plant community types do have useful predictive value.

In addition to the assumptions listed above, the method I have used to estimate the expected number of populations in each PCT-substrate combination (outlined in section 4.8.4) relies on the following assumptions:

- The distributional range of *Pterostylis saxicola* is accurately circumscribed by existing records. This is likely to be an underestimate of the true distributional range because apparently suitable habitats occur outside the known distributional range of the orchid.
- The PCT-substrate combinations in which *P. saxicola* has been recorded are assumed to be restricted to areas for which PCT maps are available as digital layers. This assumption had to be made because vegetation maps are available for only part of the total extent of occupancy of *P. saxicola*. This assumption is probably untrue and is likely to over- estimate the number of populations in the survey area.
- All populations of *P. saxicola* have already been discovered and are listed in the BioNet Atlas. This assumption is clearly unrealistic, as new populations of *P. saxicola* continue to be discovered, including two in October 2018, only one of which has already been recorded in the BioNet Atlas. However, discovery of new populations is so sporadic that it would be impossible to model the asymptote of a curve representing cumulative growth of observational records. The number of populations of *P. saxicola* used in my calculations should be regarded as a minimal estimate. My estimates of the number of individual plants in each PCT-substrate combination and in the survey area as a whole, are therefore likely to be underestimates.

4.2 Existing records and surveys

As a designated sensitive species, unredacted records of *Pterostylis saxicola* collections and observations held in the BioNet Atlas are not publicly available, so I formally applied for these records, which I received by email on 22 February 2019. This table contains 62 records, most of which are unvouchered observations. To this collection can be added 10 herbarium specimen records held by the National Herbarium of New South Wales, to which I have access as an Honorary Research Associate.

Although several targeted surveys of this species seem to have been conducted since 2000, none has been done in the survey area. Teresa James surveyed for this species across the species' distribution in spring 2007, for the NSW Department of Environment Climate Change and Water, submitting an unpublished report, observational records at five sites and a herbarium specimen (Teresa James personal communication). From November 2010 to January 2011, Total Earth Care Pty Ltd conducted a survey of threatened plant species in the Simmos Beach Recreation Reserve, Macquarie Fields for Campbelltown City Council, submitting an unpublished report and observational records at eight sites (Lachlan Laurie personal communication). In spring 2011, *P. saxicola* was again targeted at Simmos Beach Recreation Reserve by a research group from The Royal Botanic Gardens and Domain Trust that investigated the mycorrhizal associates of the orchid, with the aim of identifying and culturing the relevant fungus or fungi, adding seeds of this species to the seed collection at the Australian Plantbank, and germinating seeds of the orchid in septic culture. Two scientific papers were published, and three herbarium specimens collected as part of that project.

Highly precise grid references associated with a number of the BioNet records enabled me to identify the plant community types (as mapped by Tozer *et al.* (2010) and substrates (as mapped by Geological Survey of New South Wales 1966a,b, 1969, 1985, 1991) at sites at which these records of *Pterostylis saxicola* occurred. They were:

- 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain, on Ashfield Shale;
- 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges, on Lambie Group metasediments;
- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, on Hawkesbury Sandstone;
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney, on Hawkesbury Sandstone;
- 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain, on Mittagong Formation transitional substrates;
- An unidentified plant community type dominated by *Eucalyptus creba*, on Narrabeen Group sandstone and conglomerate.

4.3 Surveys completed for the Environmental Assessment

No targeted surveys for *Pterostylis saxicola* were conducted within the survey area for the Environmental Assessment for the reasons detailed in section 1.4.

4.4 Surveys completed for this expert report

4.4.1 Survey Methods

In the course of preparing this expert report and my earlier expert reports on *Pterostylis saxicola* in the Greater Macarthur and Wilton Growth Areas and the upstream part of the Warragamba dam raising proposal (Weston unpublished a, b, c), I characterised nine plots of native vegetation in detail, each plot being a circle of radius 30 m (an area of 2827 m^2), centred either on a plant of *P. saxicola* or on the grid point where an observation of it had been made (at times when *P. saxicola* could not be observed because it was dormant). All of those plots were sampled from outside the survey area in order to develop an improved habitat model for the species. At each plot I listed all vascular plant species that could feasibly be identified, taking photographs and sometimes specimens of plants for later reference in cases where the plant's identity was in question. The latitude and longitude of the centre of each plot was determined using a GPS instrument. The elevation of each site was determined later from 1:25,000 topographic maps. The soil and topography at each site was described and the substrate identified using the Wollongong – Port Hacking and Penrith 1:100,000 geological maps (NSW Department of Mineral Resources 1985, NSW Department of Minerals and Energy 1991) and the Sydney 1:250,000 geological map (Geological Survey of New South Wales 1966a). I identified the plant community type in each plot using the PCT identification tool in BioNet, and my list of plant species found in each plot.

4.4.2 Results of my surveys

Site and ecological data for my nine plots outside the survey area are shown in Appendix 1. According to my identifications of plant community types, *Pterostylis saxicola* was present in the following PCTs, on the following substrates in my plots:

- 849 Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain , on Ashfield Shale (2 plots);
- 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges on Lambie Group metasediments (1 plot);
- 1081 Red Bloodwood - grey gum woodland on the edges of the Cumberland Plain on Hawkesbury Sandstone (3 plots);
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney on Hawkesbury Sandstone (1 plot);
- 1395 Narrow-leaved Ironbark - Broad-leaved Ironbark - Grey Gum open forest of the edges of the Cumberland Plain on Mittagong Formation transitional substrates (2 plots).

The results of my surveys corroborate results drawn from existing records regarding the habitats in which *Pterostylis saxicola* is known to occur. Although I did not sample any sites at which *P. saxicola* had been found on Narrabeen Group sandstone in my surveys, records of the species from a site with a precise grid reference has been mapped to this substrate (section 4.2).

4.5 Inference of predicted habitat of *Pterostylis saxicola*

The outlying records of *Pterostylis saxicola* from the Gingra Range and Anvil Hill suggest that the habitats at those sites should be integrated into a general habitat model for the orchid. However, they also suggest that consideration be given to habitats intermediate between those at the outlying sites and those in the species' "core" distributional range on the margins of the Cumberland Plain. Weston (unpublished c) inferred, on the basis of these outlying records, that several PCT-substrate combinations should be added to the habitat model of *P. saxicola*. These were:

- 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain on Narrabeen Group sandstone;
- 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney on Narrabeen Group sandstone.
- 832 Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion on Lambie Group metasediments;
- 860 Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion on Lambie Group metasediments.

