SMEC
Member of the Surbana Jurong Group

local people
global experience

Artist's Impression

Environmental Impact Statement – Chapter 8: Biodiversity – Upstream

Warragamba Dam Raising

Reference No. 30012078
Prepared for WaterNSW
10 September 2021

SMEC INTERNAL REF. 30012078

Contents

List of Tables

List of Figures

8 Biodiversity – upstream

This chapter provides an assessment of upstream biodiversity during operation of the flood mitigation zone (FMZ) following the raising of Warragamba Dam. The relevant Secretary's Environmental Assessment Requirements (SEARs) are shown in Table 8-1.

Table 8-1. Secretary's Environmental Assessment requirements: Biodiversity – Upstream

Desired performance outcome	Secretary's environmental assessment requirements[1]	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*.	Section 8.2 (Assessment Methodology) Sections 8.3 to 8.11 (Existing environment, impact assessment and management measures)
	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.	Chapter 9 (Downstream ecological assessment)
	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 C.	Section 8.6 Section 8.10
	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 8.8.7

1. This chapter specifically addresses SEAR 6 in addition to those general requirements of the SEARs applicable to all chapters and as identified as such in Chapter 1 (Section 1.5, Table 1-1).

The upstream biodiversity assessment is supported by detailed investigations which are documented in Appendix F1: Biodiversity Assessment Report – Upstream (SMEC 2021). Also relevant are:

- Appendix F2: Downstream ecological assessment (SMEC 2021)
- Appendix F3: Biodiversity assessment report - construction area (SMEC 2021)
- Appendix F4: Aquatic ecology assessment report (BMT 2021)
- Appendix F6: Biodiversity offset strategy (SMEC 2021).

The proposed management and mitigation measures in this chapter are collated in Chapter 29 (EIS synthesis, Project justification and conclusion).

8.1 Project overview

8.1.1 Project description

A detailed description of the Project is provided in Chapter 5. 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 full supply level (FSL) for temporary storage of inflows in the FMZ. 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 current design includes raising the dam side walls and roadway by 17 metres to enable adaptation to projected climate change. The Project would delay downstream flooding, which would reduce current downstream flood peaks and increase the time taken for downstream water levels to recede.

Operational objectives are to:

- maintain the structural integrity of the dam
- minimise risk to life
- maintain Sydney's water supply
- minimise downstream impact of flooding to properties
- minimise environmental impact
- minimise social impact.

The dam would be subject to the following operational regimes, depending on the water level.

Normal operations

Normal operations would apply when the reservoir level is at or lower than FSL, which is when the water level in Lake Burragorang is at or below RL 116.7 mAHD (metres Australian height datum).

Flood operations

Flood operations are shown on Figure 8-1 and would apply when the water level is higher than the FSL. The FMZ would have sufficient capacity to temporarily store up to about 1,000 gigalitres. For larger floods the FMZ would be filled and uncontrolled discharge would occur over the central spillway, and potentially, auxiliary spillway of the dam.

8.1.2 Project location

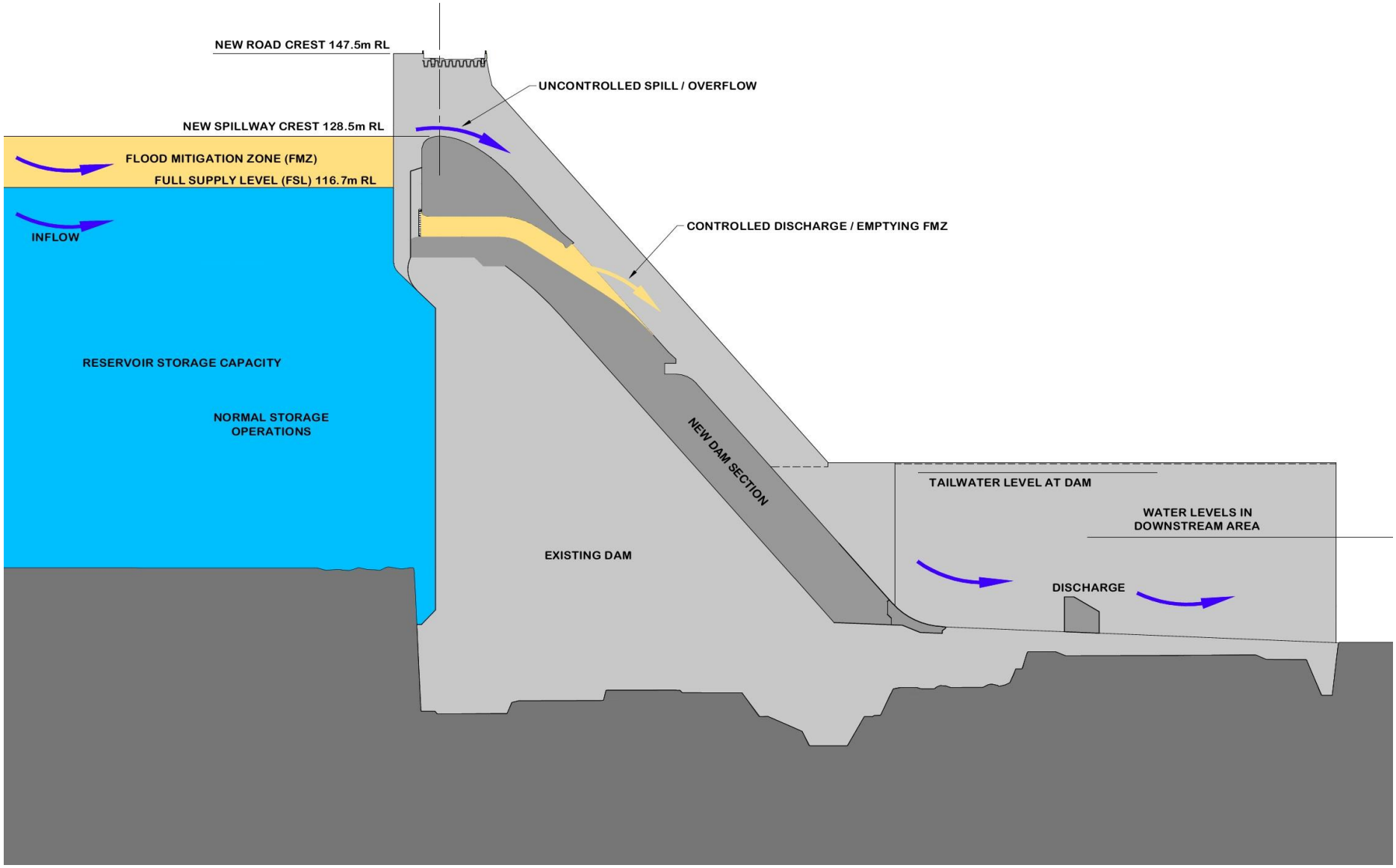
Warragamba Dam is located approximately 65 kilometres west of Sydney in a narrow gorge on the lower section of the Warragamba River, 3.3 kilometres before it joins the Nepean River. The township of Warragamba is located approximately one kilometre east of the dam wall. The upstream environment includes the reservoir formed by Warragamba Dam (Lake Burragorang) and its tributaries. The dam catchment covers an area of approximately 9,050 square kilometres, of which approximately 75 square kilometres is occupied by Lake Burragorang. The catchment includes state conservation areas, national parks and parts of the Greater Blue Mountains World Heritage Area (GBMWHA). Lake Burragorang and its catchment area are shown on Figure 8-2.

The upstream study area is about 5,280 hectares (see Section 8.2.3), equating to the area between FSL and the Project probable maximum flood (PMF[1]) level. The study area is shown on Figure 8-3 and includes protected areas, which include a small area of the GBMWHA. These protected areas include parts of:

- Blue Mountains National Park
- Burragorang State Conservation Area
- Nattai National Park
- Nattai State Conservation Area

[1] The PMF is a hypothetical flood estimate relevant to a specific catchment whose magnitude is such that there is negligible chance of it being exceeded. It represents a notional upper limit of flood magnitude and no attempt is made to assign a probability of exceedance to such an event (Ball *et al*. 2019). The PMF is unlikely to occur in nature given the size of the Warragamba Dam catchment.

Figure 8-1. Flood operations



- Yerranderie State Conservation Area.
- NSW Declared Wilderness (Kanangra-Boyd and Nattai).

Land use is detailed in Chapter 2 (Statutory and planning framework). The study area is located mainly in the Wollondilly and Blue Mountains local government areas (LGAs), with small parts in the Oberon and Wingecarribee LGAs. The Project is classified as flood mitigation infrastructure and permissible under relevant Local Environmental Plans (LEPs), which are summarised in Table 8-2.

Land is reserved for the purposes of environmental and cultural heritage conservation and is managed by the National Parks and Wildlife Service (NPWS) in accordance with relevant plans of management for the national parks estate. The study area also falls within water storage catchment 'special areas', which are areas of restricted or prohibited access to protect against pollutants entering the storage. A publicly accessible walking track is located between Katoomba and Mittagong, which crosses the study area at the Coxs River, near Mount Cookem, and Wollondilly River at Murphy's Crossing.

Table 8-2. Land zones within the study area

Land zone	Objectives	Permissibility
Wollondilly LEP 2011		
SP2: Water Supply	▪ Provide for infrastructure and related uses ▪ Prevent development that is not compatible with or that may detract from the provision of infrastructure.	Permitted with consent
E1: National Parks and Nature Reserves	▪ Enable the management and appropriate use of land that is reserved under the *National Parks and Wildlife Act 1974* or that is acquired under Part 11 of that Act ▪ Enable uses authorised under the *National Parks and Wildlife Act 1974* ▪ Identify land that is to be reserved under the *National Parks and Wildlife Act 1974* and to protect the environmental significance of that land.	Permitted if authorised under the *National Parks and Wildlife Act 1974*
E2: Environmental Conservation	▪ Protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values ▪ Prevent development that could destroy, damage or otherwise have an adverse effect on those values.	Permitted with consent
E3: Environmental Management	▪ Protect, manage and restore areas with special ecological, scientific, cultural or aesthetic values. ▪ Provide for a limited range of development that does not have an adverse effect on those values ▪ Maintain existing significant stands of native vegetation and wildlife corridors ▪ Ensure land degradation and soil disturbance are minimised.	Permitted with consent
Blue Mountains LEP 2015 and Wingecarribee LEP 2010		
E1: National Parks and Nature Reserves	▪ Enable the management and appropriate use of land that is reserved under the *National Parks and Wildlife Act 1974* or that is acquired under Part 11 of that Act ▪ Enable uses authorised under the *National Parks and Wildlife Act 1974* ▪ Identify land that is to be reserved under the *National Parks and Wildlife Act 1974* and to protect the environmental significance of that land.	Permitted if authorised under the *National Parks and Wildlife Act 1974*

Figure 8-2. Lake Burragorang and catchment area

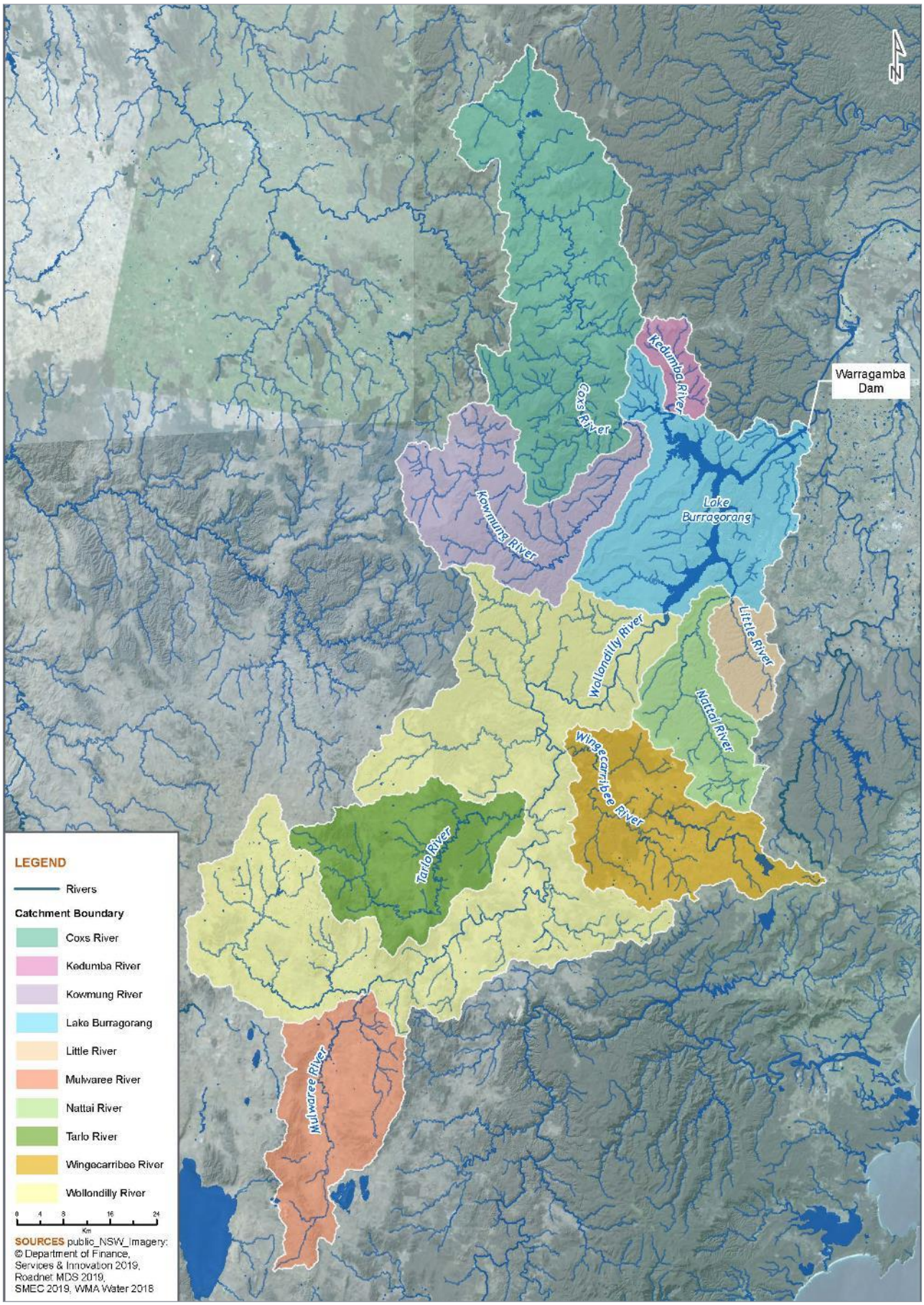
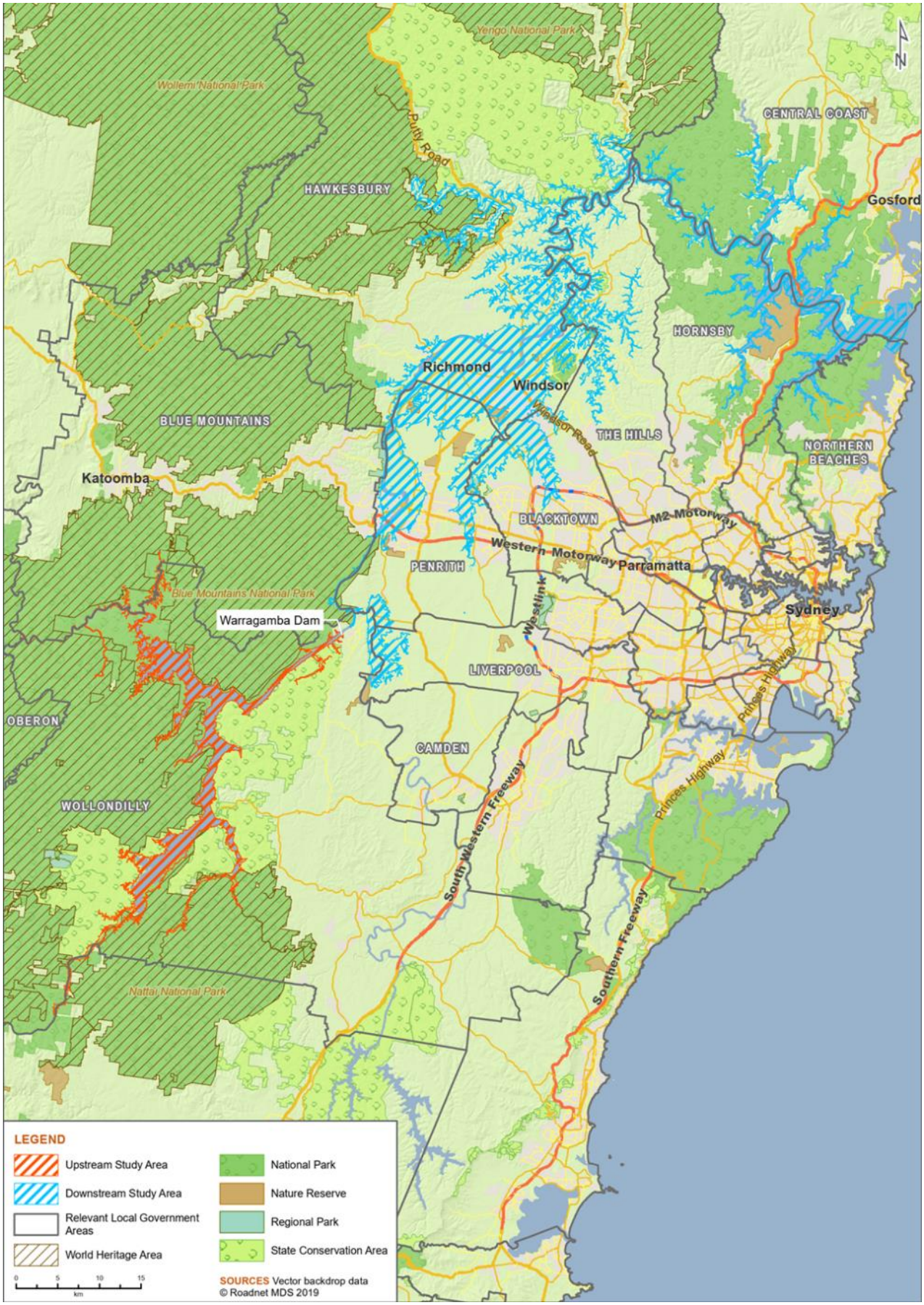


Figure 8-3. Project location and study area



8.1.3 Changes to upstream flooding

The existing and Project flooding extents were based on flood modelling which is discussed in detail in Chapter 15 (Flooding and hydrology). The inundation depth and duration of a flood event is strongly correlated with the magnitude of the related rainfall event. Generally, the larger the rainfall event the greater the extent of inundation and the depth of inundation. Within a regulated river system, the depth and duration of a flood event are also influenced by the water level of the storage at the beginning of the rainfall event. The level of the storage below FSL would, depending on the water level, attenuate to varying degrees the amount and extent of upstream inundation.

Both depth and duration of temporary inundation drive the potential impacts to biodiversity values. The frequency of temporary inundation may also influence the scale and severity of the impact as discrete impacts associated with an individual event may accumulate over time. Conceptually, smaller but more frequent inflow events, or large inflow events that occur within quick succession, would be expected to have a greater long-term impact than an inflow event that occurs much less frequently.

The magnitude and extent of impacts associated with temporary inundation could be variable depending on future rainfall events, making future impacts associated with the Project difficult to accurately characterise and quantify, particularly for the larger, less frequent events. The tolerance of individual plant species to inundation in relation to the flood characteristics and frequencies would also be a determining factor on the nature of the impact.

8.2 Assessment methodology

8.2.1 Assessment requirements

Key objectives of this assessment are to address:

- requirements of the *Framework for Biodiversity Assessment* (FBA) (Office of Environment and Heritage (OEH) 2014a), developed for Major Projects
- biodiversity matters raised in the Secretary's Environmental Assessment Requirements (SEARs) (see Table 8-1)
- OEH[2] requirements, and relevant guidance documents.

The assessment also addresses relevant regulatory requirements, which are discussed in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 2). Key legislation is summarised in Table 8-3.

This assessment has been prepared by a person accredited under the *Biodiversity Conservation Act 2016.* Details are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, see Report contents – Certification).