4.6 An improved habitat model for *Pterostylis saxicola*

I have argued that the habitat model that was published as part of OEH's threatened species profile of *Pterostylis saxicola* (NSW Office of Environment and Heritage 2018a) needs updating (section 2.4 of this report, Weston unpublished a,b). It needs to be broadened to include habitats in which *P. saxicola* has been recorded and habitats in which it has been inferred to occur, but which were not taken into account when the profile was written.

My improved habitat model is as follows:

Pterostylis saxicola occurs along an ecological gradient from:

- Clay soils derived from Ashfield Shale (Wianamatta Group) on gently hilly landscapes in PCT 849 Grey Box – Forest Red Gum grassy woodland on Flats of the Cumberland Plain;
- to: clay to sandy soils derived from Mittagong Formation substrates on gently hilly to steep landscapes, in PCT 1395 Narrow-leaved Ironbark – Broad-leaved Ironbark – Grey Gum open forest on the edges of the Cumberland Plain;
- to: thin accumulations of humus-rich sandy soil on sheets and rock shelves of Hawkesbury Sandstone, on the rims and sides of river valleys, growing in PCT 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, or PCT 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney.

This ecological gradient is inferred to extend to:

- thin accumulations of humus-rich sandy soil on sheets and rock shelves of Narrabeen Group sandstone, growing in PCTs 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain or 1181 Smooth-barked Apple - Red Bloodwood - Sydney Peppermint heathy open forest on slopes of dry sandstone gullies of western and southern Sydney.

Pterostylis saxicola also occurs on:

- Lambie group metasediments, in PCT 870 Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountains gorges.

This habitat is inferred to be part of an ecological gradient of *Pterostylis saxicola* habitats that extends to:

- Lambie group metasediments, in PCT 832 Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion, and PCT 860 Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion.

4.7 Assessment of species presence

4.7.1 Likelihood of species presence in the survey area

Given the small extent of suitable habitat that has been mapped there, the rarity of *Pterostylis saxicola* within its known distributional range and the low estimate of expected number of populations in the survey area (see section 4.8.5), my subjective assessment of the probability of *P. saxicola* occurring in the survey area is about 1%.

4.7.2 Justification for determining presence

Pterostylis saxicola has been recorded from a combination of substrate and plant community type that has been mapped in the survey area. This habitat covers only 16.96 hectares, it is estimated to be home to 0.0067 populations (see section 4.8.5). This does not mean that we literally expect a fraction of a population to live in the survey area. The estimate is probabilistic and should be interpreted as a calculation of the likelihood that any plants live there.

P. saxicola has been neither collected nor observed in the survey area but absence of evidence should not be treated as evidence of absence, especially in an area that has mostly been inaccessible, with rare exceptions, to botanists for the last 60 years. Although the probability of *P. saxicola* occurring in the survey area is very low, it is not zero. Moreover, my estimates of the number of populations in the survey area is more likely to be an underestimate than an over-estimate (see section 4.1).

4.8 Assessment of suitable habitat and abundance of populations of *Pterostylis saxicola* within the survey area

4.8.1 Suitable habitat for *Pterostylis saxicola* within the survey area

The following habitat that has been mapped in the survey area is potentially suitable habitat for *P. saxicola*:

- thin accumulations of humus-rich sandy soil on sheets and rock shelves of Hawkesbury Sandstone, on the rims and sides of river valleys, growing in PCT 1081 Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain.

4.8.2 Species polygons for *Pterostylis saxicola*

My species polygons for *Pterostylis saxicola* (figure 11) include all patches of the habitat listed in section 4.8.1 in the survey area. It was prepared with the assistance of James Taylor (SMEC), using the ESRI ArcGIS software package, from vegetation maps of the survey area produced by SMEC on 30 September 2019. A shape file for these polygons is held by SMEC. My arguments justifying these polygons have been set out in sections 2.3, 2.4, 4.1, 4.2, and 4.4 to 4.7.

4.8.3 Estimate of area of habitat of *Pterostylis saxicola* in the survey area

The area estimated to represent suitable habitat for *Pterostylis saxicola* in figure 10 is 16.96 ha.

This estimate was derived from the vegetation map of the survey area and the associated estimate of the area covered by PCT 1081 produced for the draft Biodiversity Assessment Report (SMEC 2019). My arguments justifying the polygons from which these estimates were calculated have been set out in sections 2.3, 2.4, 4.1, 4.2, and 4.4 to 4.7.

4.8.4 Method for estimating the number of populations of *Pterostylis saxicola* in the survey area

The following method was used to estimate the expected number of populations of *Pterostylis saxicola* in the survey area, given a set of simplifying assumptions, which are listed in section 4.1:

1. The known distributional range of *Pterostylis saxicola* was estimated by drawing the minimal convex polygon enclosing all records of the species.
2. *P. saxicola* has been recorded from only one combination of plant community type and substrate found in the survey area: PCT 1081 on Hawkesbury Sandstone.
3. Let **a ha** be the total area covered by PCT 1081 on Hawkesbury Sandstone within the known distributional range of *P. saxicola* for which PCT mapping was available. This was calculated

from the draft vegetation maps provided by SMEC for the survey area (received from James Taylor, 15 May 2019) and NSW Office of Environment and Heritage (2013) and from the geological data set provided by NSW Department of Planning and Environment (2018), using the ESRI ArcGIS software package.

4. Let **n** be the number of populations of *P. saxicola* that have been recorded in PCT 1081 on Hawkesbury Sandstone.
5. Then **n/a = d** populations per hectare, is the density of populations of *P. saxicola* in PCT 1081 on Hawkesbury Sandstone within the known distributional range of *P. saxicola*.
6. Let **A ha** be the total area covered by PCT 1081 on Hawkesbury Sandstone within the survey area. This was calculated from vegetation maps produced for the Environmental Assessment and from Tozer *et al.* (2010) using the ESRI ArcGIS software package.
7. Then **n/a = N/A**, where **N** is the expected number of populations of *P. saxicola* in PCT 1081 on Hawkesbury Sandstone within the survey area.
8. Re-arranging, **N = A x n/a**.
9. Substituting **d** for **n/a**, **N = A x d**.

4.8.5 Estimate of the number of plants of *Pterostylis saxicola* in the survey area

The PCT-substrate combination of PCT 1081 on Hawkesbury Sandstone covers 5040 ha within the known distributional range of *P. saxicola* (its EOO polygon).

The number of populations of *P. saxicola* that have been recorded from PCT 1081 on Hawkesbury Sandstone is 2.

Therefore, the density of populations of *P. saxicola* that have been recorded from PCT 1081 on Hawkesbury Sandstone within its known distributional range is 0.0003968 populations per hectare.

The total area of PCT 1081 on Hawkesbury Sandstone in the survey area is 16.96 ha.

Therefore, the expected number of populations of *P. saxicola* in the survey area is estimated to be 0.006730.

5. Information used in this assessment

My assessment was based on information obtained from a diversity of sources:

- Databases of observational and vouchered specimen records of *Pterostylis saxicola*:
    - National Herbarium of New South Wales specimen database;
    - BioNet Wildlife Atlas;
- Interviews with collectors, observers, propagators and scientists of *P. saxicola* (see section 6, acknowledgements);
- Fieldwork at 9 sites at which *P. saxicola* had previously been collected or observed (see Appendix 1);
- The scientific and scholarly literature (see section 7, references);
- A GIS map of the survey area with layers representing the boundaries, plant community types, substrates, prepared by SMEC;
- Background information on the survey area provided by SMEC;
- My personal knowledge and experience, gained from 40 years as a professional botanist specialising in the systematics and ecology of the Orchidaceae.

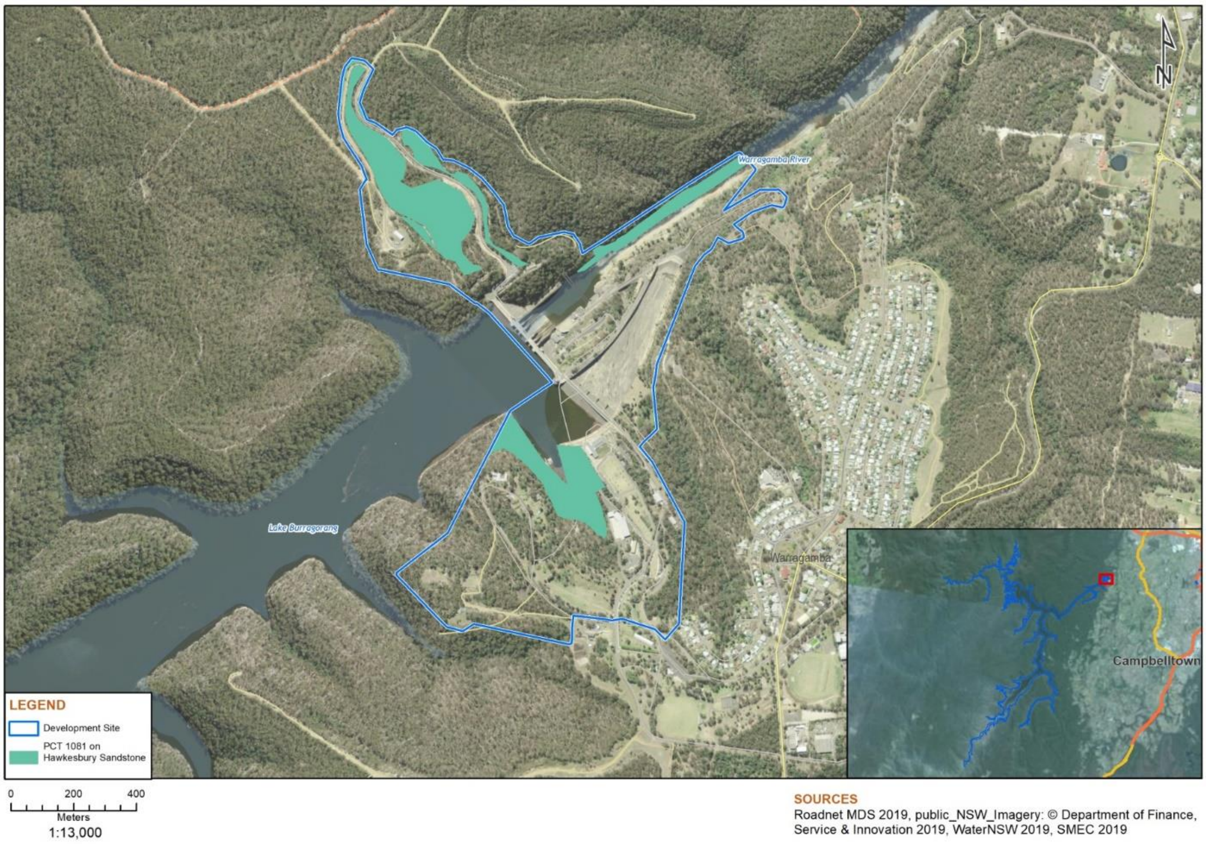

Figure 11. Polygon of suitable habitat for *Pterostylis saxicola* in the survey area: PCT 1081 on Hawkesbury Sandstone.

6. Acknowledgements

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8. Appendices

8.1 Appendix 1: Characterisation of habitat at selected sites

The tables on following pages record data that I collected at sites outside the survey area. Each site was centred on an arbitrarily selected plant of *Pterostylis saxicola*, or at a precisely specified latitude and longitude at which *P. saxicola* had been recorded. At each site the precise latitude and longitude, elevation, substrate, and soil description, were recorded. Also, at each site all plant species that could be reliably identified were recorded within a radius of 30 metres. Locations at which *P. saxicola* has been recorded by me and/or others have had their latitudes and longitudes transformed to the nearest 10 minutes.

Site	Location	Latitude	Longitude	Elevation (m)	Substrate
PS1	Old Schofield Trail, Scheyville National Park	33°40'S	150°50'E	70	Ashfield Shale
PS2	Simmos Beach Recreation Reserve Macquarie Fields	34°00'S	150°50'E	45	Hawkesbury Sandstone
PS3	Simmos Beach Recreation Reserve Macquarie Fields	34°00'S	150°50'E	43	Hawkesbury Sandstone
PS4	Boronia Rd Reserve, Peter Meadows Creek, Kentlyn	34°00'S	150°50'E	98	Hawkesbury Sandstone
PS5	Amberdale Reserve, Picnic Point	34°00'S	151°00'E	36	Hawkesbury Sandstone
PS6	Hawkesbury High School, Freemans Reach	33°30'S	150°50'E	40	Ashfield Shale
PS7	Mitchell Park Road, Cattai	33°30'S	150°50'E	25	Ashfield Shale-Mittagong Formation-Hawkesbury Sandstone
PS8	Euroka Road, The Ironbarks	33°50'S	150°40'E	170	Ashfield Shale-Mittagong Formation-Hawkesbury Sandstone
PS9	Gingra Range, Kanangra-Boyd National Park	34°00'S	150°10'E	435	Lambie Formation