Table 8-3. Key legislation

Key legislation	
NSW legislation	
Environmental Planning and Assessment Act 1979 (EP&A Act)	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.
Threatened Species Conservation Act 1995 (TSC Act)	The TSC Act was repealed when the BC Act commenced on 25 August 2017. However, the provisions of the Biodiversity Conservation (Savings and Transitional) Regulation 2017 provide for SSI projects to be assessed under the provisions of the TSC Act if the application for the SEARs was made prior to this date. The application was made prior to 25 August 2017 with the SEARs for the Project being issued on 30 June 2017. Updated SEARs for the Project were reissued on 13 March 2018. The biodiversity assessment has been carried out in accordance with the relevant provisions of the TSC Act through the effect of the Biodiversity Conservation (Savings and Transitional) Regulation 2017. Consideration has also been given to relevant matters under the BC Act, particularly about threatened species, populations and ecological communities that may have been listed, or existing listings that may have been amended subsequent to the BC Act coming into force.

[2] The assessment for the Warragamba Dam Raising formally commenced in 2017 with the issue of the SEARs for the Project. On 1 July 2019 OEH was dissolved, with its biodiversity related functions transferred to DPIE Environment, Energy and Science (EES). For the sake of convenience 'OEH' is used to refer to OEH in the historic context unless otherwise specifically noted.

Key legislation	
Biodiversity Conservation Act 2016 (BC Act)	The *Biodiversity Conservation Act 2016* (BC Act) and its supporting regulations commenced on 25 August 2017. The BC Act repeals the *Threatened Species Conservation Act 1995* (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 this Project as application for the SEARs for the Project was made 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 TSC Act. When referring to threatened species, populations, or ecological community listings, this report uses the BC Act.
Water NSW Act 2014 (WaterNSW Act)	In 2018, an amendment to the *Water NSW Act 2014* (WaterNSW Act) was enacted that related specifically to the Project and the potential impacts of temporary inundation on national parks and state conservation areas in the Warragamba Dam catchment. Under previous legislation, inundation of national park land was not permitted, however, the amendment of the WaterNSW Act provided a special provision to allow the temporary inundation of national park and state conservation area land in the Warragamba Dam catchment. To ensure the mitigation of any impacts from temporary inundation, the special provisions also require: ▪ WaterNSW to prepare an Environmental Management Plan (EMP) in consultation with the Chief Executive of the OEH and NPWS if approval for the Project is given. ▪ the NPW Minister to determine the matters that are to be addressed by an EMP. ▪ the NPW Minister with the concurrence of the Minister for Water approve an acceptable EMP. ▪ the NPW Minister with the concurrence of the Minister for Water require an approved EMP to be updated or reviewed. The NPW Minister with the concurrence of the Minister for Water may direct Water NSW to take specified actions in relation to the temporary inundation of national park land resulting from the Warragamba Dam project, including action relating to the monitoring of risks associated with the temporary inundation and relating to the rehabilitation or remediation of land. WaterNSW to implement and monitor the EMPs. Water NSW to notify the Chief Executive of the OEH if it is of the opinion that a flood event that may affect national park land in the vicinity of Warragamba Dam is likely to occur.
Other	▪ *Fisheries Management Act 1994* (FM Act) ▪ *National Parks and Wildlife Act 1974* (NPW Act) ▪ *Wilderness Act 1987* ▪ *Biosecurity Act 2015* ▪ NSW Biodiversity Offsets Policy for Major Projects
Commonwealth legislation	
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	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, and migratory species, as well as other protected matters. Among other things, it 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 communities.
EPBC Act Environmental Offsets Policy	This policy came into force in October 2012 and provides guidance on the role of offsets in environmental impact assessments and how DoEE considers the suitability of a proposed offset package. According to the policy, an offsets package is a "suite of actions that a proponent undertakes in order to compensate for the residual significant impact of a project". It can comprise a combination of direct offsets and other compensatory measures.

8.2.2 Overview of methodology and key tasks

Impacts on biodiversity values would be principally associated with the effects of temporary inundation from operation of the FMZ. The specific nature of impacts would depend on:

- the frequency of events
- the duration and depth of temporary inundation for an individual event
- the predicted change in vegetation integrity due to the differing responses of individual plant species to different temporary inundation regimes.

The Project is a challenging project for application of standard assessment methodologies, primarily because the specific impacts are difficult to predict due to both the unpredictability of the scale and timing of flood events and a lack of detailed knowledge of the response of biodiversity to temporary inundation. Because of this the methodology has been developed based on an understanding of the impacts of the Project from survey, literature review, risk assessment and modelling consistent with the requirements of the FBA. Development of the methodology has involved consultation with the former Office of Environment and Heritage (OEH, now the Environment, Energy and Science (EES) Group within the Department of Planning, Industry and Environment, DPIE), particularly on application of the FBA for the Project.

For the FBA and calculation of offset requirements, a precautionary approach has been adopted; this has assumed a 100 percent loss of vegetation/habitat within the area between the likely inundation level with the Project (10.25 m above FSL, RL 126.97 mAHD) and the likely inundation level for the existing dam (2.78 m above FSL, RL 119.5 mAHD). This is discussed further in Section 8.2.5.

8.2.3 Framework for Biodiversity Assessment

The FBA is the mechanism for implementing the NSW Biodiversity Offsets Policy for Major Projects (OEH 2014). The SEARs (6.1) make specific reference to assessing Project impacts in accordance with the FBA.

The FBA prescribes the methodology for the impact assessment and provides guidance for offsetting impacts. The FBA also sets out measures required to offset unavoidable impacts through a Biodiversity Offset Strategy (BOS), which is submitted with the BAR as part of the EIS and application for approval. The FBA is undertaken in three stages as follows.

Stage 1: Assessment of biodiversity values

Identification of the biodiversity values that would be impacted, both directly and indirectly, by the Project focussing on affected landscape values, native vegetation, and threatened species. These are addressed in Section 8.3 and include:

1) *Landscape values of the study area*. These include landscape features defined by their noted importance, IBRA bioregions and subregions, Mitchell landscapes, waterways, wetlands, native vegetation extent in the assessment circles, biodiversity links and any other landscape features.
2) *Biodiversity values of native vegetation on the study area*: Includes mapping the extent of native vegetation, identify Plant Community Types (PCTs) and ecological communities, undertake floristic site surveys, identify any threatened ecological communities, identify vegetation zones, assess site value (vegetation condition), undertake plot & transect site surveys, and assess site value score.
3) *Biodiversity values of threatened species*. This includes interrogating the Threatened Species Profile Database, assessing species that can be predicted by habitat surrogates (ecosystem credits), assessing species that cannot be predicted by habitat surrogates (species credits), undertake threatened species survey.

Stage 2: Impact assessment (biodiversity values)

Assessment of impacts on identified biodiversity values considering opportunities to avoid and minimise impacts, identification of thresholds for assessing and offsetting of unavoidable impacts and determining required offsets. These are addressed in Section 8.8 and 8.9 and include:

4) *Avoid and minimise impacts on biodiversity values*. Sets out the actions that must be undertaken to demonstrate that reasonable measures are taken to avoid and minimise the direct and indirect impacts of a proposal on biodiversity values.

5) *Thresholds for the assessment and offsetting of unavoidable impacts of development*. Sets out the impact thresholds for landscape features, native vegetation, and threatened species and populations, and impacts on biodiversity that require further consideration.
6) *Determining offset requirement*. Includes calculating: credit requirement, the future site value score for vegetation zones on the study area and the change in the site value score for vegetation zones on the study area; and implement offset rules for biodiversity values.

Stage 3: Biodiversity offset strategy (BOS)

Development of a biodiversity offset strategy (BOS). This is documented separately in Appendix F6 (Biodiversity offset strategy), which is be submitted with the Biodiversity Assessment Report (BAR) as part of the EIS and application for development consent or infrastructure approval. This is addressed in Section 8.9 and includes:

7) *Deliver long-term conservation gain for threatened entities impacted by the Project*. Includes sourcing credits from market, establishing an offset site, carrying out supplementary measures, payment into Biodiversity Conservation Trust Fund.

Section 8.4.1.4(e) of the FBA includes provisions for assessment where there are likely to be impacts on biodiversity that are infrequent, cumulative or difficult to measure over time. This was identified as being of relevance to the Project for assessment of impacts on biodiversity values in the upstream area.

The FBA also establishes specific definitions for elements of the FBA, which inform the spatial extent of the assessment and associated methodology. The Project has also adopted a defined 'survey area' which, for the purposes of this assessment, is the 1 in a 100 chance in a year event plus nine percent climate change (that is, a nine percent increase in rainfall under a climate change scenario). The survey area was delineated with input from the former Department of the Environment and Energy (DoEE)[3] prior to surveys commencing. It should be noted that 'survey area' is not a defined concept within the FBA. Subsequently, the DoEE agreed that impact assessment should be up to the 1 in 100 chance in a year flood extent. Project assessment definitions are described in Table 8-4.

Table 8-4. Project definitions for upstream biodiversity assessment

Element	FBA definition	Adopted Project definition
Development site	An area of land that is subject to a proposed Major Project that is under the EP&A Act.	1 Production Ave, Warragamba NSW 2752 Lot 1, DP87998 and Lot 1124, DP1159978 This aligns with the required information under clause 228(c) of the EP&A Regulation.
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.	This generally equates to the construction footprint for the raising of the dam wall and adjoining/nearby land affected by construction activities, refer to Appendix F3 (Biodiversity assessment report – construction area). The area of the development footprint is about 105 ha.
Study area	The area directly affected by the development and any additional areas likely to be affected by the development, either directly or indirectly. The study area should extend as far as necessary to take all potential impacts into account, for the purpose of an assessment under Subsections 9.2.4 and 9.2.5 of the FBA.	The upstream study area comprises the area between FSL and the Project PMF. This equates to an area of about 5,280 ha (and noting that a portion of this area is already potentially affected by flooding). The principal areas of interest in the study area for the assessment are the survey area and upstream impact area as defined below.

[3] The Environment portfolio within DoEE was transferred to the new Department of Agriculture, Water and the Environment (DAWE) which commenced operation on 1 February 2020.

Element	FBA definition	Adopted Project definition
Field survey area	Not defined within the FBA	The area within a 1 in 100 chance in a year event (1% AEP[1]) plus 9% climate change (that is, a 9% increase in rainfall under a climate change scenario). This equates to an area of about 3,740 ha.
Upstream impact area	Not defined within the FBA (see Section 8.2.5.2)	The area between the likely inundation level with the Project (10.25 m above FSL, RL 126.97 mAHD) and the likely inundation level for the existing dam (2.78 m above FSL, RL 119.5 mAHD). The size of this area is about 1,400 ha.

1 Annual Exceedance Probability

8.2.4 Consultation with regulatory authorities for development of assessment methodology

The SEARs require that the Proponent assess biodiversity impacts in accordance with the current guidelines including the FBA unless otherwise agreed to by OEH. WaterNSW has met with representatives of DPIE and DoEE/DAWE, to resolve how the FBA can be applied to the upstream area that would be subject to temporary inundation from the proposal, particularly as the impacts would be infrequent, cumulative and difficult to measure over time. Based on hydrological modelling the Agencies agreed that an upstream impact area can be used for calculation of impacts. This is discussed in Section 8.2.5.

8.2.5 Potential upstream impacts of the Project

8.2.5.1 Potential impacts

The Project would have impacts beyond the immediate footprint of the raised dam (that is, the development site). For the upstream area, impacts on biodiversity values would be principally associated with the effects of temporary inundation from operation of the FMZ, the lower limit of which is the existing full supply level. The exact nature of the impacts on biodiversity values would be dependent on multiple factors, such as the timing and magnitude of the rainfall events, catchment conditions at the time of the rainfall event, the existing storage level, the depth and duration of inundation, and the tolerance of plant species to inundation. These and other factors contribute to some uncertainty about quantifying the impacts on biodiversity values.

For the purposes of completing an FBA assessment and calculation of offsets an upstream impact area has been identified where it is precautionarily assumed a 100 percent loss of biodiversity values within the area. The basis for defining the impact area is outlined below.

8.2.5.2 Upstream impact area

The upstream study area comprises the area between FSL and the Project PMF. The probabilistic nature of flooding in this area presents a challenge in identifying appropriate flood events to inform an assessment of potential impacts, and noting that for a specific flood event of a particular chance of occurrence, there is already an existing potential impact associated with that particular flood event.

For the upstream study area, potential impacts would be principally associated with the effects of temporary inundation from operation of the FMZ, the lower limit of which is the existing FSL. The exact nature of the impacts would be dependent on multiple factors such as:

- the timing and magnitude of the rainfall events
- catchment conditions at the time of the rainfall event
- the existing storage level
- the duration, depth and extent of inundation for an individual flood event
- the potential change in vegetation integrity as a result of the differing responses of individual plant species to different inundation regimes
- the type and condition of Aboriginal cultural heritage items and places.

These and other factors contribute to substantial uncertainty with regard to quantifying the potential impacts on World Heritage values, notably biodiversity values and Aboriginal cultural heritage.

In view of this, it was determined that a different approach to assessing potential impacts was required in order to provide relative greater certainty around potential impacts and importantly, to provide a more objective basis for identification and development of mitigation measures. The approach taken has been to identify an 'impact area' that takes account of the variability of flood events and their extent over time.

A review of the historical record identified at least one large flood above FSL would occur within a 20 year period. Building on previous hydrological modelling carried out for the Project, further modelling was undertaken to assess the likely level of inundation upstream of the dam. Around 20,000 Monte Carlo simulated events were used to generate a 200,000 year flood record. This included the full range of possible events based on the latest hydrology analyses. This was then analysed by selecting the maximum inundation level in 20 year periods to determine the 'average' or likely inundation level. This was also undertaken for the existing dam scenario so that a comparison of inundation extents could be made.

Since flood behaviour in the Hawkesbury Nepean Valley has distinct multi-decade wet and dry periods, the inundation assessment modelled outcomes considering:

- randomly selected periods
- half wet / half dry periods
- wet dominated periods
- dry dominated periods.

The results from all these hypothetical flood sequences were then analysed to determine what the average or likely inundation outcomes would be.

The average results for the flood/drought sequence were then used to define the upper and lower elevations for the impact area as these were considered to provide the most likely outcome on a statistical basis. These are:

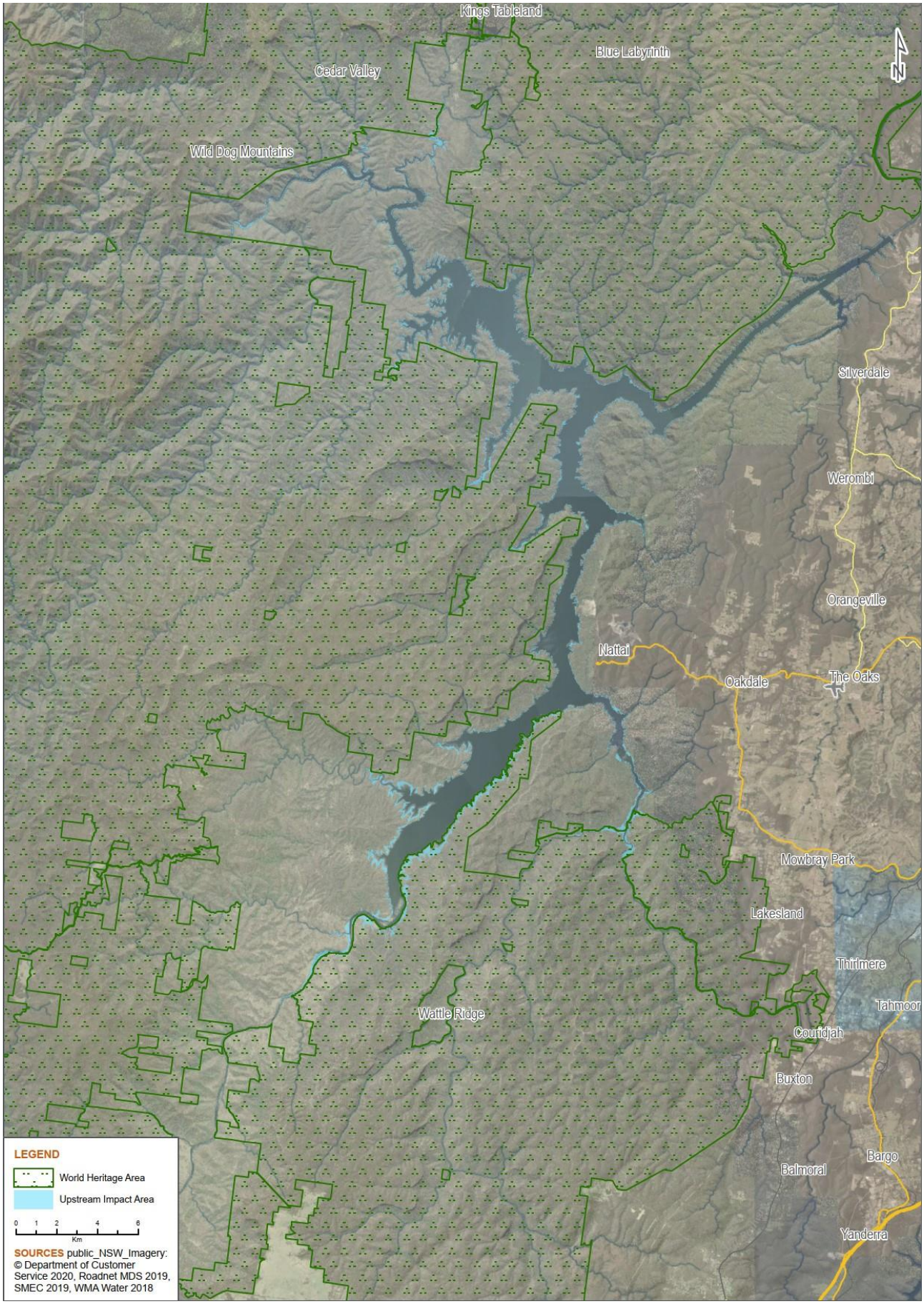
- Lower extent: 2.78 metres above FSL (119.5 mAHD)
- Upper extent: 10.25 metres above FSL (126.97 mAHD).

The likely inundation level for the existing dam is also about the maximum recorded level since construction of Warragamba Dam. For the purposes of the Project, the area between these two levels has been adopted as the upstream impact area. The size of the upstream impact area is about 1400 hectares.

The upstream impact area has been used as a means to offset the potential impacts of the Project. For the purposes of offsetting the potential impacts of the Project, it has been assumed that there would be a complete loss of values in this area. In reality, this is unlikely as sensitive areas/sites would have differing risks of impact depending on their respective locations in terms of elevation. Areas/sites at lower elevations would have a greater risk of temporary inundation than areas/sites at higher elevations within the upstream study area.

The upstream impact area is shown in Figure 8-4.

Figure 8-4. Upstream impact area



8.2.5.3 Approach to management of impacts

An offset strategy has been prepared to address the potential impacts of the Project resulting from upstream temporary inundation (See Appendix F6 - Biodiversity offset strategy). The upstream impact area has been used as the basis for the offset calculation. The assessment has used the BioBanking Credit Calculator (BBCC) to generate a credit calculation, assuming there would be 100 percent loss of ecosystem and species values within the upstream impact area.

Other impacts associated with temporary inundation would be managed in accordance with the Environmental Management Plan (EMP), which is addressed in Section 8.11.

8.2.6 Information sources

Information sources used in preparing the upstream BAR are presented in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 7.2.1) and summarised in Table 8-5, Table 8-6, and Table 8-7.