Site	Soil description	Vegetation structure (canopy)	Vegetation structure (understorey)	PCT (my identification)
PS1	brown clay-loam	Dry sclerophyll forest	sparse shrubby understory	849
PS2	brown sand	Dry sclerophyll woodland	moderately dense shrubby understory	1081
PS3	dark brown humus-rich sand	dry sclerophyll forest	moderately dense shrubby understory	1081
PS4	dark brown humus-rich sand	Dry sclerophyll woodland	moderately dense shrubby understory under dense subcanopy	1081
PS5	dark brown humus-rich sand	Dry sclerophyll woodland	moderately dense shrubby understory	1181
PS6	red-brown clay with lateritic pebbles	dry sclerophyll forest	grassy, sparsely to densely shrubby understory	849
PS7	fine, mid-brown sand	dry sclerophyll forest	grassy, moderately to densely shrubby understory	1395
PS8	brown clay-loam	dry sclerophyll forest	moderately dense shrubby understory	1395
PS9	Dark brown clay-loam	dry sclerophyll forest	grassy, sparsely to densely shrubby understory	870

Appendix 1a: Environmental data for sites visited as part of this study

Associated species	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9
Acacia falcata	0	0	0	0	0	0	0	1	0
Acacia falciformis	0	0	0	0	0	0	0	0	1
Acacia floribunda	0	0	0	0	0	0	1	0	0
Acacia implexa	0	0	0	1	0	0	0	1	0
Acacia linifolia	0	1	1	0	1	0	0	0	0
Acacia parvipinnula	0	0	0	0	0	0	0	1	0
Acacia suaveolens	0	0	0	0	1	0	0	0	0
Acacia terminalis	0	1	1	0	1	0	0	0	0
Acacia ulicifolia	0	0	1	0	1	0	0	0	0
Acrotriche divaricata	0	0	0	1	0	0	0	0	0
Adiantum aethiopicum	0	0	0	0	0	0	0	0	1
Allocasuarina littoralis	0	0	0	1	1	0	1	0	0
Allocasuaruna torulosa	0	0	0	0	0	0	0	1	1
Angophora bakeri	0	1	1	1	1	0	1	0	0
Angophora costata	0	0	0	0	1	0	0	0	0
Angophora floribunda	0	0	0	0	0	0	0	0	1
Aristida ramosa	?	?	?	?	?	1	0	0	1
Aristida vagans	?	?	?	?	?	1	0	1	0
Arthropodium milleflorum	0	0	0	0	0	1	0	0	1
Asplenium flabellifolium	0	0	0	0	0	0	0	0	1
Astroloma pinifolium	0	0	0	0	1	0	0	0	0
Banksia serrata	0	0	0	0	1	0	0	0	0
Banksia spinulosa	0	1	1	1	1	0	0	0	0
Billardiera scandens	0	0	0	0	0	0	0	1	1
Brachyloma daphnoides	0	0	1	0	0	0	0	0	0
Brachyscome graminea	0	0	0	0	0	0	0	1	1
Breynia oblongifolia	1	0	0	0	0	1	0	0	0
Brunoniella australis	1	0	0	0	0	1	0	1	0
Bursaria spinosa	1	0	0	0	0	1	1	1	1
Calandrinia pickeringii	?	?	?	?	?	0	1	0	0
Calotis dentex	0	0	0	0	0	0	0	1	0
Cassytha sp.	0	0	0	0	0	0	0	1	0
Cheilanthes sieberi	1	1	0	1	0	1	1	1	1
Clematis aristata	0	0	0	0	0	0	?	0	1
Commelina cyanea	?	?	?	?	?	0	1	0	0
Commelina ensifolia	?	?	?	?	?	1	0	0	0

Appendix 1b (continued on following page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Associated species	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9
Coronidium scorpioides	0	0	0	0	0	0	0	0	1
Corymbia gummifera	0	0	0	1	1	0	0	0	0
Crassula sieberiana	?	?	?	?	?	0	1	0	0
Cymbidium suave	0	0	0	0	0	0	1	0	0
Daviesia ulicifolia	1	0	0	0	0	1	0	0	0
Daviesia squarrosa	0	0	0	0	0	0	0	1	0
Desmodium brachypodium	0	0	0	0	0	0	0	0	0
Desmodium gunnii	0	0	0	0	0	0	0	0	1
Desmodium rhytidophyllum	0	0	0	0	0	1	0	1	0
Dianella longifolia var. *stenophylla*	?	?	?	?	?	0	1	?	0
Dichondra repens	1	0	0	0	0	1	1	0	1
Dillwynia sieberi	1	0	0	0	0	0	0	0	0
Dodonaea triquetra	0	0	0	0	1	0	0	1	0
Doodia aspera	0	0	0	0	0	0	0	0	1
Echinopogon sp.	?	?	?	?	?	0	0	1	0
Einadia hastata	?	?	?	?	?	1	1	0	0
Entolasia stricta	0	0	0	0	0	0	1	1	1
Eremophila debilis	1	0	0	0	0	0	0	0	0
Eriostemon australasius	0	0	0	1	0	0	0	0	0
Eucalyptus beyeriana	0	0	0	0	0	0	0	1	0
Eucalyptus crebra	1	0	0	0	0	1	0	0	1
Eucalyptus eugenioides	0	0	0	0	0	0	0	0	1
Eucalyptus fibrosa	0	0	0	0	0	0	0	1	0
Eucalyptus globoidea	0	0	0	0	0	0	1	0	0
Eucalyptus moluccana	1	0	0	0	0	0	0	0	0
Eucalyptus piperita	0	0	0	0	1	0	0	0	0
Eucalyptus punctata	0	0	1	1	1	0	1	1	1
Eucalyptus sclerophylla	0	1	1	1	0	0	0	0	0
Eucalyptus sparsifolia	0	1	0	0	0	0	0	1	0
Eucalyptus tereticornis	0	0	0	0	0	1	1	0	1
Exocarpos cupressiformis	1	0	0	0	1	0	0	0	0
Exocarpos strictus	0	0	1	1	1	0	0	0	1