Table 8-5. Guideline and database analysis

	Guideline and database analysis
1.	Aerial maps, Project layers and environmental layers provided by WaterNSW and OEH
2.	Department of the Environment and Energy Species Profiles and Threats database (SPRAT) (DoEE, n.d.b)
3.	Department of Environment, Climate Change and Water Mitchell Landscapes NSW OEH v3 Bioregional Assessment Source Dataset (DECCW 2010a)
4.	Department of the Environment and Energy Protected Matters Search Tool (DoEE 2015)
5.	Matters of National Environmental Significance Significant Impact Assessment Guidelines 1.1 (DoE 2013)
6.	NSW OEH's BioBanking credit calculator (OEH n.d.a)
7.	NSW OEH's Atlas of NSW Wildlife (OEH 2017b)
8.	OEH Threatened Species Profiles (OEH 2017g)
9.	Mitchell Landscapes with per cent cleared estimates (Eco Logical Australia 2007)
10.	Office of Environment and Heritage Framework for Biodiversity Assessment: NSW (OEH 2014b)
11.	Office of Environment and Heritage NSW Biodiversity Offsets Policy for Major Projects (OEH 2014)
12.	Vegetation Classification Database (OEH 2017c)
13.	Bureau of Meteorology Atlas of Groundwater Dependent Ecosystems (BOM 2019)
14.	NSW Government's Biodiversity Values Map and Threshold Tool (OEH 2019a)
15.	Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings (Fairfull & Witheridge 2003)

Table 8-6. Literature review

	Literature review
1.	Warragamba Dam EIS - Dam Site Environmental Studies, Fauna and Flora (Mount King Ecological Surveys 1992)
2.	Warragamba Dam Raising Preliminary Environmental Assessment (BMT WBM Pty Ltd 2016)
3.	Warragamba Dam Auxiliary Spillway Project – Construction Environmental Management Plan Framework (Australian Water Technologies & SKM 2003)
4.	Safeguarding Warragamba Dam: proposed auxiliary spillway (Sydney Water 1996)
5.	*Eucalyptus benthamii* Inundation Experiment: Reporting on stand health and soil properties over a 12-month monitoring period (Bush, et al. 2018)

	Literature review
6.	Glasshouse evaluation of inundation tolerance of Camden White Gum (*Eucalyptus benthamii*) (Marcar 1995)
7.	The Native Vegetation of the Warragamba Special Area, Part A: Technical Report (NPWS 2003a)
8.	Terrestrial Vertebrate Fauna of the Greater Southern Sydney Region (DECC 2007a) (DECC 2007b) (DECC 2007c)
9.	Threatened and pest animals of Greater Southern Sydney (DECC 2007d)
10.	Literature and Field Assessment of Environmental Impacts of Temporary Inundation Upstream of Queensland Flood Mitigation Dams (Hydrobiology 2020)

Table 8-7. Aerial photography

Information sources: aerial photography	
Aerial imagery was taken from the SIXmaps imagery managed by the Department of Finance and Services (2017), as well as Nearmaps where appropriate, and original imagery supplied by WaterNSW. The SIXmaps aerial details are:	
BlockName	Penrith; Burragorang; Katoomba
BlockType	ADS40_SC
BlockStartDate	19 September 2013; 29 September 2013; 3 September 2013
BlockEndDate	N/A

8.2.7 Field surveys

8.2.7.1 Native vegetation survey and mapping

A review of available information was undertaken that included analysis of relevant data bases, publications, maps, aerial photographs and vegetation classification data. The field survey area is defined in Table 8-4. Most of the field surveys including vegetation mapping, plot and transect surveys, and threatened flora and fauna surveys were carried out within this area. A smaller number of plots and incidental observations of threatened species were recorded outside of the field survey area, within the study area and adjacent lands.

The survey was done in accordance with the FBA and included assessment of the Mapped Warragamba_VISmap_2380 polygons, which were assigned to a NPWS Map Unit (NPWS 2003a), Plant Community Types (PCTs), and Endangered Ecological Communities (EECs) where relevant. They were also assigned to an assessment method as follows:

- ground truthed: Polygon visited by SMEC and floristics directly compared to PCTs.
- rapid assessment: Polygon either visited by SMEC but no formal floristic data collected, or polygon not visited by SMEC, but floristics assessed at distance via binoculars.

Survey details are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Sections 4.2 and 4.3) and summarised as follows:

- vegetation surveys within the study area were conducted between 11 October 2017 and 18 January 2019 over a period of approximately 39 non-consecutive weeks. About 2,870 hectares (approximately 80 percent) of the survey area was assessed as shown in Figure 8-5.
- Floristic plots and plot and transect surveys were conducted to verify the PCTs and collect site value data from the identified vegetation zones. Vegetation mapping, PCT identification as well as full floristic plots and plot transect surveys were undertaken concurrently, with periodic refinements during the survey period. For six of the PCTs, access was not feasible to all plot locations due to topographical constraints of the site. For these PCTs, the balance of plots has been met using surrogate plots using benchmark data. A total of 95 plot and transects sites were surveyed, as summarised in Table 8-8 and shown on Figure 8-6.
- Identification of the PCTs occurring within the study area was guided by the information review, site surveys and a review of the PCTs held within the Vegetation Information System (VIS) Classification Database. Consideration was given to occurrence within the South Sydney Basin and South Eastern Bioregions and

relevant subregions, vegetation formation, landscape position and dominant upper, mid and ground strata species.

Eighteen PCTs were identified within the study area. These were stratified into areas represented by the locally-defined vegetation communities and divided into different condition classes, which resulted in the creation of 21 vegetation zones.

Table 8-8. Survey effort

	Survey
1	**Plot-based full floristic survey** Ninety-five (95) full floristic plots were surveyed, comprising of 20 m x 20 m full floristic plots in accordance with Table 1 of the FBA.
	▪ Stratum (and layer): stratum and layer in which each species occurs. ▪ Growth form: growth form for each recorded species. ▪ Species name: scientific name and common name. ▪ Cover: a measure or estimate of the appropriate cover measure for each recorded species; recorded from 1–5% and then to the nearest 5%. If the cover of a species is less than 1% and the species is considered important, then the estimated cover should be entered (for example, 0.4). ▪ 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.
2	**Plot and transect surveys** Ninety-five (95) plot and transect sites were surveyed within the field survey area and have been utilised in this assessment. The following information was collected at each of the 20 m x 50 m plot and transect sites in accordance with Section 5.3.2 of the FBA.
	▪ Native species richness recorded within each stratum of a 20 m x 50 m sub-plot. ▪ Native overstorey cover recorded at 10 points along a 50 m transect. ▪ Native mid-storey cover recorded at 10 points along a 50 m transect. ▪ Native ground cover recorded at 50 points along a 50 m 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 overstorey, mid-storey and ground cover). ▪ Number of trees with hollows visible from the ground within the 20 m x 50 m plot. ▪ The total length of fallen logs >10 cm in diameter within the 20 m x 50 m plot. ▪ The proportion of regenerating overstorey species within the vegetation zone.

8.2.7.2 Threatened species survey

Habitat assessment

Fauna habitat assessments were undertaken within the study area and adjoining land between October 2017 and April 2018. 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 areas such as creeks and soaks, 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.

Flora surveys

Targeted threatened flora surveys were undertaken for 10 subject flora species using the survey technique outlined in the *NSW Guide to Survey Threatened Plants* (OEH 2016a) and described in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5.5.2.1, Figure 5-1 and Table 5.9). The remaining candidate flora species requiring assessment are outlined in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5.8)) and are assumed to be present within the upstream study area.

Flora survey descriptions and maps are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5.4, Figure 5-2 and Table 5-10) and summarised on Figure 8-5 and Figure 8-6. Detailed maps are available in Appendix L to Appendix F1: Biodiversity Assessment Report – Upstream.

Fauna surveys

General fauna surveys, including nocturnal searches, were conducted within the study area between October 2017 and April 2018. Fauna field surveys were based on the survey effort recommendations of *Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities (Working Draft)* (Department of Environment and Conservation (DEC) 2004) regarding the size of the survey sites, broad scale vegetation communities and major sampling stratification units. In addition, expert reports were prepared for three amphibian species: Giant Burrowing Frog, Red-crowned Toadlet and Stuttering Frog.

Threatened fauna survey descriptions and maps are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5.5.2.2, Figure 5-2 and Table 5-10) and summarised on Figure 8-7.

8.2.8 Threatened species

The type and occurrence of threatened species and populations that could potentially be impacted by the proposal were appraised in accordance with the FBA which comprised assessment of:

- **Existing data**: Develop a list of species and populations potentially occurring within the study area. This information was used to determine candidate ecosystem credit species and species credit species.
- **Ecosystem credits**: A measurement of the value of PCTs, Endangered Ecological Communities (EECs), Critically Endangered Ecological Communities (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 study area and the gain in biodiversity values at an offset site. Ecosystem credit species were determined using the following criteria:
  - Interim Biogeographical Regionalisation of Australia (IBRA) subregions
  - associated PCTs
  - condition of vegetation: moderate to good (all vegetation zones).
- **Species credit species**: 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. Candidate species were identified in accordance with the FBA (Section 6.5.1.2). The BioBanking Credit Calculator (BBCC) generates a list of candidate species based on the distribution of the species occurring within the same IBRA subregion as the study area and the presence of habitat features and components associated with these species. A wide range of habitat features, and components have been used to assess the presence/absence of species within the study area.

Figure 8-5. Flora field surveys

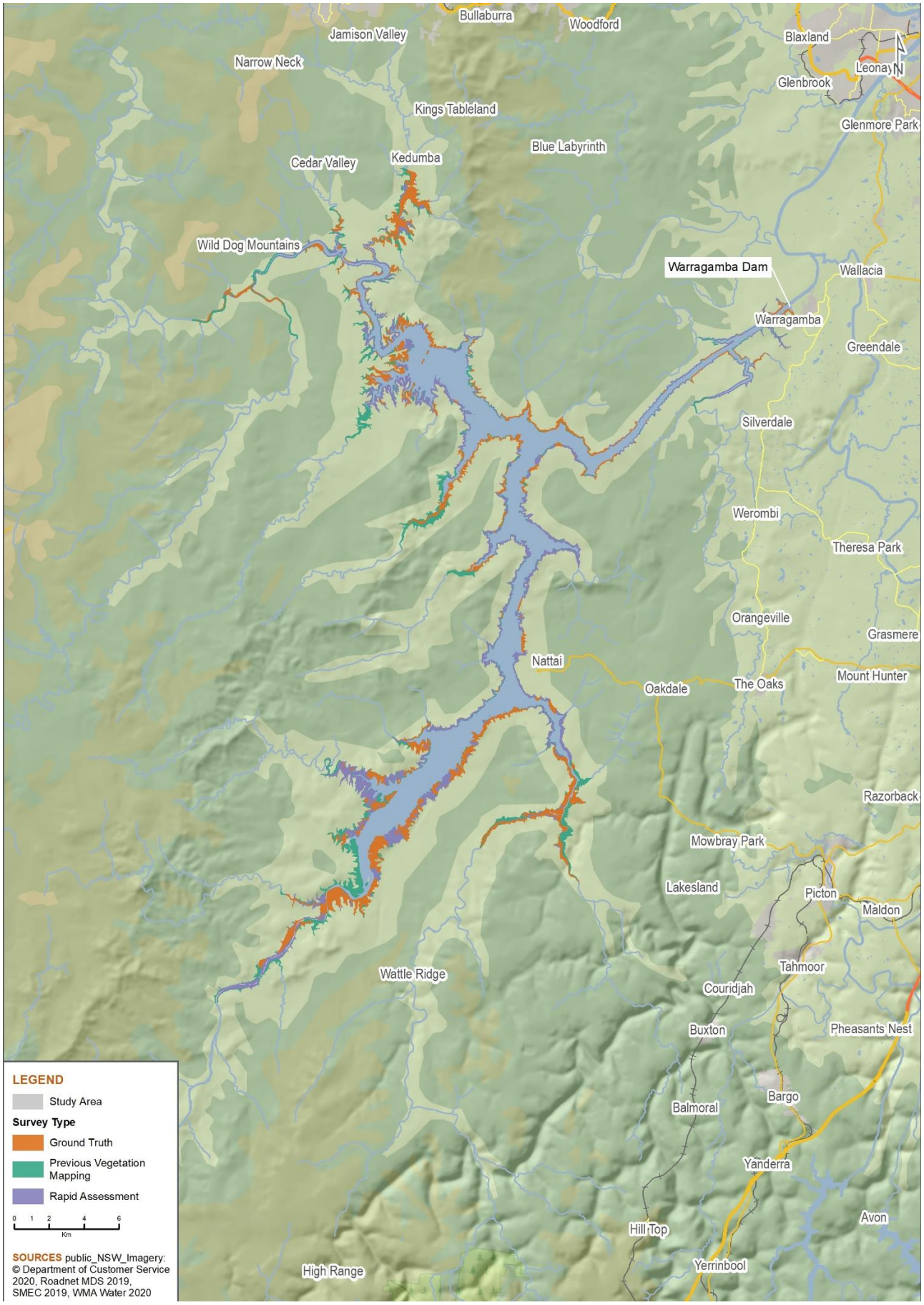


Figure 8-6. Plot-based floristic survey and plot and transect survey

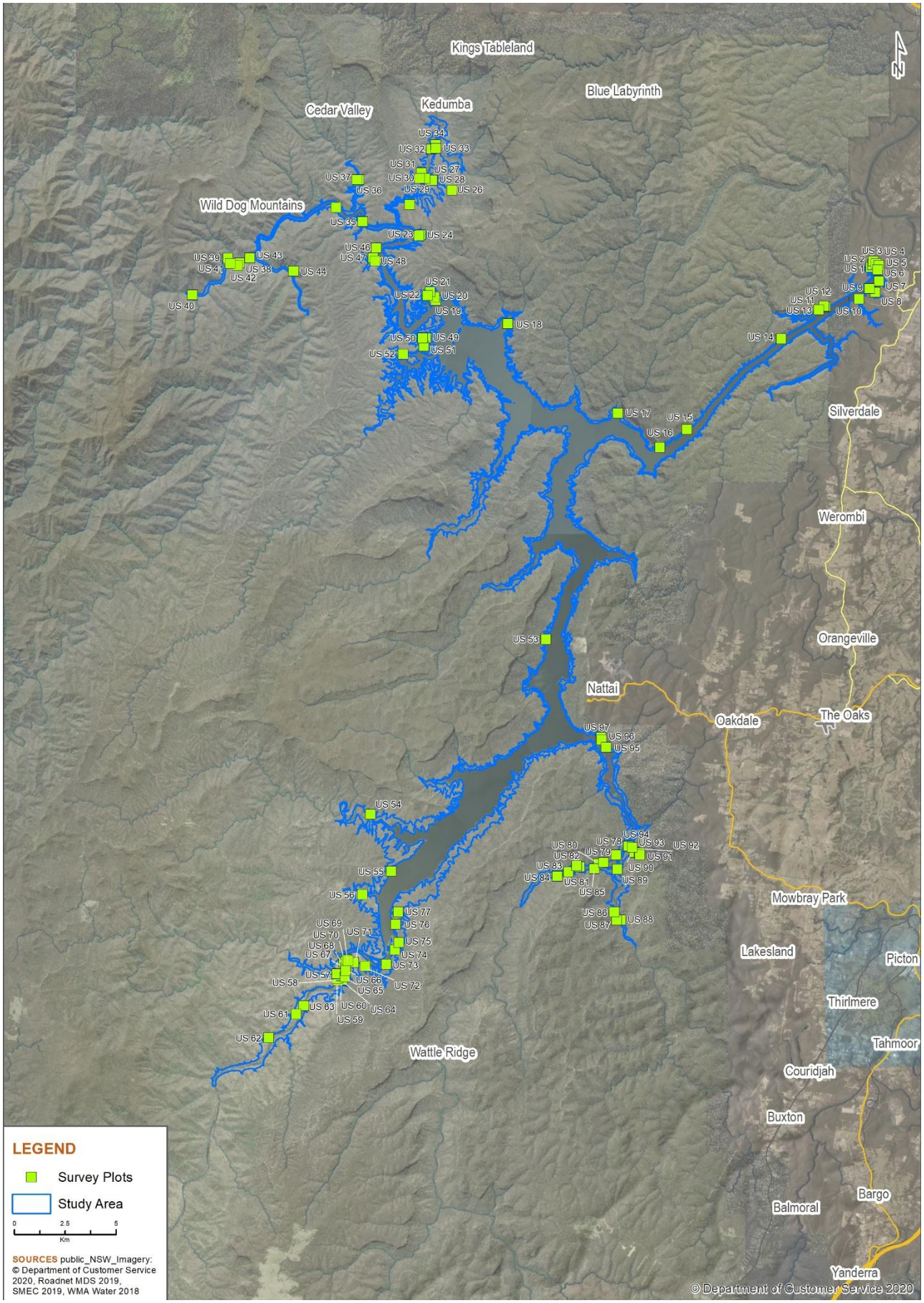
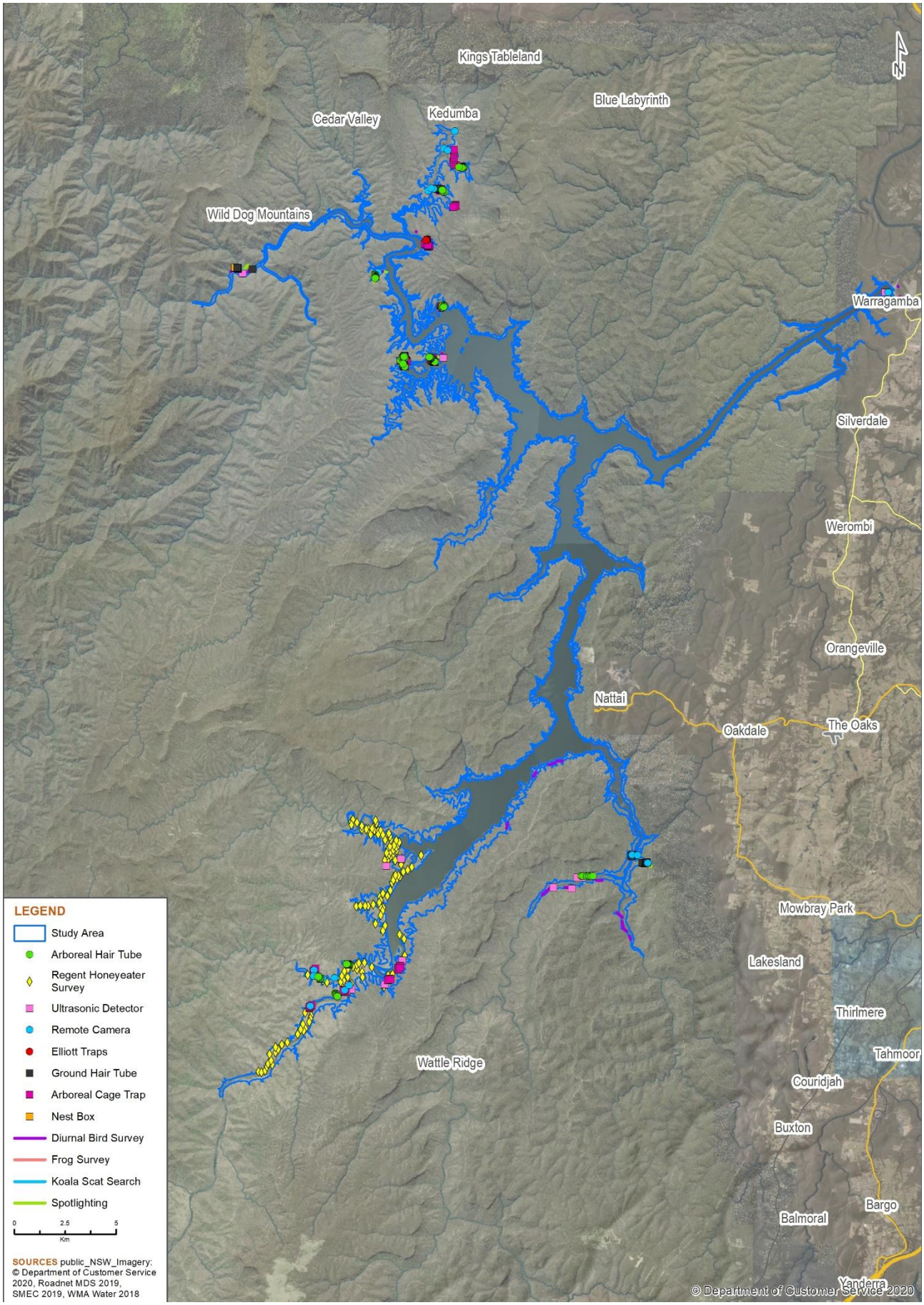


Figure 8-7. Threatened fauna survey locations



8.3 Existing environment

8.3.1 Introduction

The study area surrounds Lake Burragorang and comprises timbered hills, ridges and broad open valleys. Upstream of Warragamba Dam are two major river systems that drain into Lake Burragorang. In the north are the Coxs River and its tributaries, including the Kowmung River, Kedumba Creek, Butcher Creek and Green Wattle Creek. In the south are the Wollondilly River and its tributaries, including the Wingecarribee River, Nattai River, Tonalli River, Byrnes Creek and Jooriland Creek.

Terrain varies dramatically across the study area, with elevations ranging between 90 and 180 mAHD. The narrow stretch of lake immediately upstream of the dam is characterised by almost vertical sandstone walls and benches, while the main lake and its tributaries are bordered by sandstone escarpments and associated colluvial slopes. Most of the study area falls within these colluvial sloping landscapes (see Section 8.3.2) that vary from steep to gently sloping. Terrain around the Wollondilly River and Nattai River typically consists of alluvial flats and rolling hills, while terrain around the Coxs River and Kowmung River is steep with talus and scree slopes.