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Associated species	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9
Glycine tabacina	0	0	0	0	0	1	1	0	1
Glycine clandestina	0	0	0	0	0	0	1	1	0
Gompholobium grandiflorum	0	1	0	0	0	0	0	0	0
Goodenia hederacea	0	0	1	0	0	1	1	0	0
Grevillea sericea	0	0	0	0	1	0	0	0	0
Grevillea sphacelata	0	1	1	0	0	0	0	0	0
Hakea laevipes	0	1	1	1	0	0	0	0	0
Hakea sericea	0	1	1	1	1	0	0	0	0
Hardenbergia violacea	1	0	0	0	0	1	0	0	0
Hibbertia aspera	0	0	0	0	0	0	0	1	0
Hibbertia diffusa	?	?	?	?	?	1	1	1	0
Hibbertia obtusifolia	0	0	0	0	0	0	0	0	1
Hypericum gramineum	0	0	0	0	0	0	0	0	1
Hypoxis hygrometrica	?	?	?	?	?	0	0	1	0
Imperata cylindrica	0	0	0	0	0	0	1	0	0
Indigofera australis	0	0	0	0	0	0	0	0	1
Isopogon anemonifolius	0	1	1	1	0	0	0	0	0
Jacksonia scoparia	0	0	0	1	0	0	0	0	0
Kunzea ambigua	0	1	1	1	1	0	1	0	0
Lagenophora gracilis	0	0	0	0	0	0	0	1	1
Lagenophora stipitata	0	0	0	0	0	1	1	0	0
Lambertia Formosa	0	1	1	0	1	0	0	0	0
Laxmannia gracilis	?	?	?	?	?	0	1	0	0
Lepidosperma laterale	0	0	0	0	0	0	1	1	1
Leptospermum parvifolium	0	1	0	0	0	0	0	0	0
Leptospermum trinervium	0	1	1	1	1	0	1	0	0
Leucopogon juniperinus	0	0	0	0	0	0	0	0	1
Lissanthe strigosa	0	0	0	1	0	0	0	1	0
Lobelia purpurascens	?	?	?	?	?	1	1	1	1
Lomandra longifolia	0	0	0	0	1	0	1	0	1
Lomandra multiflora	0	0	0	0	0	0	1	1	1
Lomandra obliqua	0	1	1	1	1	0	0	0	0
Lomatia silaifolia	0	0	0	0	1	0	0	0	0
Macrozamia spiralis	0	0	0	1	0	0	0	0	0
Melaleuca nodosa	0	0	1	0	1	0	0	0	0
Microlaena stipoides	?	?	?	?	?	1	1	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

Associated species	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9
Monotoca scoparia	0	0	1	1	1	0	0	0	0
Notelaea longifolia	0	0	0	0	1	0	0	0	1
Olearia viscidula	0	0	0	0	0	0	0	0	1
Opercularia diphylla	?	?	?	?	?	1	1	1	1
Oplismenus imbecilis	?	?	?	?	0	0	1	0	0
Oxalis perennans	?	?	?	?	?	0	1	0	1
Ozothamnus diosmifolius	1	0	1	0	0	1	0	1	0
Pandorea pandorana	0	0	0	0	0	0	0	0	1
Panicum simile	?	?	?	?	?	0	0	1	0
Parsonsia straminea	0	0	0	0	0	0	1	0	0
Pellaea falcata	0	0	0	0	0	0	0	0	1
Persoonia levis	0	1	1	1	1	0	0	0	0
Persoonia linearis	0	0	1	1	1	0	0	1	1
Petrophile sessilis	0	1	0	1	1	0	0	0	0
Phyllanthus hirtellus	0	0	0	0	0	0	0	1	0
Pittosporum undulatum	0	0	0	0	1	0	0	0	0
Plantago debilis	?	?	?	?	?	1	0	0	1
Plectranthus sp.	0	0	0	0	0	1	0	0	1
Pomax umbellata	0	0	0	0	0	0	0	1	0
Pteridium esculentum	0	0	0	0	1	0	0	0	0
Pterostylis saxicola	1	?	1	?	?	1	?	?	?
Pultenaea villosa	0	0	0	0	0	0	0	1	0
Ricinocarpos pinifolius	0	0	0	0	1	0	0	0	0
Sigesbeckia orientalis	0	0	0	0	0	0	0	0	1
Solanum prinophyllum	1	0	0	0	0	1	1	1	1
Stellaria pungens	0	0	0	0	0	0	0	0	1
Stylidium laricifolium	0	0	0	1	0	0	0	0	0
Stypandra glauca	0	0	0	0	0	0	0	0	1
Themeda triandra	0	0	0	0	0	1	1	0	0
Tricoryne elatior	?	?	?	?	?	1	1	0	0
Tylophora barbata	0	0	0	0	0	0	0	0	1
Viola hederacea	?	?	?	?	?	0	1	0	0
Xanthorrhoea concava	0	0	0	0	1	0	0	0	0
Xanthorrhoea media	0	1	1	0	1	0	0	1	0
Xanthosia pilosa	0	0	0	0	1	0	0	0	0

Appendix 1b (continued from previous page): Data on presence (1) or absence (0) of associated species for sites characterised as part of this study.

8.2 Appendix 2: Peter Weston's curriculum vitae

Personal details

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Academic Qualifications

i) **B.Sc.** (first class honours; equal first in order of merit) School of Biological Sciences, University of Sydney; 1975-78, conferred 7 April 1979.
Thesis title: "The evolution and classification of *Boronia* Sm."

ii) **Ph.D.**, School of Biological Sciences, University of Sydney, 1979-83; conferred 18 May 1985.
Thesis title: "Systematics and biogeography of the Persooniinae (Proteaceae)".

Awards, Fellowships and Scholarships

2014	Nancy Burbidge Medal (awarded by the Australasian Systematic Botany Society to a person who has made a longstanding and significant contribution to Australasian systematic botany. It is the foremost award that can be conferred by ASBS).
2014	Australian Biological Resources Study-sponsored Winston Churchill Fellowship for an established career researcher in taxonomy.
2009	Grady L. Webster Structural Botany Publication Award for 2008 and 2009 from the Botanical Society of America. The BSA component of the award (it is awarded in alternate years by the BSA and the American Society of Plant Taxonomists) recognizes the most outstanding paper published in the *American Journal of Botany* in the field of structural and developmental botany (i.e., anatomy and morphology) over a two-year period. It was awarded to Gregory J. Jordan, Peter H. Weston, Raymond J. Carpenter, Rebecca A. Dillon and Timothy J. Brodribb for: "The evolutionary relations of sunken, covered, and encrypted stomata to dry habitats in Proteaceae," American Journal of Botany, Volume 95, Issue 5; May 2008.
2006	Carrick Award for Australian University Teaching from the Australian Learning and Teaching Council (one of five members of a teaching team from the University of New England cited for Outstanding Contributions to Student Learning).
1992-93	Posting to Royal Botanic Gardens, Kew, as Australian Botanical Liaison Officer.
1982	Charles Gilbert Heydon Travelling Fellowship for the biological sciences (not taken up).
1980-82	University of Sydney Postgraduate Scholarship.

1979-82	Commonwealth Postgraduate Award.
1977	G.S. Caird Scholarship for Third Year Botany, University of Sydney.
1976	Slade Prize for Practical Plant Biology, University of Sydney.