Almost all land within the study area is covered with natural vegetation, with small areas categorised as cleared-modified land and exposed rock. Vegetation is typically associated with dry sclerophyll forest of shrubby sub-formation, as well as areas of wet sclerophyll forest, dry rainforest, warm temperate rainforest, grassy woodlands, and forested wetlands.

Average yearly rainfall throughout the catchment (BOM 2018a,b,c) varies from 542 millimetres at Warragamba, 863 millimetres at Oakdale (Wollondilly River) in the south and 970 millimetres at Oberon in the north-west (Coxs River). The highest rainfall generally occurs in the warmer months, with the highest falls occurring in February.

8.3.2 Soil landscape

Ten soil landscapes have been mapped within the study area, which are described in Table 8-9.

Table 8-9. Soil landscape description (Bannerman & Hazelton 1990; King 1994)

Soil landscape	Description
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. Mostly uncleared Eucalypt open-woodland (dry sclerophyll forest) and tall open-forest (wet sclerophyll forest).
Faulconbridge	Level to gently undulating crests and ridges on plateau surfaces of the Hawkesbury Sandstone. Local relief <20 m, slopes <5%. Infrequent rock outcrop. Partially cleared Eucalypt woodland.
Warragamba	Narrow convex crests and ridges and steep colluvial side slopes on Narrabeen Group sandstones with minor cliffs and scarps on steeper slopes. Local relief 80 – 130 m. Slopes >35%. Elevation mostly <700 m. Uncleared tall open-forest.
Cedar Valley	Rolling to steep hills, narrow valleys and narrow crests away from sandstone escarpments in the Kedumba Valley and Cedar Valley and near Lake Burragorang. Local relief 50 – 150 m. Elevation <600 m. Slope gradients 15 – 60%. Uncleared woodland.
Round Mount	Steep to very steep hills and mountains on Carboniferous granite in the Hartley Valley and Kanangra Gorge. Local relief <400 m. Slopes generally >35%. Elevation <150 – 1,200 m. Granite rock outcrop (tor) is commonplace. Occasional cliffs. Open-woodland.
Hassans Walls	Cliffs derived from Narrabeen Group sandstones and steep colluvial talus side slopes developed over the Illawarra Coal Measures and the Shoalhaven Group. Local relief >100 – 500 m. Slopes mostly >40%. Elevation 200 – 1,100 m. Open-forest and open-woodland.
Kanangra Gorge	Steep to very steep deeply incised valleys beneath narrow convex crests on Devonian and Silurian metasediments in the Kanangra Gorge and Cedar Valley. Local relief is >300 m. Slopes >30%. Elevation generally 120 – 1,000 m. Uncleared woodland, open-forest and closed-forest.

Soil landscape	Description
Kedumba	Undulating to rolling rises and broad valley flats on Shoalhaven Group sediments in the Kedumba Valley and on Scotts Main Range. Local relief <30 m. Slope gradients 5 – 15 %. Elevation 120 – 230 m. Open-woodland.
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. Cleared Eucalypt woodland and tall open-forest (dry sclerophyll forest).
Gymea	Undulating to rolling rises and low hills on Hawkesbury Sandstone. Local relief 20–80 m, slopes 10–25%. Rock outcrop <25%. Broad convex crests, moderately inclined side slopes with wide benches, localised rock outcrop on low broken scarps. Extensively cleared open forest (dry sclerophyll forest) and eucalypt woodland.
Notes: The *Soil Landscapes of the Penrith 1:100,000 sheet* (Bannerman & Hazelton 1990) and the *Soil Landscapes of the Katoomba 1:100,000 Sheet map and report* (King 1994) There is no soil landscape mapping within the study area south of Lacys Bay and Brimstone Bay down the Wollondilly River arm of Lake Burragorang.	

8.3.3 Hydrology and wetlands

The study area 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). Lake Burragorang is the dominant hydrological feature of the study area, which was created by damming the Warragamba River and flooding the Burragorang Valley.

Upstream of Warragamba Dam are two major river systems that drain into Lake Burragorang. In the north are the Coxs River and its tributaries, including the Kowmung River, Kedumba Creek, Butcher Creek and Green Wattle Creek. In the south are the Wollondilly River and its tributaries, including the Wingecarribee River, Nattai River, Tonalli River, Byrnes Creek and Jooriland Creek. All stream reaches within the study area are within a protected area. A section of the Kowmung River within the study area was declared under the National Parks and Wildlife Act 1974 (NPW Act) as a Wild River (DEC 2005b). Wild Rivers are rivers that are in near-pristine condition and free from unnatural rates of siltation and bank erosion (OEH 2018c) and have high conservation value.

A previous investigation found that 57 percent of stream reaches within the wider catchment were either in good condition or in a protected area (GHD 2013a). To be assessed as being in good condition, the following characteristics must be met:

- river character and behaviour is similar to the pre-development state presenting a high potential for ecological diversity
- minimal alteration to catchment controls such as sediment supply and the hydrological regime allowing fast recovery from natural disturbance
- relatively intact and effective vegetation coverage dominated by native species, giving resistance to natural disturbance and accelerated erosion.

Strahler classifications[4] for major rivers within the study area are as follows:

- Wollondilly River: 8th order Strahler stream
- Nattai River: 7th order Strahler stream
- Little River: 6th order Strahler stream
- Coxs River: 8th order Strahler stream
- Kowmung River: 7th order Strahler stream

[4] The Strahler stream ordering system is a classification system that gives a waterway an 'order' according to the number of tributaries associated with it (Strahler 1952). This system provides a measure of system complexity and therefore the potential to support important habitat. DPIE recognises 3rd order streams and above as likely to display valuable fish habitat, and hence could support viable fish populations.

- Kedumba River: 6th order Strahler stream
- Lake Burragorang: 9th order Strahler stream.

One wetland (Lake Burragorang) has been identified within the study area (DECCW 2010f). There are smaller dams mapped to the east of the study area, while the Nepean River and Penrith Lakes have been mapped to the north. No Ramsar Wetlands have been mapped within 10 kilometres of the study area.

8.3.4 Flora and fauna

8.3.4.1 Native vegetation

Broad scale native vegetation mapping around Lake Burragorang is shown on Figure 8-8. Detailed vegetation maps are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Appendix L). Most of the study area (99 percent) is covered with native vegetation, with small areas classified as cleared-modified land and exposed rock. Eleven vegetation classes are identified (Keith 2004), these being:

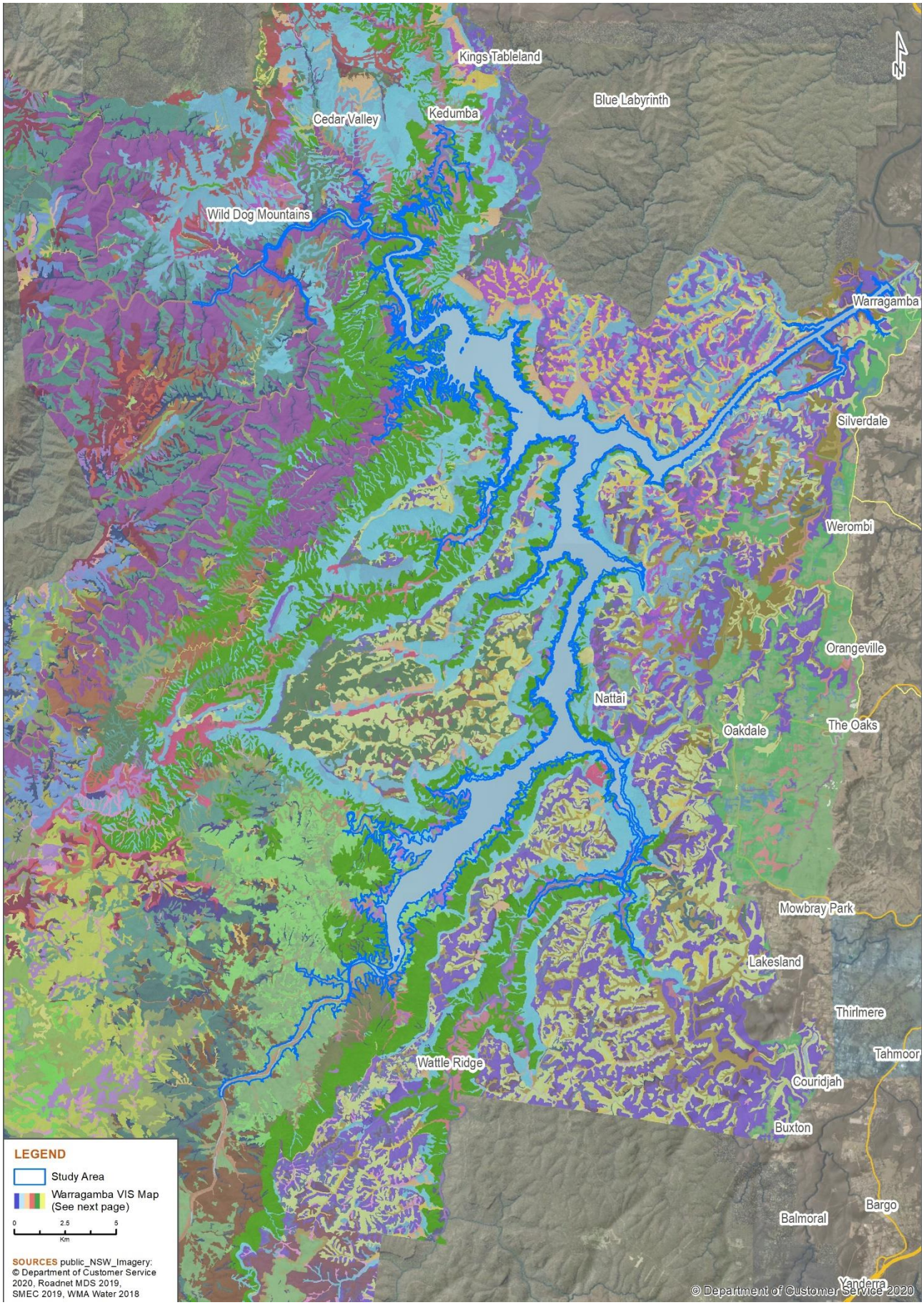
- Northern Warm Temperate Rainforests
- Central Gorge Dry Sclerophyll Forests
- Sydney Sand Flats Dry Sclerophyll Forests
- Dry Rainforests
- Coastal Floodplain Wetlands
- Sydney Hinterland Dry Sclerophyll Forests • Sydney Coastal Dry Sclerophyll Forests
- Eastern Riverine Forests
- North Coast Wet Sclerophyll Forests
- Western Slopes Grassy Woodlands
- Northern Hinterland Wet Sclerophyll Forests.

The study area is centred around Lake Burragorang, which was created following construction of Warragamba Dam in 1960. Consequently, vegetation surrounding Lake Burragorang is not typical riparian or flood plain vegetation but is composed of vegetation characteristic of ridgetops on skeletal soils and valley slopes. Most of the study area supports dry sclerophyll forest of shrubby sub-formation, as well as areas of wet sclerophyll forest, dry rainforest, warm temperate rainforest, grassy woodlands, and forested wetlands. General characteristics are summarised as follows:

- vegetation immediately west of Warragamba Dam on the walls of the Warragamba Gorge is dominated by species characteristic of ridgetop woodlands around the Sydney Basin, including *Angophora costata*, *Eucalyptus piperita*, *Eucalyptus eugenioides*, *Eucalyptus sieberi* and *Corymbia gummifera*
- pockets of Warm Temperate Rainforest are present in sheltered, south-facing gullies
- most of the area around Lake Burragorang is characterised by Dry sclerophyll forest communities, which are dominated by *Eucalyptus punctata*, *Eucalyptus tereticornis*, *Eucalyptus glaucina*, *Eucalyptus deanei*, *Eucalyptus fibrosa*, and *Eucalyptus crebra*
- vegetation within drainage lines consists of tall wet forest dominated by *Eucalyptus deanei* and dry rainforest dominated by *Backhousia myrtifolia* and *Melaleuca styphelioides*
- vegetation near the mouth of the Wollondilly River and along the river itself is dominated by grassy woodland consisting of *Eucalyptus melliodora*, *Eucalyptus tereticornis*, *Eucalyptus glaucina*, *Eucalyptus albens-moluccana* intergrade, and *Brachychiton populneus*. This vegetation conforms to White Box Yellow Box Blakely's Red Gum Woodland Critically Endangered Ecological Community (CEEC)
- forested wetlands dominated by *Eucalyptus deanei*, *Eucalyptus elata*, *Eucalyptus benthamii*, and *Casuarina cunninghamiana* are present along the Nattai River, Kedumba River, Coxs River, and many other smaller tributaries flowing into Lake Burragorang. Much of this vegetation conforms to River Flat Eucalypt Forest on Coastal Wetlands Endangered Ecological Community (EEC)
- extensive areas of Dry Rainforest dominated by *Backhousia myrtifolia* are present along the Coxs River and Kowmung River. The dry sclerophyll forest within this area is dominated by *Eucalyptus crebra*, *Eucalyptus tereticornis*, *Eucalyptus punctata*, and various stringybark species
- approximately 207 hectares of remnant native vegetation have been mapped below the FSL (outside the study area), with most extents occurring within the tributaries flowing into Lake Burragorang. This includes the first and second order streams, as well as major tributaries, such as Nattai, Wollondilly, and Coxs Rivers. This vegetation did not appear to be part of the regrowth that colonises the areas below FSL when the dam levels

are low for an extended time, which typically comprises of stands of *Casuarina cunninghamiana,* sedges and graminoid species, and exotic plants.

Figure 8-8. Broad scale vegetation mapping (NPWS 2003)




LEGEND
warragamba_VISmap_2380
1 Sandstone Warm Temperate Rainforest
10 Sheltered Sandstone Smooth-barked Apple Forest
11 Sheltered Sandstone Blue-leaved Stringybark Forest
12 Escarpment Mountain Grey Gum Forest
13 Sheltered Escarpment Blue Gum Forest
14 Escarpment Grey Gum Forest
15 Highlands Gorge River Peppermint Forest
16 Bindook Highlands Open Forest
17 Yerranderie White-topped Box Forest
18 Sheltered Porphyry Forest
2 Montane Cool - Warm Temperate Rainforest
20 Montane Sheltered Narrow-leaved Peppermint Forest
21 Kanangra Gorge Sheltered Grey Gum Forest
22 Oakdale Blackbutt Gully Forest
23 Burragorang River Flat Forest
24 Highlands Sandstone Dry Shrub Forest
25 Blue Mountains Sandstone Dry Shrub Forest
26 Nattai Sandstone Dry Shrub Forest
27 Burragorang Sandstone Dry Shrub Forest
28 Kowmung Sheltered Red Gum Forest
29 Exposed Devonian Grey Gum Forest
3 Grey Myrtle Dry Rainforest
31 Highlands Slopes Grey Gum - Stringybark Forest
32 Permian Footslopes Grassy Grey Box Forest
33 Tonalli Escarpment Dry Shrub Forest
34 Montane Sandstone Silvertop Ash Shrub Forest
35 Montane Exposed Silvertop Ash Forest
36 Montane Slopes Stringybark Forest
37 Montane Sandstone Dry Shrub Forest
38 Oakdale Alluvial Rough-barked Apple Forest
39 Tablelands River Oak Forest
4 Kowmung Dry Rainforest
40 Exposed Blue Mountains Sandstone Woodland
41 Exposed Burragorang Sandstone Shrub Woodland
42 Rocky Sandstone Heath Woodland
46 Kanangra Gorge Narrow-leaved Ironbark Woodland
47 Exposed Permian Sandstone Woodland
48 Escarpment Slopes Dry Ironbark Woodland
49 Dry Alluvial Paperbark Woodland
5 Highlands Basalt Acacia Scrub
50 Douglas Scarp Woodland
51 Devonian Red Gum - Yellow Box Woodland
52 Devonian Red Gum - Ironbark Woodland
53 Devonian Red Gum - Grey Box Woodland
55 Highlands Transitional Shale Woodland
56 Cumberland Plain Shale Sandstone Transition Forest (Low Sandstone Influence)
57 Cumberland Plain Shale Sandstone Transition Forest (High Sandstone Influence)
58 Cumberland Plain Alluvial Woodland
59 Cumberland Plain Shale Hills Woodland
6 Sandstone Riparian Scrub
60 Cumberland Plain Shale Plains Woodland
61 Rock Plate Heath-Mallee
62 Montane Heath-Mallee
64 Rosy Paperbark Heath
66 Kowmung Acacia Scrub
67 Regenerating Vegetation
68 Highlands Peat Swamp
69 Highlands Swamp Gum - Tea Tree Heath-Woodland
7 Montane Gully Brown Barrel Forest
70 Montane Sedgeland Heath
71 Upland Swamps Cyperoid Heath
72 Upland Swamps Tea Tree Thicket
73 Sandstone Brittle Gum Swamp Woodland
74 Thirlmere Sand Swamp Woodland
75 Lepironia Freshwater Wetland
76 Bindook Highlands Grassland
77 Exposed Rock
78 Cleared-Modified Land
79 Water Bodies
8 Sandstone Moist Blue Gum Forest
9 Sheltered Sandstone Intermediate Blue Gum Forest

8.3.4.2 Fauna habitats

Across the broader landscape of the study area, different habitats provide specific features and resources that are key elements required by native fauna for the maintenance of life cycles, including breeding, sheltering and foraging. Fauna habitats and their extents within the study area are presented in Table 8-10.

The study area is dominated by dry sclerophyll forest habitat (51 percent), followed by grassy box woodland (28 percent) and alluvial woodland (15 percent) habitat types. Aquatic habitats comprise Lake Burragorang and its tributaries which are addressed in Appendix F4 (Aquatic ecology assessment report).

Table 8-10. Fauna habitats in study area

Fauna habitats in study area
1. Alluvial woodland: 794 ha (15 percent)
Consists of a tall canopy, dense mid-storey and often sparse understorey. Predominant canopy species are *Eucalyptus deanei*, *Eucalyptus elata*, *Eucalyptus benthamii, Angophora floribunda,* and *Casuarina cunninghamiana*. Common mid-storey shrubs are *Leptospermum spp* and *Acacia spp* and Coffee Bush (*Breynia oblongifolia*). The groundcover is dominated by species such as Lomandra species, *Pratia purpurascens* and *Pteridium esculentum*.  Alluvial woodland occurs on the banks of the major rivers in the study area; the Wollondilly, Nattai, Kowmung, Coxs and Kedumba. The river banks are often steep with numerous rock outcrops. Other key habitat features present in the woodland areas include fallen timber, fragmented rock and hollow bearing trees. Sap feed trees for the Yellow-bellied Glider have been identified in this habitat. Alluvial woodland has been identified as a priority animal habitat within the Warragamba Special Area (DECC 2007d). It provides important foraging habitat for several threatened species including the Large-eared Pied Bat, which was recorded in vegetation along the Nattai River.
2. Grassy box woodland: 1,468 ha (28 percent)
Occurs on flat or undulating topography – predominantly in the south of the study area around Jooriland, on the banks of the Wollondilly River. Only a small area of this habitat occurs in the study area. There is a low distribution of canopy trees, predominately Grey Box (*Eucalyptus moluccana – albens intergrade*) and Forest Red Gum (*Eucalyptus tereticornis*). The understorey consists of perennial grasses, while shrubs are rare. Low rock outcrops are common amongst the groundcover.  Land previously cleared for agricultural purposes is beginning to regenerate but is still subject to continuous grazing pressure from large populations of native and introduced herbivores (for example Eastern Grey Kangaroos, deer and goats). Grassy Box Woodland has been identified in a study of the fauna of the Warragamba Special Area (DECC 2007a) as the highest priority fauna habitat, as it supports several threatened species that do not persist elsewhere in the region due to extensive clearing of similar habitat for the expansion of metropolitan Sydney. Species for which the Grassy Box Woodland of the Burragorang Valley is extremely important include the critically endangered Regent Honeyeater and Swift Parrot (DECC 2007d).

Fauna habitats in study area

3. Dry sclerophyll forest: 2,689 ha (51 percent)

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

The flooding of the Burragorang Valley has resulted in habitat that would usually occur only on ridgetops, occurring close to the surface level of the lake. Dry sclerophyll forest is the most common habitat within the study area and occurs close to the lake edges and adjacent to areas of alluvial woodland along the major rivers.

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. Suitable foraging habitat for microbats occurs.