Employment

Present Position: Honorary Research Associate, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney and independent botanical consultant.

Previous positions held:
2008-2016 Senior Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

2000-2008 Principal Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1994-2000 Senior Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1989-1994 Research Scientist, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1982-1989 Scientific Officer, National Herbarium of New South Wales, Royal Botanic Gardens and Domain Trust, Sydney.

1979-82 Part-time demonstrator, School of Biological Sciences, University of Sydney.

Adjunct and visiting university appointments

2018-	Visiting Fellow, Western Sydney University.
2013-	Adjunct Associate Professor, La Trobe University.
2011-2016	Adjunct Associate Professor, University of New South Wales.
2006	Visiting Lecturer, Rhodes University, Grahamstown, South Africa.
2004-2009	Adjunct Associate Professor, University of New England.
2000-2004	Adjunct Senior Lecturer, University of New England.

Administrative/management experience

2009	Acting Manager Plant Diversity
2002-2003	Member, Plant Diversity Research Program Leaders Committee
1998-99	Systematics Liaison Officer
1997-98	Member RBGS Market testing working party
1997	Member, RBGS advisory committee for restructuring senior management
1990-91	Systematics Co-ordinator
1996-98	Member, RBGS Joint Consultative Committee

Membership of Learned Societies

1996-	Society of Australian Systematic Biologists
1984-	Willi Hennig Society (Elected Fellow, 1992-, Council member, 1998-2000)
1979-	Society of Systematic Biologists (member, Editorial Board 1993-95)

1978- Australasian Systematic Botany Society (formerly Australian Systematic Botany Society: President, 2009-2012, Vice President, 2008-2009, Chairman, Hansjörg Eichler Research Fund Committee, 1998-2002, Council member, 1996-2002)

Membership of External Committees

2015- Financial Grants Standing Committee (formerly the Grants Policy Standing Committee) of the Australasian Systematic Botany Society

2012-2013 Conference Organising Committee of *Systematics Without Borders*, a joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, University of Sydney (Chairman)

2011- Editorial Board, *Phytotaxa*

2008-2009 Corresponding Member, Editorial Advisory Committee, *Australian Systematic Botany*

2006-2014 Ira Butler Memorial Trophy Committee (a joint committee of the Australasian Native Orchid Society and the Orchid Society of New South Wales) (Chairman)

2004- Editorial Advisory Board, *Kew Bulletin*

2001-2006 Panel of Judges, Eureka Prize for Biodiversity Research

2000-2012 Bushland Management Advisory Committee, Lane Cove Council (Chairman, 2008-2010)

1999-2004 Editorial Advisory Committee, *Australian Systematic Botany*

Spoken presentations at conferences (not including presentations delivered by others)

2015 Building Our Botanical Capital, annual conference of the Australasian Systematic Botany Society: "A database of variation in floral characters in the Proteaceae, and implications for key questions in floral evolution".

2014 Next Generation Systematics, annual conference of the Australasian Systematic Botany Society: Nancy Burbidge Memorial Lecture: "Problems and progress in plant systematics since Nancy Burbidge"

2013 Genetics Society of Australasia conference, Sydney *Genetics in the Harbour City*: "Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications".

2013 Joint conference of the Australasian Systematic Botany Society, Society of Australian Systematic Biologists and Invertebrate Biodiversity and Conservation, Sydney, *Systematics Without Borders*: "Molecular phylogeny of the subtribe Hakeinae (Green Plants: Proteaceae tribe Embothrieae) and its implications".

2012 Australasian Systematic Botany Society conference, Perth, *Local knowledge, global delivery*: "Contested, Uncontested and Potentially Controversial Taxonomic Changes in the Proteaceae: How Do They Differ?"

2011 37th annual conference of the South African Association of Botanists, *Plants in a Changing World* and 9th conference of the South African Society of Systematic Biologists, *Biodiversity Matters*; plenary address: "Cenozoic environmental change and the systematics of southern hemisphere plants"

2011 XVIII International Botanical Congress, Melbourne: "Floral evolution in animal-pollinated Australian angiosperm clades: patterns and potential explanations".

2010 VI Southern Connection Congress, Bariloche: "Cladistic biogeography, molecular dating, fossils and the Proteaceae"

2010 VI Southern Connection Congress, Bariloche: "Diversification of the Proteaceae in Mediterranean hotspots of the Southern Hemisphere and in tropical rainforests"

2010 Australian Systematic Botany Society conference *Systematic Botany Across the Ditch: Links Between Australia and New Zealand*; Keynote address: “Cenozoic environmental change and the systematics of southern hemisphere plants”

1999 XVI International Botanical Congress, Saint Louis: “Historical biogeography of Proteaceae”.

1997 II Southern Connection Congress, Valdivia: “Cladistic biogeography of a key woody group: Proteaceae”.

1997 First Biennial International Conference of the Systematic Association, Oxford: “Rolf Sattler’s Plant Morphology and Cladistic Analysis”.

1996 *An International Symposium on the Biology of Proteaceae*, Melbourne: “ITS squence variation in the Proteaceae and what it tells us about phylogeny”.

1993 Joint conference of The Systematics Associations and The Linnean Society on *Models in Phylogeny Reconstruction*, London: “Direct methods for polarising character transformation series”.

1990 IXth meeting of the Willi Hennig Society, Canberra: “Transoceanic cladistic patterns in the Proteaceae”.

2003 The Third International Conference on *the Comparative Biology of the Monocotyledons*, Ontario: “Co-evolution of *Chiloglottis* (Orchidaceae) and its Thynnine wasp pollinators”.

2005 XVII International Botanical Congress, Vienna: “Food is good but sex is better: the evolution of deceptive pollination in the tribe Diurideae (Orchidaceae)”.

2006 Australian Systematic Botany Society conference, Cairns, *Plant Diversity in the Tropics*: “A new suprageneric classification of the Proteaceae”.

2007 5th Southern Connection Congress, Adelaide: “‘I’m not dead yet’ – Gondwana (the Proteaceae are at least partially congruent with Gondwanic fragmentation)”.

1989 Australian Systematic Botany Society symposium, on *Gondwanan Elements in the Australian Flora*, Sydney: “Transpacific cladistic patterns in the Proteaceae and Elaeocarpaceae”.

1988 Symposium on *Panbiogeography of New Zealand*, Wellington: “Problems with the statistical testing of panbiogeographic hypotheses”.