4. Wet sclerophyll forest: 77 ha (2 percent)

This tall, open forest occurs in patches across the study area, particularly around Brereton Head. The canopy is dominated by Turpentine (*Syncarpia glomulifera*), Grey Gum (*Eucalyptus punctata*), Blackbutt (*Eucalyptus 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 study area, 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 forging habitat for microchiropteran bats.

5. Dry rainforest: 264 ha (5 percent)

Found around Lake Burragorang and has a moderately tall canopy (10 to 15 m) dominated by Grey Myrtle (*Backhousia myrtifolia*), Lilly Pilly (*Acmena smithii*), Coachwood (*Ceratopetalum apetalum*) and Sassafras (*Doryphora sassafras*). Beneath the canopy, a sparse understorey of scattered ferns, small shrubs and herbs occurs including Gristle Fern (*Blechnum cartilagineum*), Rough Treefern (*Cyathea australis*) and Necklace Fern (*Asplenium flabellifolium*). There is an abundance of leaf litter, fallen logs, rock outcrops and dry creek beds are often rocky.

This habitat generally occurs in small patches in sandstone gullies where the sides are steep with a southerly aspect. Suitable locations generally occur on small tributaries of the Kowmung and Coxs Rivers.

Dry rainforest provides suitable sheltering, breeding and foraging habitat for the threatened Eastern Pygmy-possum (*Cercartetus nanus*) and Brush-tailed Rock-wallaby (*Petrogale pencilliata*). While neither species was recorded during the current surveys, Brush-tail Rock-wallabies have previously been recorded within the study area, and Eastern Pygmy-possums have been recorded within the locality. Both species are assumed to be present within the study area.

Fauna habitats in study area
6. Aquatic
Aquatic habitat is addressed in Appendix F4 (Aquatic ecology assessment report). This report describes the upstream environment of the Warragamba catchment. Riverine (for example, Wollondilly River) and lacustrine (Lake Burragorang) wetlands comprise the largest areas in the catchment. There are no Ramsar or nationally significant wetlands in the study area. Despite being an artificial environment, WaterNSW reports that Lake Burragorang supports an abundance of aquatic flora and fauna. Minimal aquatic vegetation occurs within the creeks flowing into Lake Burragorang due shading, instability of substrates and high velocity flows. Platypuses were observed foraging within the Wollondilly, Kedumba, Coxs and Nattai Rivers during the current surveys. The species was generally observed in relatively deep pools with overhanging vegetation, between shallow riffle systems. Waterways within the study area are mapped as Key Fish Habitat under the FM Act. No detailed fish surveys were conducted, however the report noted one threatened fish species (Macquarie Perch *Macquaria australasica*) has been detected in the study area. Tributary streams feeding into Lake Burragorang provide suitable habitat for two semi-aquatic invertebrate species: Adam's Emerald Dragonfly (*Archaeophya adamsi*) and Sydney Hawk Dragonfly (*Austrocordulia leonardi*) (DPI 2007, referenced in Appendix F4 (Aquatic ecology assessment report).

8.3.4.3 Flora and fauna survey

Site surveys identified a wide of range of flora and fauna species, including several species listed under the BC Act and/or EPBC Act. Species lists are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5.8, Appendices E and Appendix F). Detailed maps are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Appendix L). Threatened flora and fauna species crwedit species and ecosystem credit species recorded in the study area are listed in Table 8-11 and Table 8-12 respectively. Threated flora and fauna records in the study area are shown on Figure 8-9 and Figure 8-10 respectively.

In addition, as per the FBA assessment process, predicted ecosystem credit species and species credit species (see Section 8.2.7 for definitions) were also identified, which are discussed in Section 8.5.

Table 8-11. Recorded species credit species in the study area

Genus	Common name	BC Act status	EPBC Act status
Flora			
Acacia clunies-rossiae	Kanangra Wattle	V	-
Bossiaea oligosperma	Few-seeded Bossiaea	V	V
Callistemon linearifolius	Netted Bottle Brush	V	-
Eucalyptus benthamii	Camden White Gum	V	V
Eucalyptus glaucina	Slaty Red Gum	V	V
Grammitis stenophylla	Narrow-leaf Finger Fern	V	-
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	V	V
Hakea dohertyi	Kowmung Hakea	E	E
Pomaderris brunnea	Brown Pomaderris	E	V
Solanum amourense	-	E	-
Fauna			
Anthochaera phrygia	Regent Honeyeater	CE	CE
Chalinolobus dwyeri	Large-eared Pied Bat	V	V
Pseudophryne australis	Red-crowned Toadlet	V	-
Varanus rosenbergi	Rosenberg's Goanna	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

Table 8-12. Recorded ecosystem credit species in the study area

Scientific name	Common name	BC Act status	EPBC Act status
Artamus cyanopterus cyanopterus	Dusky Woodswallow	V	-
Callocephalon fimbriatum	Gang-gang Cockatoo	V	-
Calyptorhynchus lathami	Glossy Black-cockatoo	V	-
Chthonicola sagittata	Speckled Warbler	V	-
Climacteris picumnus victoriae	Brown Treecreeper (eastern subspecies)	V	-
Daphoenositta chrysoptera	Varied Sittella	V	-
Falsistrellus tasmaniensis	Eastern False Pipistrelle	V	-
Glossopsitta pusilla	Little Lorikeet	V	-
Haliaeetus leucogaster	White-bellied Sea-eagle	V	-
Hieraaetus morphnoides	Little Eagle	V	-
Lophoictinia isura	Square-tailed Kite	V	
Melanodryas cucullata cucullata	Hooded Robin (south-eastern form)	V	-
Melithreptus gularis gularis	Black-chinned Honeyeater (eastern subspecies)	V	-
Miniopterus australis	Little Bent-winged Bat	V	-
Micronomus norfolkensis	Eastern Coastal Free-tailed Bat	V	-
Neophema pulchella	Turquoise Parrot	V	-
Ninox connivens	Barking Owl	V	-
Ninox strenua	Powerful Owl	V	-
Petauroides volans	Greater Glider	-	V
Petaurus australis	Yellow-bellied Glider	V	-
Pteropus poliocephalus	Grey-headed Flying-fox	V	V
Saccolaimus flaviventris	Yellow-Bellied Sheathtail-Bat	V	-
Scoteanax rueppellii	Greater Broad-nosed Bat	V	-
Tyto novaehollandiae	Masked Owl	V	-
Tyto tenebricosa	Sooty Owl	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

Figure 8-9. Threatened flora species records

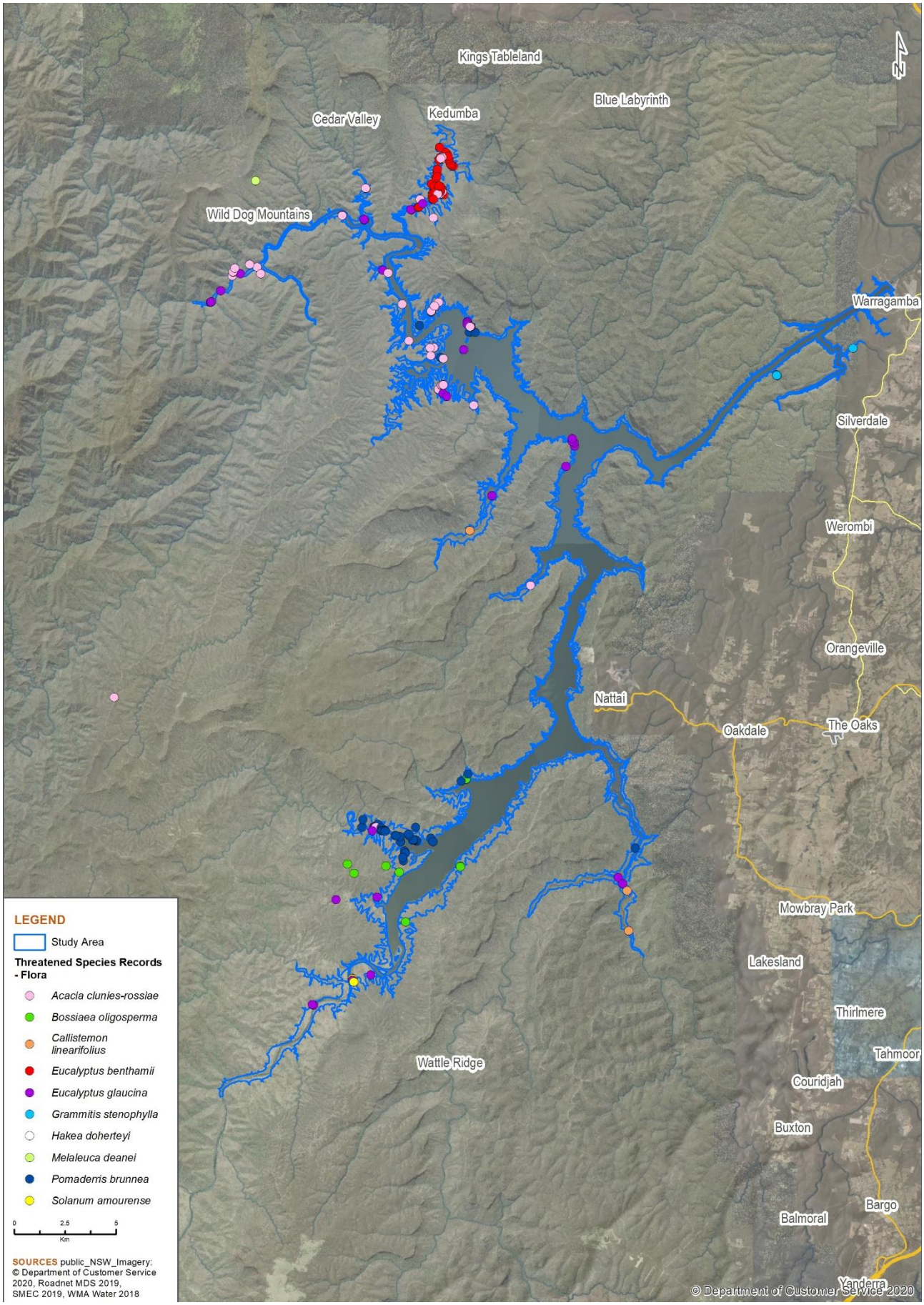
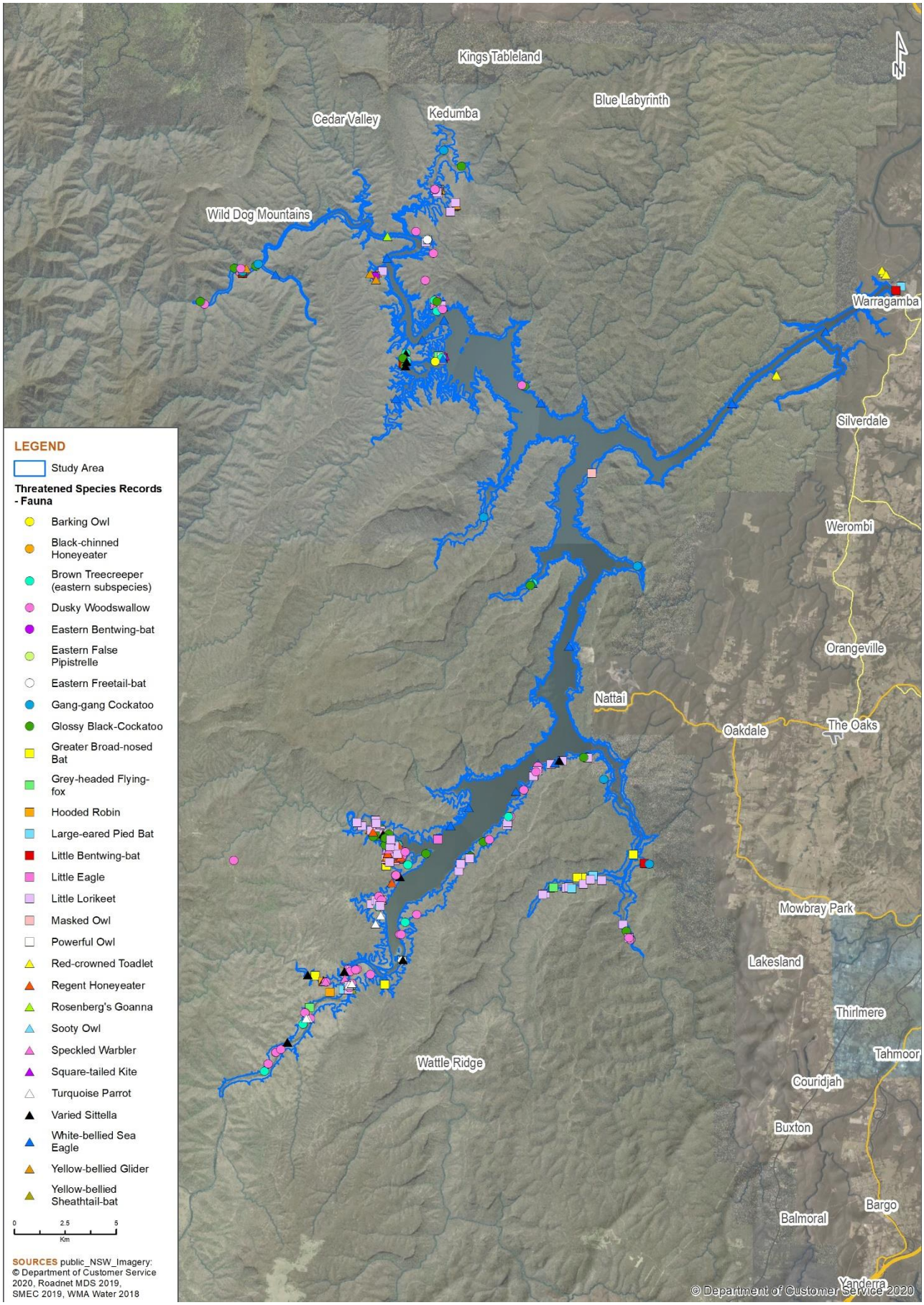


Figure 8-10. Threatened fauna species records



8.3.4.4 Fauna habitat connectivity

The study area lies within a large area of native vegetation maintained for water supply. Most of the area has been relatively undisturbed since the construction of Warragamba Dam in 1960 and the establishment of a three-kilometre exclusion zone to protect Lake Burragorang. Parts of the study area are in the Blue Mountains National Park, Kanangra-Boyd National Park, Nattai National Park and the Burragorang, and Nattai and Yerranderie State Conservation Areas.

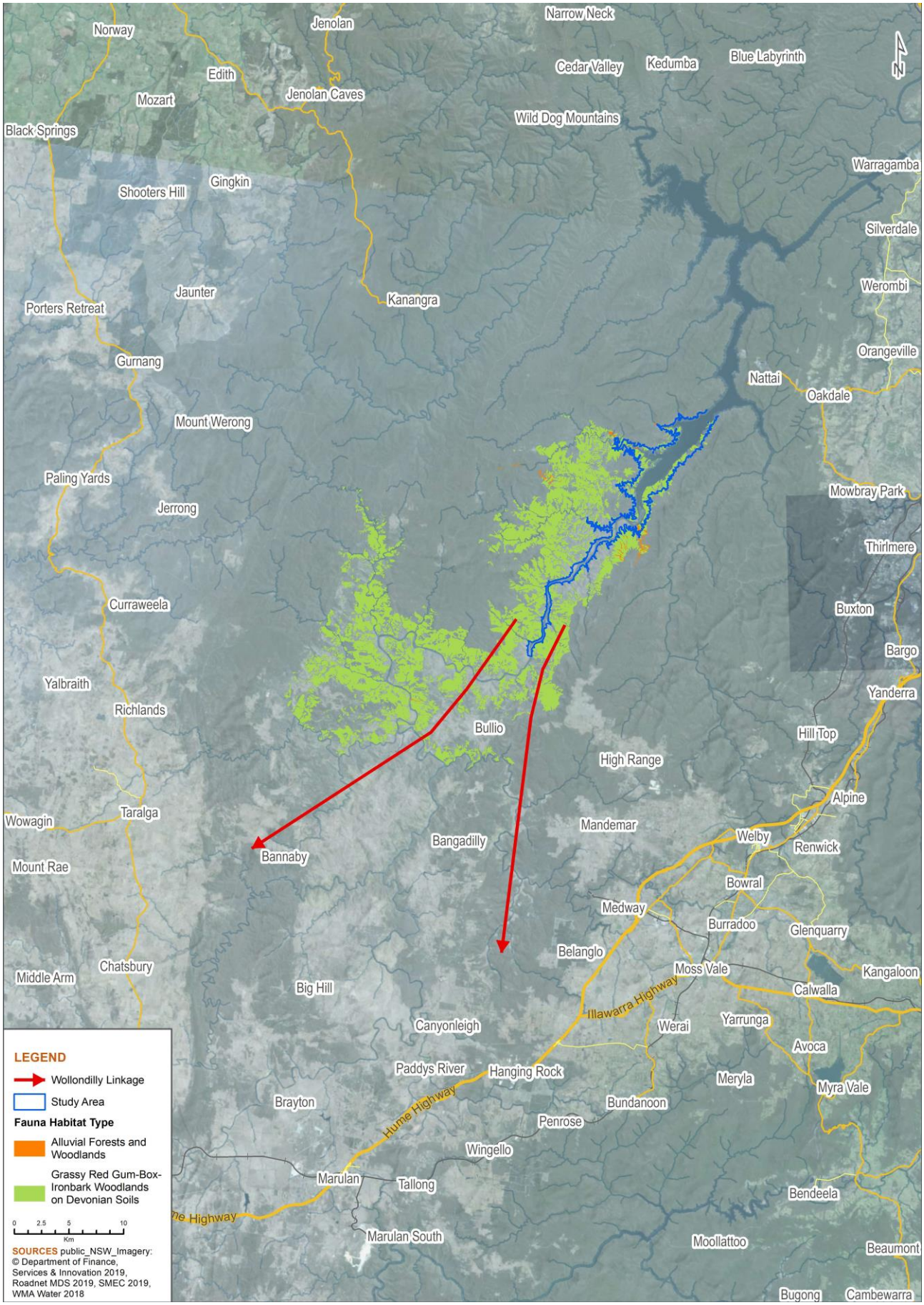
The study area is within a broader vegetation area of approximately 200,000 hectares and there is extensive connectivity between habitat in the study area and neighbouring areas. Physical barriers are formed by naturally occurring landscape features such as escarpments and gorges, and human-made trails for vehicle and pedestrian access. Lake Burragorang and major rivers also act as barriers to terrestrial species.

Animals often use landscape features to guide their dispersal. Riparian vegetation is used by some species, such as the Spotted-tailed Quoll, to move through the landscape. These areas are important given the presence of escarpments and cliffs that most ground-dwelling species would be incapable of negotiating.

The Wollondilly Linkage forms an important corridor connecting Grassy Box Woodland environments, occurring on a small part of the study area around Jooriland. This link extends from Jooriland to the south along the Wollondilly River to Bullio (DECC 2007a). The northern end of this link falls within the study area and is shown on Figure 8-11.

A small and steep rocky stream connects the Warragamba River to Lake Burragorang, which provides an important pathway for juvenile eels to migrate around the Dam wall; see Appendix F4 (Aquatic ecology assessment report).

Figure 8-11. Wollondilly Linkage fauna corridor



8.3.5 IBRA Bioregions

Bioregions are large and 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 units for assessing the status of native ecosystems and their level of protection in the National Reserve System.

The study area and landscape buffer are located across two bioregions (DOEE 2018) and four subregions as follows:

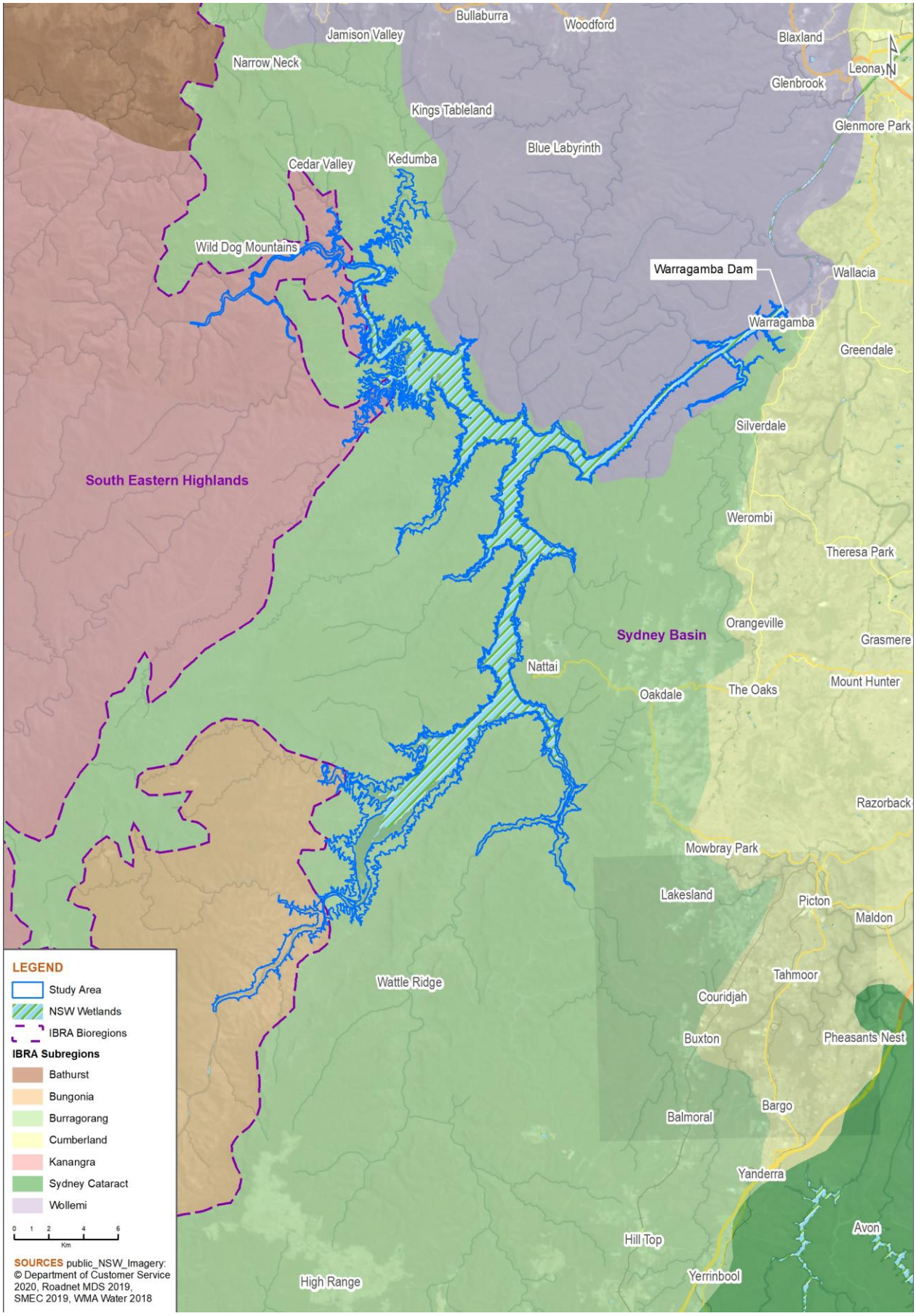
- The **Sydney Basin Bioregion** occupies approximately 3.6 million hectares (about five percent of NSW) and extends from just north of Batemans Bay to Nelson Bay on the central coast, and almost as far west as Mudgee (NPWS 2003a). It is one of two bioregions contained wholly within the state. The Sydney Basin Bioregion is one of the most species diverse in Australia, which is the result of the variety of rock types, topography and climates in the bioregion (NPWS 2003a). Two IBRA subregions occur within the study area:
  - Burragorang IBRA subregion
  - Wollemi IBRA subregion.
- The **South-Eastern Highlands Bioregion** occurs in NSW, most of the ACT and extends south into Victoria. In NSW, the South-Eastern Highlands cover some 4.9 million hectares, or six percent of the state (OEH 2016b, NPWS 2003b), and lies just inland from the coastal bioregions of the South-East Corner and the Sydney Basin, bounded by the Australian Alps and South Western Slopes bioregions to the south and west. Two IBRA subregions occur within the study area:
  - Kanangra IBRA subregion
  - Bungonia IBRA subregions.

The IBRA Bioregions and subregions are described in Table 8-13 and shown on Figure 8-12.

Table 8-13. IBRA Bioregion descriptions

Subregion	Geology	Characteristic landforms	Typical soils	Vegetation
SYDNEY BASIN BIOREGION Occupies about 3.6 million ha (approximately 5 percent of NSW) and extends from just north of Batemans Bay to Nelson Bay on the central coast, and almost as far west as Mudgee (NPWS 2003b). The Sydney Basin Bioregion is one of the most species diverse in Australia, which is the result of the variety of rock types, topography and climates in the bioregion (NPWS 2003b).				
Burragorang Part A	Permian and Triassic sandstones and shales on the western edge of the Basin. Limited basalt caps.	Rolling hills on a sandstone plateau with deep gorges and sandstone cliffs in Burragorang valley.	Rocky outcrops, texture contrast soils and uniform sands on sandstone. Boulder debris with sandy clay matrix below cliffs. Rich loams in alluvium.	Heath, shrubland and woodland with black ash, hard-leaved scribbly gum, Sydney peppermint and red bloodwood on sandstone similar to other parts of the Basin. Deane's gum, turpentine, blue-leaved stringybark immediately below escarpment passing to grey gum, narrow-leaved ironbark and thin-leaved stringybark on bouldery slopes. River oak along main streams below the plateaus.
Wollemi	Hawkesbury Sandstone and equivalent quartz sandstones of Narrabeen Group, sub-horizontal bedding, strong vertical joint patterns. A few volcanic necks.	Highest part of the Blue Mountains. Sandstone plateau with benched rock outcrops. Creek directions controlled by jointing deep gorge of the Capertee and Wolgan Rivers.	Thin sands or deep yellow earths on plateau, thin texture contrast soils on shale benches. Organic sands in swamps and joint crevices, bouldery slope debris below cliffs, sandy alluvium in pockets along the streams. Red brown structured loams on basalts.	Red bloodwood, yellow bloodwood, rough-barked apple, smooth-barked apple, hard-leaved scribbly gum, and grey gum with diverse shrubs and heaths on plateau. Smooth-barked apple, Sydney peppermint, blue-leaved stringybark, and turpentine and gully rainforests in gullies and canyon heads. Ribbon gum and Blaxland's stringybark on basalt. River oak along main streams.
SOUTH EASTERN HIGHLANDS BIOREGION Occupies about 8.8 million ha, of which about 4.9 million ha lies within NSW (approximately 6 percent of NSW). It lies inland from the coastal bioregions of the South-East Corner and the Sydney Basin, and is bounded by the Australian Alps and South Western Slopes bioregions to the south and west. The bioregion includes most of the ACT and extends south into Victoria.				
Kanangra	Devonian sandstones with small areas of granite and fine-grained Silurian and Ordovician sediments at the edge of the Sydney Basin.	Ridges and small plateaus to 1,200 m, deep valleys, swampy upper tributary floors, outcrops and tors on granite hills.	Red and yellow earths and structured loams. Well drained slopes, moderate fertility.	Grey gum, Blaxland's stringybark on lower areas, and brown barrel, mountain gum, narrow-leaved peppermint and ribbon gum on higher areas. Patches of snow gum. High diversity swamps on Boyd Plateau with carex and tea tree, sphagnum bogs in streams.
Bungonia	Primarily fine-grained Palaeozoic sedimentary and meta-sedimentary rocks, with minor areas of acid volcanics and limestone. Areas of Tertiary river terrestrial sediments and low sandsheets in the south with very limited basalt.	Distinct plateau with very steep, deep margins on the Great Escarpment dropping into the Shoalhaven River. Strong linear ridges on resistant sandstones and volcanics, wide valleys with some cold air drainage and inverted tree lines.	Mostly yellow texture contrast soils some with harsh clay subsoils. Shallow structured organic loams on limestone and basalt, deep siliceous sands and clayey sands on Tertiary sediments.	Mottled gum, broad-leaved peppermint, white gum, red stringybark and black ash forests and woodlands. Snow gum with and snow grass in cold pockets. Black she-oak common as understorey and in regeneration areas. Limited distribution of argyle apple.

Figure 8-12. IBRA subregions within the study area



8.3.6 NSW landscape regions (Mitchell Landscapes)

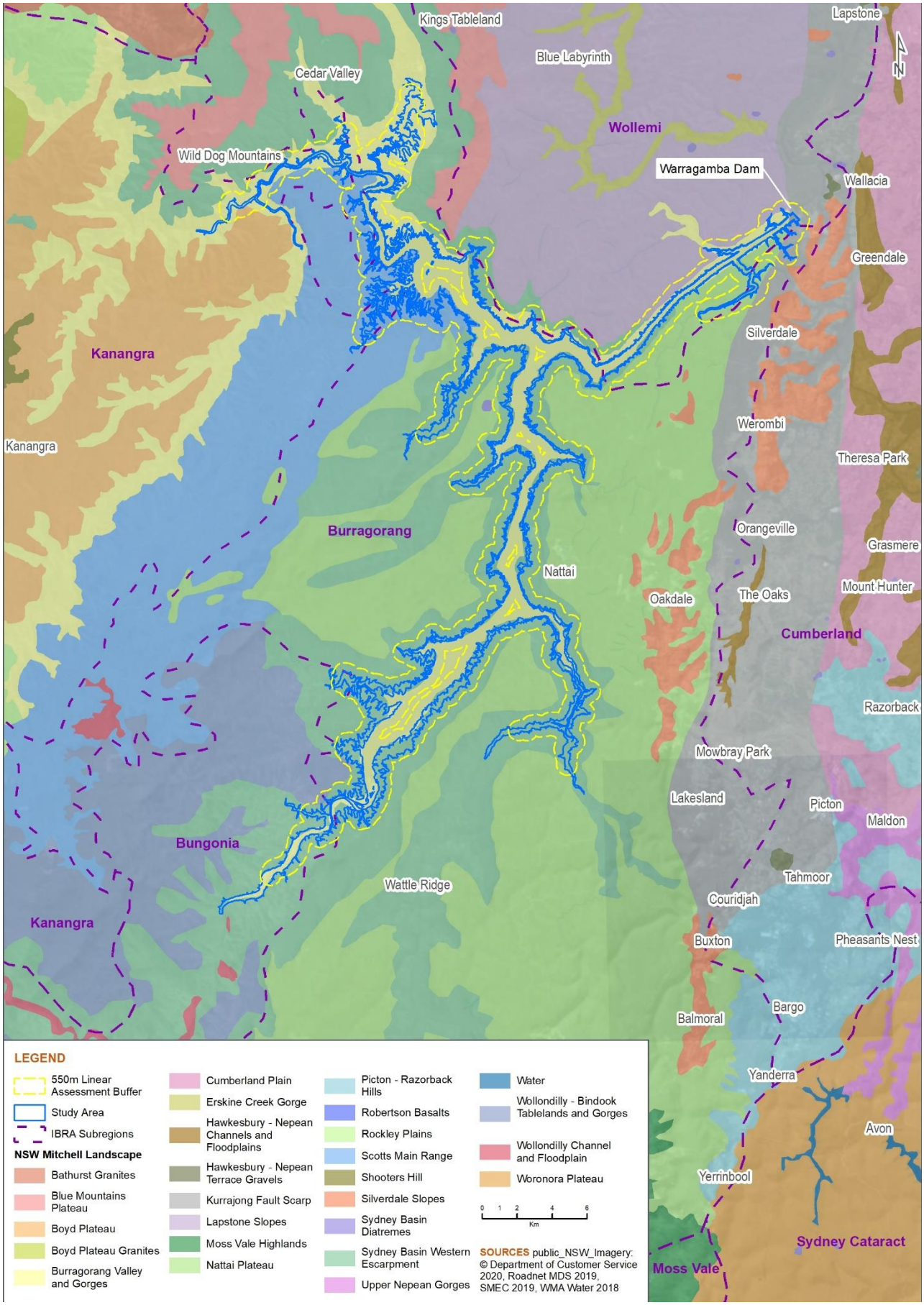
The study area is located across 10 landscape regions, which are described in Table 8-14. Burragorang Valley and Gorges occurs over most of the study area followed by Sydney Basin Western Escarpment, Scotts Main Range, and Nattai Plateau.

Table 8-14. Landscape regions in the study area

Mitchell landscape
Boyd Plateau (3 ha)
Plateau with extensive swamps, low hills and deeply dissected margin on Devonian sandstone, siltstone, shale and conglomerate. Small areas capped by horizontal Permian lithic sandstone, quartz sandstone, conglomerate and shale. General elevation 1,100 to 1,250 m, local relief <80 m. Extensive rock outcrop, thin stony loams on Palaeozoic rocks, thin wet siliceous sands on sandstone and gleyed texture-contrast soils on shale benches. Heath and scrub of mountain mallee (*Eucalyptus stricta*), dwarf casuarina (*Allocasuarina nana*), heath banksia (*Banksia ericifolia*), finger hakea (*Hakea dactyloides*), tea-tree (*Leptospermum sp.*), scribbly gum (*Eucalyptus rossii*) and snow gum (*Eucalyptus pauciflora*).
Burragorang Valley and Gorges (8,134 ha)
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 150 m high with waterfalls, general elevation 50 to 220, 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. Red bloodwood (*Corymbia gummifer*a), turpentine (*Syncarpia glomulifera*), and rainforest elements at the base of the gorge in sandstone. Steep debris slopes below cliff upstream with forest red gum (*Eucalyptus tereticornis*), red stringybark (*Eucalyptus macrorhyncha*), narrow leaved ironbark (*Eucalyptus crebra*), and brittle gum (*Eucalyptus mannifera*). Moist protected environments with Sydney blue gum (*Eucalyptus saligna*), mountain grey gum, (*Eucalyptus cypellocarpa*) yellow stringybark (*Eucalyptus muelleriana*) and gully gum (*Eucalyptus smithii*). Gallery forest of river oak (*Casuarina cunninghamiana*) with round-leaved gum (*Eucalyptus deanei*) and Camden white gum (*Eucalyptus benthamii*) along the main streams.
Kurrajong Fault Scarp (43 ha)
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 yellowbrown sand and occasional yellow texture-contrast soils. Open forest with a shrubby understorey of; blue-leaved stringybark *(Eucalyptus agglomerata*), turpentine (*Syncarpia glomulifera*), red bloodwood (*Corymbia gummifera*). Smooth-barked apple (*Angophora costata*), Sydney peppermint (*Eucalyptus piperita*), narrow-leaved peppermint (*Eucalyptus radiata*), grey gum (*Eucalyptus punctata*), blackbutt (*Eucalyptus pilularis*) and she-oaks (*Allocasuarina sp.*). Several streams have formed extensive reed swamps behind the fault block with deep organic sands and scattered forest red gum (*Eucalyptus tereticornis*), roughbarked apple (*Angophora floribunda*) and white stringybark (*Eucalyptus globoidea*) on the margins.
Lapstone Slopes (3 ha)
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. Red bloodwood (*Corymbia gummifera*), yellow bloodwood (*Corymbia eximia*), grey gum (*Eucalyptus punctata*), forest oak (*Allocasuarina torulosa*), silvertop ash (*Eucalyptus sieberi*), narrow-leaved peppermint (*Eucalyptus radiata*) with diverse shrubby understorey.
Nattai Plateau (166 ha)
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 thin-leaved stringybark (*Eucalyptus eugenioides*), broad-leaved ironbark (*Eucalyptus fibrosa ssp. fibrosa*), Port Jackson pine (*Callitris rhomboidea*), silvertop ash (*Eucalyptus sieberi*), Blaxland's stringybark (*Eucalyptus blaxlandii*), brown barrel (*Eucalyptus fastigata*) and manna gum (*Eucalyptus viminalis*).

Mitchell landscape
Scotts Main Range (859 ha)
Linear ranges with small sandstone caps, string structural control of drainage by folded Devonian basement, prominent cliff lines in Triassic units with joint control. Triassic lithic sandstone, conglomerate and siltstone over Permian conglomerates and lithic sandstones unconformably on upper Devonian quartzose sandstone and shale. General elevation 400 to 850 m, local relief 250 m with a few peaks to 1,000 m. Shallow sand and occasional yellow texture-contrast soils. Woodland of narrow-leaved ironbark (*Eucalyptus crebra*), grey gum (*Eucalyptus punctata*), thin-leaved stringybark (*Eucalyptus eugenioides*), scribbly gum (*Eucalyptus sclerophylla*), and narrow-leaved apple (*Angophora bakeri*).
Silverdale Slopes (<1 ha)
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; grey gum (*Eucalyptus punctata*), white box (*Eucalyptus albens*), grey ironbark (*Eucalyptus paniculata*), narrow-leaved ironbark (*Eucalyptus crebra*), broad-leaved ironbark (*Eucalyptus fibrosa ssp. fibrosa*), grey box (*Eucalyptus moluccana*), forest oak (*Allocasuarina torulosa*), thin-leaved stringybark (*Eucalyptus eugenioides*) and occasional turpentine (*Syncarpia glomulifera*).
Sydney Basin Diatremes
Widely distributed across the Sydney Basin and distinguished as a landscape because they always contain locally different landform, soil and vegetation. Diatremes are circular volcanic vents filled with layered, brecciated country rock cemented by a fine-grained basaltic matrix. Some contain a core of basalt. In sandstone country, the volcanic breccia weathers and erodes more rapidly than the sandstone and the landform is a deep and circular with the appearance of a crater. Soils in the crater are dominated by sandstone detritus from the surrounding slopes but the subsoil is a fertile and well-structured clay derived from the breccia and these protected sites carry more mesic variants of the local vegetation. In shale country, the breccia is more resistant than the shale and the diatremes form a low rounded hill with red-brown gradational profiles of clay loam and structured clay with moderate to high fertility. General elevation varies considerably across the basin, local relief of positive landforms up to 25 m, negative landforms (‘craters’) 180 m.
Sydney Basin Western Escarpment (4,542 ha)
Steep dissected slopes on the western margin of the Triassic rocks and descending into the Permian conglomerate, shale and sandstone. Cliffs and gorges to 100 m, general elevation 250 to 1,000 m, local relief 150 m. Brown loamy sands in rubbly soil on debris slopes, with deeper accumulations toward the valley floor. Dry aspects; open forest of Sydney peppermint (*Eucalyptus piperita*), smooth-barked apple (*Angophora costata*), grey gum (*Eucalyptus punctata*), broad-leaved ironbark (*Eucalyptus fibrosa ssp. fibrosa*) and rough-barked apple (*Angophora floribunda*). Moist aspects; tall open forest of round-leaved gum (*Eucalyptus deanei*), turpentine (*Syncarpia glomulifera*), Sydney blue gum (*Eucalyptus saligna*), blueleaved stringybark (*Eucalyptus agglomerata*), thin-leaved stringybark (*Eucalyptus eugenioides*) and narrow-leaved ironbark (*Eucalyptus crebra*). Coachwood (*Ceratopetalum apetalum*) and sassafras (*Doryphora sassafras*) in the gullies.
Wollondilly - Bindook Tablelands and Gorges (2 ha)
Dissected tablelands, marginal gorges and scree slopes on massive Devonian quartz porphyry and small areas of massive Devonian granite. General elevation 600 to 900 m, local relief 250 m. Thin gritty uniform profiles on steep slopes and around rock outcrops, grey and yellow texture-contrast profiles on flatter slopes. Woodland and open forest of forest red gum (*Eucalyptus tereticornis*), yellow box (*Eucalyptus melliodora*), grey box (*Eucalyptus moluccana*), white box (*Eucalyptus albens*), black wattle (*Acacia mearnsii*), Parramatta wattle (*Acacia parramattensis*), black she-oak (*Casuarina litoralis*) with numerous shrubs, bracken (*Pteridium esculentum*) and grasses.

Figure 8-13 NSW landscape regions



8.3.7 State or regionally significant biodiversity links

Biodiversity links are defined in the FBA and include State significant, regionally significant, very large area, large area and local area biodiversity links. To date, no biodiversity corridor plans have been approved by the Chief Executive of the former OEH (now the Coordinator-General of the EES Group within DPIE).

The FBA (Appendix 2) outlines riparian buffer widths required for each order of stream classified in accordance with the Strahler system (see Section 8.3.3). Under the FBA, riparian buffers for 6th order streams or higher are a state significant biodiversity link. The Project would impact upon the 50-metre riparian buffer for seven streams higher than a 6th order stream, including one stream (Lake Burragorang) that is a 9th order stream (see Section 8.3.3). Consequently, the project would be impacting upon a state significant biodiversity link.