1985 Australian Flora Foundation Symposium on *Waratahs*, Canberra: “Drifting waratahs or continents?”

1984 Australian Systematic Botany Society symposium on *Cladistics, Systematics and Phylogeny*, Canberra: “A reappraisal of Nelson's direct method of character analysis”.

Refereeing manuscripts, grant applications, reports and examining postgraduate theses (last five years)

2018: *Candollea*; *Flora of the Hunter Region*; *Journal of Biogeography.*

2017: *Australian Systematic Botany*; *Evolution*; *New Zealand Journal of Botany*; *Nuytsia*; *South African Journal of Botany.*

2016: *Australian Systematic Botany*; *Botanical Journal of the Linnean Society*, *National Research Foundation* (South Africa).

2015: *American Journal of Botany*; Australian Research Council (4); *Australian Systematic Botany*; *Muelleria*; *Nuytsia*; *Phytotaxa*; *PLOS One*; *Telopea* (6).

2014: Australian Research Council (3); *Australian Systematic Botany* (2); *Cunninghamia*; *Journal of Biogeography* (2); *Muelleria*; National Research Foundation (South Africa); *Orchadian*; *Perspectives in Plant Ecology, Evolution and Systematics*; *Plant Systematics and Evolution*; *Telopea* (3).

Research

My research has been in the theoretical and practical aspects of systematic botany, with emphasis on the theory and practice of phylogenetic analysis, and the broader uses to which phylogenetic knowledge may be applied. I have phylogenetically analysed groups in the plant families Proteaceae, Fabaceae, Orchidaceae, Rutaceae, Winteraceae and Lauraceae, contributed to more general analyses of angiosperm phylogeny, and used the results of these analyses to improve biological classification and to test theories of historical biogeography, trait evolution, co-evolution and adaptation. I have earned an international reputation for my contributions to both theoretical and empirical developments in this field.

Herbarium curation and collections

My curatorial responsibilities at the National Herbarium of New South Wales have included the families Rutaceae (1982-1998), Proteaceae (1982-2016), Orchidaceae (1986-2016) and Fabaceae subfamily Faboideae (1986-2016). I have collected plant specimens (mostly angiosperms) in Australia, England, New Zealand, New Caledonia, Chile, South Africa, and Argentina, mostly for the herbarium and living collections of the Royal Botanic Gardens and Domain Trust, Sydney. Duplicates of my collections have been distributed to over 20 herbaria in 8 different countries.

Teaching

I have been actively involved in the preparation and teaching of four third year undergraduate courses in biosystematics:
Western Sydney University (2015-2018): “Principles of Evolution” (unit 300980), “Botany” (unit 300836).
University of New South Wales (2010-2016): “Assembling the Tree of Life” (BIOS3221)
University of New England (2000-2010): Biosystematics (Biosyst 301, Biosyst 302, Evol 301/501).
Botany Department, Rhodes University, Grahamstown, South Africa (February-March 2006): “Plant Biodiversity” course in collaboration with Associate Professor Nigel Barker.

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I have examined 14 honours and postgraduate theses:
Australian National University (Ph.D., 2003, 2007, 2008)
University of Melbourne (Ph.D., 1995, 2011)
University of Newcastle (M.Phil., 2003)
University of Queensland (Ph.D., 2003)
University of Sydney (Ph.D., 1991, 1994, 1997, 2009)
University of Wollongong (B.Sc. Hons., 2001, 2003)
Victoria University (Ph.D., 2007)

Competitive Research and Infrastructure Grants

Peakall, R., Pichersky, E., Linde, C., Weston, P.H. (2015-2019) The biosynthesis and evolution of novel semiochemicals in orchids. $644,800, Australian Research Council Discovery Grant DP150102762.

Hoebee, S.E., Weston, P.H., & Edwards, T.J. (2015-19) Evolution in action or the demise of iconic Australian flora? $217,700, Australian Research Council Discovery Grant DP150100508.

He, T., Lamont, B., Weston, P.H., & Cowling, R. (2012-2014) Origin and evolution of plant functional traits in relation to fire. $310,000, Australian Research Council Discovery Grant DP120103389.

Rossetto, M., Crayn, D.M. & Weston, P.H. (2008-2010) Integrating molecular and morphological data for generic delimitation and species identification in Lauraceae. $73,333, Australian Biological Resources Study.

Cantrill, D., Murphy, D. & Weston, P.H. (2008-10) Understanding the origins of the Australian flora by integrating molecular phylogenies and fossil data in the Proteaceae. $88,900, Hermon Slade Foundation.

Rossetto, M. & Weston, P.H. (2007-2009) Speciation in the Australian flora: testing explanatory hypotheses in waratahs and their allies. $78,000, Hermon Slade Foundation.

Considine, J.A., Krauss, S.L. & Weston, P.H. (2002-2004) A biological basis for the efficient breeding of native plants for export markets: a case study with the Australian Goodeniaceae. $168,126, ARC – Linkage (Krauss and Weston representing industry partners)

Whelan, R.J., Ayre, D.J., England, P., Auld, T.D., & Weston, P.H. (2000-2002) Ecology and genetics of fire-sensitive *Persoonia* species: threatened species recovery and management. $126,480, Australian Research Council (ARC– SPIRT, Auld and Weston representing industry partners).

Trent, R. *et al.* (2000) Enhancement of DNA sequencing equipment for the Sydney University and Prince Alfred Molecular Analysis Centre. $600,000, Australian Research Council (ARC-REIF).

Weston, P.H. (1999-2001) Comparative biology of *Chiloglottis* (Orchidaceae) and its thynnine wasp pollinators (Tiphiidae). $75,000, Hermon Slade Foundation.

Weston, P.H. (1997-2000) Taxonomic revision of *Dillwynia* (Fabaceae: Faboideae: Mirbelieae). $62,836, Australian Biological Resources Study.

Weston, P.H. & Thomson, J.A. (1993) A molecular approach to the evolution and biogeography of the Queensland tree waratahs. $4000, Queensland Wet Tropics Management Authority

Weston, P.H. & Thomson, J.A. (1991-92) A molecular approach to the evolution and biogeography of the waratahs. $80,100, Australian Research Council (large grants scheme).

Weston, P.H. (1984) Establishment of a data bank for eucalypt specimens held by NSW. $20,000, Australian Biological Resources Study.