8.3.8 Biodiversity values map

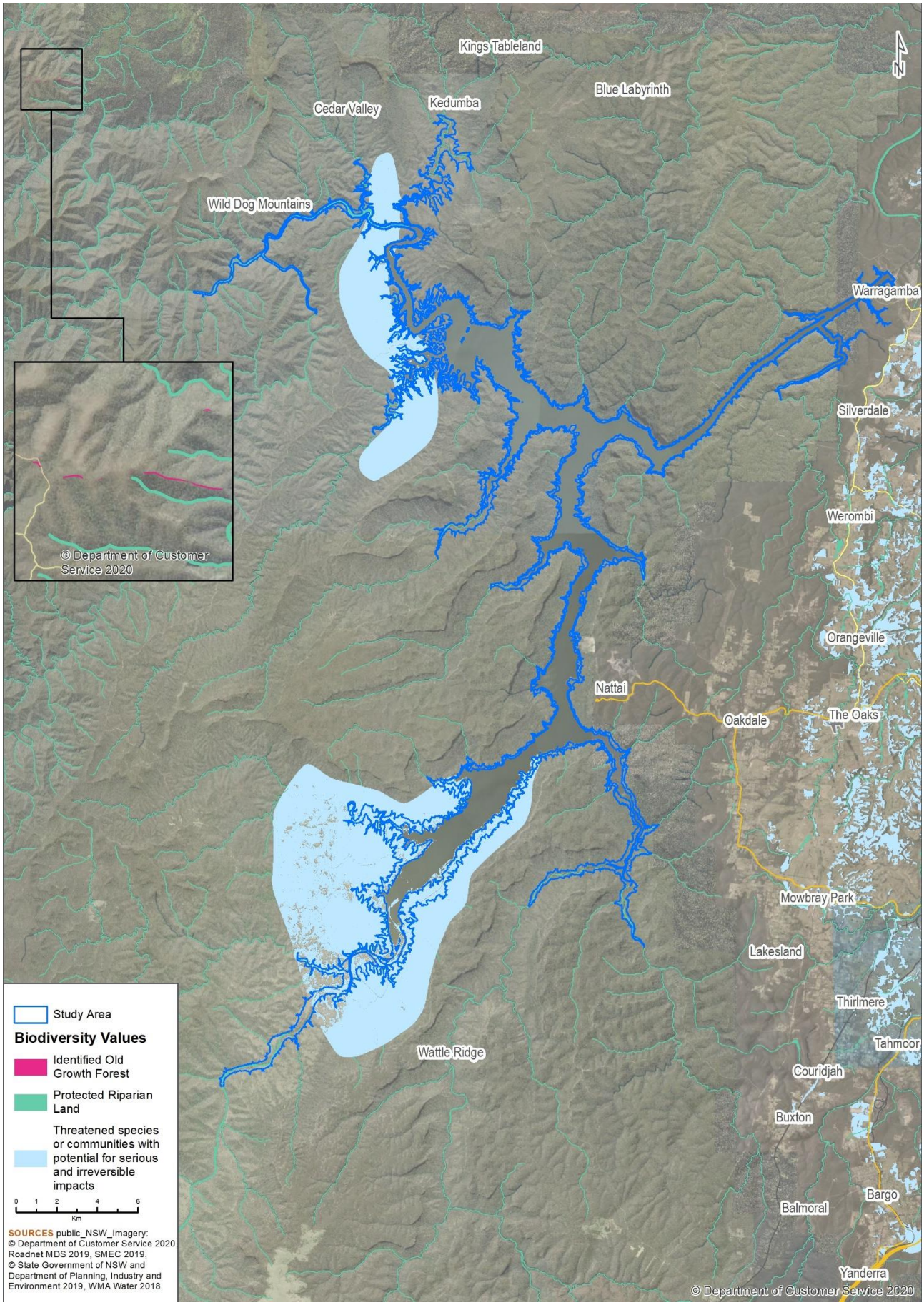
The biodiversity values map identifies land with high biodiversity value that is especially sensitive to impacts from development and clearing. Land types that may be included on the biodiversity values map include:

- core koala habitat identified in a plan of management prepared under the former SEPP 44
- 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 Forest Policy Statement (Commonwealth of Australia 1995) but excluding areas not meeting the criteria published jointly by the Minister of 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.

Biodiversity values are shown on Figure 8-14. Most of the areas mapped are riparian buffers around streams and rivers. Two areas (around the mouth of the Wollondilly River and in the west of the study area between Butchers Creek and Coxs River) have been mapped as land containing threatened species or threatened ecological communities identified as potential serious and irreversible impacts (SAII) under section 6.5 of the BC Act.

As discussed in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 2.2.2), the Project is being assessed under the provisions of the TSC Act and therefore consideration of SAII under the BC Act is not required. This notwithstanding, the biodiversity values information has been included to complement the ecological assessment.

Figure 8-14. Areas mapped on Biodiversity Values Map occurring within the study area



8.3.9 Groundwater dependent ecosystems

Ecosystems which depend on groundwater for some or all of their water source/s are classified as groundwater dependent ecosystems (GDE) (Geoscience Australia n.d.), and the Bureau of Meteorology (BOM 2020) states that GDEs are 'Natural ecosystems that require access to groundwater to meet all or some of their water requirements on a permanent or intermittent basis, so as to maintain their communities of plants and animals, ecosystem processes and ecosystem services.'

Potential GDEs found within the study area have been assessed in accordance with the following community attributes:

- *vegetation type*: Describes the broad characteristics of the ecological community
- *landscape*: Describes the topography of the area, which has an effect on the flow of water (Argent 2016)
- *IBRA Bioregion*: The IBRA Bioregion the area belongs to
- *landuse*: The main land use in the area, which has an effect on ecological processes (DPIE, n.d.)
- *groundwater Management Area*: The administrative management area to which the GDE belongs.
  Inflow Dependent Ecosystem (IDE) Likelihood: IDEs are ecosystems that are 'likely to be using another source of water in addition to rainfall' (BOM 2020), which includes GDEs. The BOM GDE Atlas uses values from 1 (low) to 10 (high) to represent the likelihood that this GDE is an IDE
- *GDE Classification*: This is the likelihood that this particular ecosystem is a GDE, which is determined to either have a low, moderate or high potential.

Nineteen GDEs were identified within the study area using the BOM GDE Atlas (BOM 2019). These are described and mapped in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 4.6) and summarised in Table 8-15.

Table 8-15. Groundwater dependent ecosystems within the study area

	Vegetation type	GDE classification summary
1.	Blue Mountains Heath	Low to moderate GDE
2.	Burragorang Escarpment Forest	Low to moderate GDE for most areas
3.	Burragorang Hillslope Forest	High GDE for most areas
4.	Burragorang River Flat Forest	Low to Moderate GDE
5.	Burragorang Rocky Slopes Woodland	Low to Moderate GDE
6.	Burragorang-Nepean Hinterland Woodland	Low to Moderate GDE
7.	Coastal Sandstone Ridgetop Woodland	Low to Moderate GDE
8.	Grey Myrtle Dry Rainforest	High GDE for most areas
9.	Hinterland Sandstone Gully Forest	High GDE for most areas
10.	Kowmung Dry Shrub/Herb Forest – *E. punctate*	Low GDE
11.	Kowmung-Wollondilly Gorge Forest	High GDE for all areas
12.	Lower Blue Mountains Wet Forest	High GDE for most areas
13.	Megalong-Tonalli Sandstone Forest	High GDE for most areas
14.	Riparian Acacia Shrub/Grass/Herb Forest: *Casuarina cunninghamiana*	High GDE for all areas
15.	Riverbank Forest	High GDE for most areas
16.	Sandstone Riparian Scrub	High GDE for all areas
17.	Sandstone Scarp Warm Temperate Rainforest	High GDE for most areas
18.	Sydney Hinterland Transition Woodland	High GDE for all areas
19.	Wollondilly-Cox-Shoalhaven Gorge Woodland	Low to Moderate GDE

8.3.10 Landscape value score components

Landscape value score components were used for assessing the compensatory package. Due to the Project boundary crossing multiple IBRA subregions, four BioBanking Credit Calculator (V4.0) assessments were completed for the Project. The methodology used is described in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 3.2), which includes assessment of percent native vegetation cover in the landscape, connectivity value, area/perimeter ratio and patch size. A summary of the landscape value score components for each IBRA Subregion is provided in Table 8-16, Table 8-17, Table 8-18 and Table 8-19.

Table 8-16. Burragorang Subregion: landscape value score components

Components	Value	Score
Native vegetation cover before development	69%	0.5
Native vegetation cover after development	64%	
Connectivity value	State significant biodiversity link	12.50
Area/Perimeter ratio proportional change	22%	3
Patch Size (Mitchell Landscape)	Seven landscapes assessed above 1,000 ha	11.60
Landscape value score	**27.60**	

Table 8-17. Bungonia Subregion: landscape value score components

Components	Value	Score
Native vegetation cover before development	55%	0.50
Native vegetation cover after development	49%	
Connectivity value	State significant biodiversity link	12.50
Area/Perimeter ratio proportional change	11%	2
Patch Size (Mitchell Landscape)	Three landscapes assessed above 1,000 ha	12.50
Landscape value score	**27.50**	

Table 8-18. Kanangra Subregion: landscape value score components

Components	Value	Score
Native vegetation cover before development	86%	0.40
Native vegetation cover after development	82%	
Connectivity value	State significant biodiversity link	12.50
Area/Perimeter ratio proportional change	16%	2
Patch Size (Mitchell Landscape)	Four landscapes assessed above 1000 ha	12.50
Landscape value score	**27.40**	

Table 8-19. Wollemi Subregion: landscape value score components

Components	Value	Score
Native vegetation cover before development	79%	0.00
Native vegetation cover after development	77%	
Connectivity value	State significant biodiversity link	12.50
Area/Perimeter ratio proportional change	17%	2
Patch Size (Mitchell Landscape)	Six landscapes assessed above 1000 ha	12.50
Landscape value score	**27.00**	

8.3.11 Bushfires

8.3.11.1 Historic 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 2020). Most of the study area has been historically affected by wildfire 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, and since construction of the dam, the catchment has experienced at least four major wildfire events: 1964-65 1994-95 1997-98 and 2001-02 (DPIE 2020).

8.3.11.2 Bushfire event:- 2019-2020

Following field surveys for this biodiversity assessment, the catchment of Lake Burragorang experienced severe wildfire 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 national park estate, more than 81 percent of the World Heritage listed Greater Blue Mountains Area and 54 percent of the NSW components of the Gondwana Rainforests of Australia World Heritage property (DPIE, Understanding the effects of the 2019–20 fires 2020). The most affected ecosystems were rainforests (37 percent of their state-wide extent), wet sclerophyll forests (50 percent) and heathlands (52 percent) (DPIE 2020).

The fires affecting the study area began in late October 2019 within remote bushland near Lake Burragorang, near Yerranderie, as well as within Kanangra-Boyd National Park. Due to the affected area's isolation and rugged inaccessible terrain, the fire spread and merged to eventually become the Green Wattle Creek Fire on 27 November 2019, which burnt out of control for at least nine weeks. A total of 278,700 hectares in the Wollondilly area was 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.

8.3.11.3 Bushfire mapping

The NSW DPIE Remote Sensing and Landscape Science team, in collaboration with other organisations, developed fire mapping and modelling of the 2019-2020 bushfire event 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), which was developed in collaboration with University of NSW, was developed 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 2020). 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 2020).
- Fire extent and severity map (FESM), which was developed in collaboration with RFS, was developed as a semi-automatic approach to mapping fire extent and severity through a machine learning framework based on Sentinel 2 satellite imagery (DPIE 2020). 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 2020). 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 utilised over the rapid GEEBAM mapping 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, and the approximate extent of severity classes within the upstream study area and upstream impact area are provided in Table 8-20. Figure 8-15 shows the extent of the severity classes relative to the Project study area.

Table 8-20. FESM burn severity classes and approximate burn extent within the upstream study area and upstream impact area

Severity class	Description	Percent foliage fire affected	% of upstream study area	% within upstream impact area
Unburnt	Unburnt surface with green canopy	0% canopy and understory burnt	26.9%	30.2%
Low	Burnt understory with unburnt canopy	>10% burnt understory >90% green canopy	27.7%	35.4%
Moderate	Partial canopy scorch	20-90% canopy scorch	35.6%	25.4%
High	Complete canopy scorch (+/- partial canopy consumption)	>90% canopy scorched <50% canopy consumed	5.3%	4.6%
Extreme	Complete canopy consumption	>50% canopy biomass consumed	4.5%	4.4%

8.3.11.4 Bushfire impacts

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 some species (both threatened and not currently threatened) have had their entire global populations burnt in the 2019-2020 fires. This includes some species and ecological communities that are known to be sensitive to severe fire (DPIE 2020b).

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[5]. 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 be extirpated or significantly reduced in density over their affected ranges. Other ecological inputs following fire can have additional impacts on post-fire ecology, which may include recurrent fire, drought, intense rainfall, flood, erosion and predation.

It is expected that threatened ecological communities, threatened species, and non-threatened species have been severely impacted by the 2019-2020 bushfires. Following the bushfire event, DAWE released an initial provisional list of 113 fauna species as high priority for urgent management intervention on 11 February 2020. An updated list[6] was released on 20 March 2020. A similar list was released for plant species, the latest being released on 12 October 2020[7].

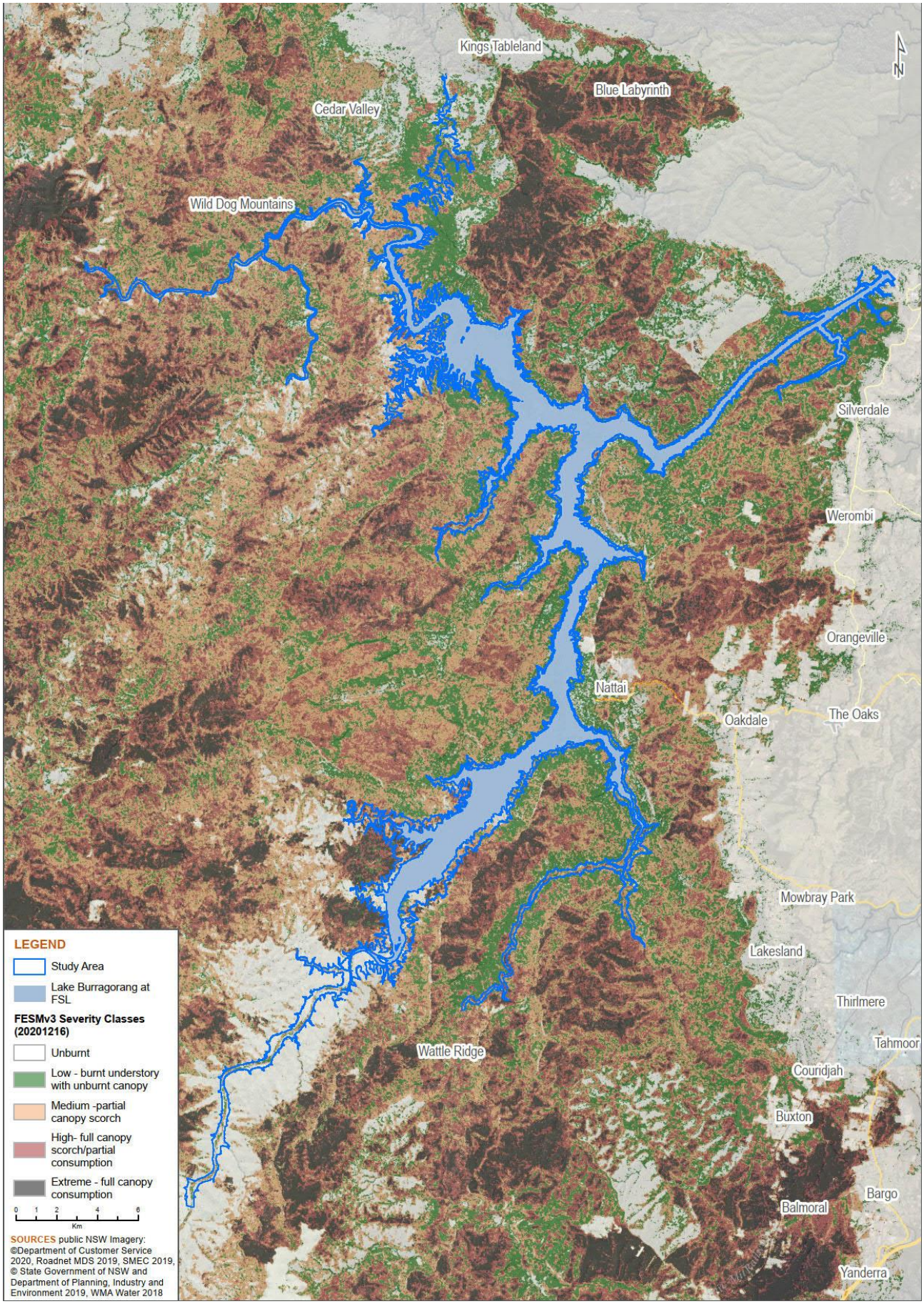
As part of the assessment of the potential impacts of the Project on biodiversity-related matters contributing to the Oustanding Universal Value of the GBMWHA (refer Appendix J World Heritage Assessment Report, Section 6.1.22), an analysis was carried out to estimate areas of habitat utilised by animal and plant species on the DAWE priority lists identified in the upstream biodiversity assessment (Appendix F1 Biodiversity Assessment Report – Upstream) as having a moderate or greater likelihood of occurring in the upstream study area, or had been recorded in the upstream study area., and how much of this was affected by the bushfire event.

[5] https://www.environment.nsw.gov.au/topics/parks-reserves-and-protected-areas/fire/plants-animals-and-fire#:~:text=If%20fires%20occur%20too%20frequently,in%20the%20soil%20before%20germinating

[6] https://www.environment.gov.au/system/files/pages/ef3f5ebd-faec-4c0c-9ea9-b7dfd9446cb1/files/provisional-list-animals-requiring-urgent-management-intervention-20032020.pdf

[7] https://www.environment.gov.au/system/files/pages/289205b6-83c5-480c-9a7d-3fdf3cde2f68/files/summary-final-list-plants-requiring-urgent-managment-intervention.pdf

Figure 8-15. Bushfire event 2019–2020



Estimates of areas of suitable habitat were derived based on associated PCTs occurring in the upstream study area. This was carried out for:

- the total upstream study area (about 5,280 hectares)
- the upstream impact area (about 1,400 hectares)
- the area of the GBMWHA within the upstream impact area (about 304 hectares).

Estimates of suitable habitat affected by the bushfire event were then derived for the same areas. This was based on the fire extent and severity mapping developed by the DPIE Remote Sensing and Landscape Science team in collaboration with the RFS (refer Section 2.5) using the following three burn severity classes:

- Medium: Partial canopy scorch (20-90% canopy scorch)
- High: Full canopy scorch/partial consumption (>90% canopy scorched, <50% canopy consumed)
- Extreme: Full canopy consumption (>50% canopy biomass consumed).

Areas mapped as 'Unburnt or 'Low' (>10% burnt understory, >90% green canopy) were excluded from the assessment as habitat in these areas was considered to be relatively unaffected in terms of utilisation by the species considered.

The results of the analysis for the upstream study area and upstream impact area are summarised in the following table.