Scientific Publications

[the numbers in square brackets following a reference indicates: 1. the journal's 2016-17 impact factor according to ISI Web of Knowledge, then the number of literature citations for the paper found by Google Scholar, as of 13 Feb 2019]

H-index = 34, total number of citations = 4081 as of 13 Feb 2019

1. Craw, R.C. & **Weston, P.H.** (1984) Panbiogeography: a progressive research program? *Systematic Zoology* 33: 1-13. [8.917, 90]

2. **Weston, P.H.**, Carolin, R.C., & Armstrong, J.A. (1984) A cladistic analysis of *Boronia* Sm. and *Boronella* Baill. (Rutaceae). *Australian Journal of Botany* 32: 187-203. [0.793, 49]

3. Morrison, D.A. & **Weston, P.H.** (1985) Analysis of morphological variation in a field sample of *Caladenia catenata* (Smith) Druce (Orchidaceae). *Australian Journal of Botany* 33: 185-195. [0.793, 11]

4. Crisp, M.D. & **Weston, P.H.** (1987a) Waratahs - how many species? Pp. 3-15, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 13]

5. Crisp, M.D. & **Weston, P.H.** (1987b) Cladistics and legume systematics, with an analysis of the Bossiaeeae, Brongniartieae and Mirbelieae. Pp. 65-130, in C.H. Stirton (ed.) *Advances in Legume Systematics Part 3* (Royal Botanic Gardens: Kew). [-, 131]

6. **Weston, P.H.** (1987) *Persoonia* (Proteaceae). Pp. 348-350, in N.G. Marchant *et al*. (eds.) *Flora of the Perth Region* (Western Australian Herbarium: Perth). [-, 0]

7. **Weston, P.H.** & Crisp, M.D. (1987) Evolution and biogeography of the Waratahs. Pp. 17-34, in J.A. Armstrong (ed.) *Waratahs, Their Biology, Cultivation and Conservation* (Australian National Botanic Gardens: Canberra). [-, 14]

8. **Weston, P.H.**, Wilson, P.G., & Hill, K.D. (1987) Identification of *Cannabis*. *Department of Agriculture New South Wales Miscellaneous Bulletin* 25: 148-150. [-, 0]

9. **Weston, P.H.** (1988a) A revision of *Hicksbeachia* (Proteaceae). *Telopea* 3: 231-239. [0.6, 3]

10. **Weston, P.H.** (1988b) Indirect and direct methods in systematics. Pp. 27-56, in C.J. Humphries (ed.) *Ontogeny and Systematics* (Columbia Univ. Press: New York). [-, 76]

11. **Weston, P.H.** (1989) Problems with the statistical testing of panbiogeographic hypotheses. *New Zealand Journal of Zoology* 16: 511. [0.811, 7]

12. **Weston, P.H.** (1990) Notes on *Boronia* (Rutaceae) in New South Wales, including descriptions of three new species. *Telopea* 4: 121-128. [0.6, 6]

13. **Weston, P.H.** & Johnson, L.A.S. (1991) Taxonomic changes in *Persoonia* (Proteaceae) in New South Wales. *Telopea* 4: 269-306. [0.6, 9]

14. Crisp, M.D. & **Weston, P.H.** (1991) *Almaleea*, a new genus of Fabaceae from south-eastern Australia. *Telopea* 4: 307-311. [0.6, 10]

15. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae), a new genus from New Guinea and eastern Australia. *Telopea* 4: 497-507. [0.6, 12]

16. **Weston, P.H.** (1991) Key to genera, *Persoonia* (Proteaceae), *Medicago*, *Trifolium*, *Pultenaea* and *Dillwynia* (Fabaceae). Pp. 2-19, 452-455, 456-461, 481-497, 499-504, in G. Harden (ed.) *Flora of New South Wales* vol. 2 (New South Wales Univ. Press: Sydney). [-, 0]

17. **Weston, P.H.** & Crisp, M.D. (1991) *Alloxylon* (Proteaceae) and *Almaleea* (Fabaceae). Pp. 29-30, 497-498, in G. Harden (ed.) *op. cit.* [-, 0]

18. **Weston, P.H.** & Porteners, M.F. (1991) *Boronia*, *Eriostemon* and *Phebalium* (Rutaceae). Pp. 227-236, 250-254, 255-263, in G. Harden (ed.) *op. cit.* [-, 0]

19. Porteners, M.F. & **Weston, P.H.** (1991) *Correa* and *Crowea* (Rutaceae). Pp. 247-249, 254-255, in G. Harden (ed.) *op. cit.* [-, 0]

20. Crisp, M.D. & **Weston, P.H.** (1991) *Telopea*. Pp. 30-31, in G. Harden (ed.) *op. cit.* [0.6, 0]

21. Gross, C.L. & **Weston, P.H.** (1992) *Macadamia jansenii* (Proteaceae), a new species from central Queensland. *Australian Systematic Botany* 5: 725-28. [0.75, 8]

22. Crisp, M.D. & **Weston, P.H.** (1993) Geographic and ontogenetic variation in morphology of Australian waratahs (*Telopea*: Proteaceae). *Systematic Biology* 42: 49-76. [14.387, 76]

23. Gilmore, S., **Weston, P.H.**, & Thomson, J.A. (1993) A simple, rapid, inexpensive and widely applicable technique for purifying plant DNA. *Australian Systematic Botany* 6: 139-148. [0.75, 41]

24. **Weston, P.H.** (1993) Key to genera, *Cyrtostylis*, *Cryptostylis*, *Zeuxine*, *Cheirostylis*, *Pseudovanilla*, *Erythrorchis*, *Epipogium*, *Gastrodia*, *Oberonia*, *Liparis*, *Dendrobium*, *Calanthe*, *Phaius*, *Geodorum*, *Dipodium*, *Cymbidium*, *Sarcochilus*, *Rhinerrhiza*, *Peristeranthus*, *Papillilabium*, *Schistotylus*, *Plectorrhiza*, *Taeniophyllum* (Orchidaceae). Pp. 134-138, 218-219, 219-221, 221-233, 236-247, in G. Harden (ed.) *Flora of New South Wales* vol. 4 (New South Wales Univ. Press: Sydney). [-, 0]

25. **Weston, P.H.** & Hill, K.D. (1993) *Bulbophyllum* (Orchidaceae). Pp. 233-236, in G. Harden (ed.) *op. cit.* [-, 0]

26. **Weston, P.H.** & Crisp, M.D. (1994) Cladistic biogeography of Waratahs and their allies (Embothrieae: Proteaceae) across the Pacific. *Australian Systematic Botany* 7: 225-249. [0.75, 73]

27. **Weston, P.H.** (1994) The Western Australian species of subtribe Persooniinae (Proteaceae: Persoonioideae: Persoonieae). *Telopea* 6: 51-165. [0.6, 19]

28. **Weston, P.H.** & Johnson, L.A.S. (1994) Three new species of *Persoonia* (Proteaceae) from Queensland. *Telopea* 6: 31-37. [0.6, 1]

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