Table 8-21. DAWE priority list species habitat affected by 2019-2020 bushfires

Scientific name	Common name	Upstream study area			Upstream impact area		
		Total area (ha)	Burnt area[1] (ha)	%	Total area (ha)	Burnt area[1] (ha)	%
Fauna							
Heleioporus australiacus	Giant Burrowing Frog	3,270.5	1,217.2	37%	28.5	271.9	33%
Anthochaera phrygia	Regent Honeyeater	5,203.6	2,115.4	41%	1,369.7	531.0	39%
Callocephalon fimbriatum	Gang-gang Cockatoo	5,205.1	2,115.7	41%	1,370.2	531.0	39%
Calyptorhynchus lathami	Glossy Black-cockatoo	4,973.9	2,063.6	41%	1,320.1	517.9	39%
Monarcha melanopsis	Black-faced Monarch	5,205.1	2,115.7	41%	1,370.2	531.0	39%
Dasyurus maculatus maculatus	Spotted-tailed Quoll	5,205.1	2,115.7	41%	1,370.2	531.0	39%
Macropus parma	Parma Wallaby	36.6	30.4	83%	14.7	3.4	23%
Petauroides volans	Greater Glider	5,203.6	2,115.4	41%	1,369.7	531.0	39%
Petaurus australis	Yellow-bellied Glider	4,555.7	1,848.1	41%	1,221.2	494.8	41%
Petrogale penicillata	Brush-tailed Rock-wallaby	4,415.0	1,693.8	38%	1,164.9	464.0	40%
Phascolarctos cinereus	Koala	5,205.1	2,115.7	41%	1,370.2	531.0	39%
Potorous tridactylus tridactylus	Long-nosed Potoroo	4,400.3	1,806.2	41%	1,186.9	484.9	41%
Pseudomys novaehollandiae	New Holland Mouse	165.6	33.3	20%	43.9	6.5	15%
Pteropus poliocephalus	Grey-headed Flying-fox	5,205.1	2,115.7	41%	1,370.2	531.0	39%
Hoplocephalus bungaroides	Broad-headed Snake	4,016.7	1,607.6	40%	1,017.3	335.5	33%
Heleioporus australiacus	Giant Burrowing Frog	3,270.5	1,217.2	37%	828.5	271.9	33%

Scientific name	Common name	Upstream study area			Upstream impact area		
		Total area (ha)	Burnt area[1] (ha)	%	Total area (ha)	Burnt area[1] (ha)	%
Flora							
Acacia clunies-rossiae	Kanangra Wattle	4,496.4	1,806.8	40%	1,184.5	472.6	40%
Acacia flocktoniae	Flockton's Wattle	2,152.1	756.8	35%	554.3	192.8	35%
Baloskion longipes	Dense Cord-rush	368.2	193.9	53%	84.2	21.4	25%
Callistemon megalongensis	Megalong Valley Bottlebrush	84.6	31.7	37%	11.0	7.8	71%
Epacris purpurascens var. purpurascens	–	69.1	16.6	24%	23.2	4.9	21%
Hakea dohertyi	Kowmung Hakea	1,452.6	561.5	39%	383.8	116.0	30%
Isopogon fletcheri	Fletcher's Drumsticks	800.4	343.1	43%	212.9	64.2	30%
Persoonia acerosa	Needle Geebung	125.2	32.2	26%	32.3	4.6	14%
Pomaderris brunnea	Brown Pomaderris	1,375.7	618.2	45%	326.9	98.4	30%
Pultenaea glabra	Smooth Bush-pea	125.2	32.2	26%	32.3	4.6	14%
Rhodamnia rubescens	Scrub Turpentine	324.1	73.8	23%	77.1	13.7	18%
Solanum armourense	–	4,179.1	1624.9	39%	1,110.7	452.2	41%
Trachymene scapigera	Mountain Trachymene	1703.5	846.4	50%	491.6	246.0	50%
Velleia perfoliata	–	1,829.7	752.5	41%	457.2	141.1	31%
Zieria covenyi	Coveny's Zieria	58.2	15.5	27%	16.3	3.4	21%
Zieria murphyi	Velvet Zieria	58.2	15.5	27%	16.3	3.4	21%

1 Mapped as 'Medium', 'High' or 'Extreme' as per DPIE FESM mapping (refer Table 8-20).

Based on the analysis, it was identified that there are still substantial areas (mostly >50 percent) of unburnt habitat in the upstream impact area and upstream study area.

In March 2020, DPIE released a set of guidelines relating to carrying out biodiversity assessments, specifically Biodiversity Assessment Methodology (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. The guidelines state that where the Stage 1 BAM assessment has been completed prior to severe bushfire, the assessor should use this information to prepare the impact assessment. Given that Stage 1 of the FBA is broadly consistent with the objectives and outcomes of Stage 1 of the BAM, it is reasonable to conclude that further assessment in line with the guidelines is not required for this assessment.

8.4 Plant communities

8.4.1.1 Plant Community Types (PCTs)

Vegetation within the study area is aligned with 18 Plant Community Types (PCTs), which are defined within the Vegetation Information System (VIS) Classification Database. These are described and mapped in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 4.4, Appendix L) and summarised in Table 8-22.

Table 8-22. PCTs within the study area (HN: Hawkesbury-Nepean)

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
1) HN517 (PCT 769) **Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies, Sydney Basin Bioregion**	**Rainforest**	**Northern Warm Temperate Rainforests**	**5**	**1.52**	**0.53**
Occurs within deeply incised gorges and steep south facing slopes along the west Warragamba Wall. The vegetation community is composed of a closed canopy dominated by *Acmena smithii*, *Ceratopetalum apetalum*, and *Doryphora sassafras* although emergent *Eucalyptus deanei* are occasionally present. The midstorey was generally open, containing species such as *Stenocarpus salignus, Guioa semiglauca*, and *Melicope micrococca* at low densities. Ferns including *Blechnum cartilagineum, Blechnum patersonii, Microsorum scandens*, and *Cyathea australis* occur in isolated pockets within sandstone crevices. In some locations, the community is dominated by climbers such as *Cissus hypoglauca, Gynochthodes jasminoides* and *Smilax australis*. Much of this community within the study area was mapped as 'Cleared-Modified' by NPWS (2003b) despite being generally being relatively undisturbed and weed free. This PCT is broadly equivalent to 'MU1 Sandstone Warm Temperate Rainforest' in NPWS (2003a) and 'RF p114: Sandstone Scarp Warm Temperate Rainforest' in Tozer et al. (2010).					
2) HN525 (PCT 832) **Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion**	**Dry Sclerophyll Forest (shrub/grass sub-formation)**	**Central Gorge Dry Sclerophyll Forests**	**5**	**544.90**	**143.14**
Occurs on both relatively exposed and sheltered, dry slopes along the Coxs River, Cedar Creek, Kedumba River, Kowmung River, and around the main lake area, primarily north-west of Green Wattle Creek, usually on soils derived from Devonian quartzites. The community is an open forest showing a variation of species dominance because of differing exposure across its occurrence in the area surveyed. In more exposed aspects, or where the soil is shallower and rockier, the structure of the community is a low, dry open woodland with a scattered shrub layer and a mixed ground cover dominated mostly by grasses. In areas with more protection, this community may be taller, with a more developed shrub layer and more forbs in the groundcover stratum. The more exposed extents of this community have a canopy typically dominated by *Eucalyptus crebra, Eucalyptus tereticornis* and *Eucalyptus glaucina*, with subdominants being *Eucalyptus punctata, Angophora floribunda, Eucalyptus melliodora, Eucalyptus sparsifolia, Eucalyptus eugenioides*, and rarely *Eucalyptus fibrosa* and *Eucalyptus sideroxylon*. A sub-canopy of small trees typically includes species such as *Allocasuarina torulosa, Acacia binervia and Allocasuarina littoralis*. Shrubs such *as Bursaria longisepala, Lissanthe strigosa* and *Exocarpos strictus* typically form a sparse shrub layer. A ground layer of forbs and graminoids commonly includes *Cymbopogon refractus, Dianella revoluta, Cheilanthes* spp, *Lomandra* spp, *Aristida* spp, *Desmodium varians* and *Rytidosperma* spp. More protected extents of this community are typically dominated by Eucalyptus tereticornis, with minor associates of *Eucalyptus crebra, Angophora floribunda, Eucalyptus punctata* and *Eucalyptus moluccana*. A small tree layer is often present, dominated by *Brachychiton populneus, Backhousia myrtifolia* and *Allocasuarina torulosa*. A moderately dense shrub layer is dominated by *Acacia clunies-rossiae, Olearia viscidula, Melicytus dentatus, Bursaria spinosa, Dodonaea* viscosa and *Notelaea longifolia*. In these more protected extents of the community, soft leaved ground covers such as *Dichondra repens, Pratia purpurascens, Plectranthus parviflorus, Adiantum aethiopicum, Oplismenus* spp, *Microlaena stipoides* var. *stipoides, Plectranthus parviflorus* and *Glycine clandestina*. Climbers are relatively abundant and commonly include *Aphanopetalum resinosum, Geitonoplesium cymosum, Pandorea pandorana, Clematis* spp and *Stephania japonica*. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU46 Kanangra Gorge Narrow-leaved Ironbark Woodland' and 'MU28 Kowmung Sheltered Red Gum Forest' within NPWS (2003a) and 'DSF p36: Kowmung - Wollondilly Gorge Woodland' in Tozer *et al*. (2010).					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
3) HN527 (PCT 840) **Forest Red Gum - Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands**	**Dry Sclerophyll Forest (shrub/grass sub-formation)**	**Central Gorge Dry Sclerophyll Forests**	**50**	**490.47**	**127.75**

Occurs south of Higgins Bay along the shores of Lake Burragorang and through the Lower Wollondilly River Valley and Joorilands. This PCT typically occurs on soils derived from fertile Porphyry sediments on undulating foothills as well as on erodible slopes with an abundance of surface rock and rock outcrops. Meets the Final Determination for White Box Yellow Box Blakey's Red Gum Woodland under the BC Act, and White Box-Yellow Box-Blakey's Red Gum Grassy Woodland and Derived Native Grassland under the EPBC Act.

Consists of an open grassy eucalypt woodland with a variable understorey of shrubs, grasses, forbs and graminoids. In areas where there has been historical agricultural land usage, it occurs as a derived native grassland. On the rolling hills and lowlands of the PCT, the canopy is dominated by a mosaic of *Eucalyptus tereticornis, Eucalyptus glaucina, Eucalyptus melliodora*, and *Eucalyptus albens-moluccana* intergrade with occasional *Eucalyptus crebra, Eucalyptus punctata, Angophora floribunda*, and *Brachychiton populneus*. The shrub layer is almost non-existent within these areas but where present it consists of *Acacia floribunda, Acacia implexa, Lissanthe strigosa, Breynia oblongifolia, Dodanea viscosa, Persoonia linearis*, and *Hibbertia* sp. The ground cover within these areas are a diverse mix of grasses, forbs, and graminoids including *Cymbopogon refractus, Aristida* sp., *Bothriochloa macra, Austrostipa* sp., *Rytidopserma* sp., *Desmodium* sp., *Lomandra* sp., *Wahlenbergia* sp., *Vittadinia* sp., *Calotis lappulacea*, and *Zornia dyctiocarpa*.

On steeper slopes, the canopy is dominated by *Eucalyptus tereticornis* and *Eucalyptus albens-moluccana* intergrade with *Brachychiton populneus* and *Ficus rubiginosa* occasionally present as a small tree. The understorey is much shrubbier within these areas, and consists of *Olearia viscidula*, *Cassinia* sp., *Bursaria spinosa*, and *Breynia oblongifolia*. The ground cover contains similar species those found in lower lying and less steep areas. In sheltered sites, Backhousia myrtifolia and Melaleuca stypheloides comprise a significant component of the midstorey.

An area of old growth vegetation is present within the study area, near the homestead by Joorilands crossing. This area contains over 20 very large Eucalyptus albens-moluccana with a diameter at breast height (DBH) of over 1.5 m.

Because of past land use practices, exotic weed species are present primarily through the groundcover stratum of this PCT. Exotic species present within the PCT include *Bidens* sp., *Echium plantaginuem, Senecio madgascariensis, Verbena* sp., and *Sida rhomifolia*. Notwithstanding, the PCT was found to be in moderate to good condition and consists as two condition classes: Moderate/Goodand Moderate/Good_derived native grassland.

This PCT is broadly equivalent to three map units described in NPWS (2003a):

- MU53 Devonian Red Gum-Grey Box Woodland
- MU51 Devonian Red Gum-Yellow Box Woodland
- Components of MU52 Devonian Red Gum-Ironbark Woodland.

It is also broadly equivalent to 'DSF p35: Wollondilly-Cox-Shoalhaven Gorge Woodland' in Tozer et al. (2010).

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
4) HN532 (PCT 860) **Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion**	**Dry Sclerophyll Forest (shrub/grassy sub-formation)**	**Central Gorge Dry Sclerophyll Forests**	**25**	**963.64**	**226.04**
Occurs throughout study area, primarily occurring on the escarpment slopes surrounding Lake Burragorang, and along the main river tributaries such as the Nattai River, Little River, Green Wattle Creek, and Kedumba River. This community occurs as a dry, open forest or woodland on exposed slopes containing shallow, infertile soils. These soils are predominantly colluvial in nature comprising a mix of eroded Triassic Sandstone material and Permian sediments from the underlying strata. This PCT often occurs adjacent to the other two dominant communities; PCT 871: Grey Gum shrubby open forest on gorge slopes of the Blue Mountains, Sydney Basin Bioregion, and PCT 1401: Narrow-leaved Ironbark – Forest Red Gum on rocky slopes of the Lower Burragorang Gorge, Sydney Basin Bioregion. Compared to many of the other Eucalyptus-dominated communities in the Warragamba Special Area, this community has a relatively sparse and low canopy. This canopy is dominated by *Eucalyptus fibrosa, Eucalyptus punctata* and *Eucalyptus eugenioides*. While not as common as *Eucalyptus fibrosa, Eucalyptus crebra* was also recorded occurring in this community. *Allocasuarina littoralis, Angophora bakeri* and *Brachychiton populneus* make up a sparse sub-canopy. An open shrub layer occurs in this community, consisting of species such as *Persoonia linearis, Notelaea longifolia, Bursaria spinosa, Bursaria longisepala* and *Leptospermum polygalifolium*. A diverse ground-cover was recorded throughout this community. Component species include *Aristida vagrans, Lomandra multiflora* ssp. *multiflora, Lomandra glauca, Pomax umbellata, Gahnia aspera* and *Dianella revoluta*. Fewer fern and vine taxa were recorded with *Cheilanthes sieberi* and *Glycine clandestina* being the most common. The lower recorded fern and vine species richness may have been a result of an extended dry period prior to and during surveys. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU48 Escarpment Slopes Dry Ironbark Woodland' in NPWS (2003a) and 'DSF p5: Burragorang Hillslope Forest' in Tozer *et al*. (2010).					
5) HN533 (PCT 862) **Grey Gum - Hard Leaved Scribbly Gum woodland of the Cox River Valley**	**Dry Sclerophyll Forest (shrubby sub-formation)**	**Sydney Sand Flats Dry Sclerophyll Forests**	**20**	**84.62**	**10.97**
Occurs from the edge of Lake Burragorang near the Coxs River, Green Wattle Creek, and from the Kedumba Valley. All locations are exposed and supported by low-nutrient skeletal soils. This community is a low, dry woodland that is not dominated by any one canopy species despite what the PCT name suggests. *Eucalyptus signata, Eucalyptus crebra, Eucalyptus eugenioides* and *Angophora bakeri* have all been recorded as canopy species. The sub-canopy is sparse with the most common species being *Acacia binervia*. A diverse shrub layer exists comprising of species such as *Lissanthe strigosa, Grevillea arenaria, Persoonia linearis, Banksia spinulosa* and the threatened wattle *Acacia clunies-rossiae*. Few fern taxa were recorded occurring in this PCT with *Cheilanthes* sieberi being the most common. Several climbers and vines were found to occur with species such as Hardenbergia violacea, Glycine clandestina and Parsonsia straminea occurring commonly. species such as *Xanthorrhoea media, Dianella revoluta, Cyathochaeta diandra* and Lo*mandra obliqua* occurred frequently throughout the understorey. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU47 Exposed Permian Sandstone Woodland' in NPWS (2003a) and 'DSF p5: Burragorang Hillslope Forest' in Tozer et al. (2010).					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
6) HN535 (PCT 870) **Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges, Sydney basin Bioregion**	**Dry Sclerophyll Forest (shrub/grassy sub-formation)**	**Central Gorge Dry Sclerophyll Forests**	**10**	**91.26**	**22.17**
Occurs within the north of the study area, along the Coxs River, Kedumba River, and around the edge of Lake Burragorang north from Butcher's Creek. The community is a tall open forest, characterised by an open shrubby understorey with a ground cover of grasses, forbs and moisture loving herbs. It occurs on rocky, sandy clay loam soils and the sheltered aspect of slopes. The dominant canopy species is *Eucalyptus punctata*, however other species such as *Eucalyptus eugenioides, Eucalyptus crebra* and *Eucalyptus tereticornis* also occur. The small tree layer is primarily made up of *Allocasuarina torulosa*. The open shrub layer is generally consistent between locations, comprising *Breynia oblongifolia, Indigofera australis, Olearia viscidula* and *Bursaria spinosa*. The ground layer consists of *Pratia purpurascens, Dichondra repens, Echinopogon ovatus* and *Microlaena stipoides*. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU21 Kanangra Gorge Sheltered Grey Gum Forest' in NPWS (2003a) and 'DSF p37: Kowmung-Wollondilly Grassy Gorge Forest' in Tozer et al. (2010).					
7) HN536 (PCT 871) **Grey Gum shrubby open forest on gorge slopes of the Blue Mountains, Sydney Basin Bioregion**	**Dry Sclerophyll Forest (shrub/grassy sub-formation)**	**Central Gorge Dry Sclerophyll Forests**	**5**	**800.41**	**212.92**
Occurs throughout the study area, from the Kedumba River in the north to Nattai and Little Rivers in the south and surrounding the edge of Lake Burragorang. The community occurs on the colluvial slopes beneath the escarpment cliffs and walls, on typically infertile soils derived from a mixture of eroded sandstone from the surrounding walls and Permian sediments from the Shoalhaven Group parent geology. On protected sites and within sheltered aspects, generally immediately beneath the escarpment walls, the PCT is dominated by *Eucalyptus deanei,* with *Syncarpia glomulifera* subsp. *glomulifera*, *Eucalyptus punctata, Eucalyptus eugenioides* and *Angophora floribunda* also present at lower densities. The shrubby midstorey consists of *Allocasuarina torulosa, Pittosporum undulatum, Acacia decurrens* and *Melaleuca stypheloides*. The understorey predominantly contains ferns, grasses, graminoids, and an abundance of vines and climbers. Species within this stratum include Pellea falcata, Doodia aspera, Adiantum aethiopicum, Cissus hypoglauca, Stephania japonica, Tylophora barbata, Marsdenia suaveolens, and Gynochthodes jasminoides. In less protected and sheltered areas, the PCT is slightly drier and as such Eucalyptus deanei occurs less frequently. Within these areas, the canopy is dominated by Eucalyptus punctata and Eucalyptus eugenioides, with Eucalyptus tereticornis, Syncarpia glomulifera subsp. glomulifera, and Angophora floribunda occurring less frequently. The understorey consists of a relatively sparse shrub layer of Breynia oblongifolia, Persoonia linearis, and Olearia viscidula, while the ground cover species consist of Microlaena stipoides, Oplismenus aemula, Dichondra repens, and Hibbertia sp. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU13 Sheltered Escarpment Blue Gum Forest' and 'MU14 Escarpment Grey Gum Forest' in NPWS (2003a) and 'DSF p88: Burragorang Escarpment Forest' in Tozer et al. (2010).					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
8) HN537 (PCT 875) **Grey Myrtle - Lilly Pilly dry rainforest in dry gullies of the Sydney Basin Bioregion and South East Corner Bioregion**	**Rainforest**	**Dry Rainforest**	**10**	**16.07**	**5.62**
Occurs within one location along Cedar Creek which feeds into the Coxs River. At the time, Cedar Creek contained water and was running through a dry, sheltered gorge. HN537 occurred as a closed forest with a larger number of species compared to the similar HN538: Grey Myrtle dry rainforest of the Sydney basin Bioregion and South East corner Bioregion. The canopy was composed of species such as *Acmena smithii, Ceratopetalum apetalum* and *Backhousia myrtifolia*. A sub-canopy including *Glochidion ferdinandi* var. *ferdinandi*, *Melaleuca styphelioides* and *Acacia implexa* was also prevalent throughout this community. Due to its location along Cedar Creek a number of riparian species such as *Casuarina cunninghamiana, Tristaniopsis laurina* and *Stenocarpus salignus* were recorded. The observed shrub-layer was relatively sparse with the most common species being *Pittosporum undulatum, Melicytus dentatus* and *Alectryon subcinereus*. Like most rainforests, a diverse assemblage of climbers and vines was present in this community. Recorded species include Pandorea pandorana, Gynochthodes jasminoides, Smilax australis, *Cissus antarctica* and *Scaropetalum harveyanum*. A diverse groundcover with an assemblage of species comprising of immigrants from the surrounding dry gorge slopes and riparian zone was recorded. Such species include *Dichondra repens*, *Viola* sp., *Pellaea falcata, Lomandra longifolia, Entolasia marginata* and *Hydrocotyle* sp. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'RF p40: Temperate Dry Rainforest' in Tozer et al. (2010). An equivalent vegetation community is not mapped in NPWS (2003a).					
9) HN538 (PCT 877) **Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion**	**Rainforest**	**Dry Rainforest**	**25**	**231.16**	**50.15**
This was the most common rainforest community recorded in the Warragamba Special Area. It was recorded occurring on a variety of different soil types and adjacent to most other communities. Grey myrtle dry rainforest occurred in any form of sheltered terrain where moisture could accumulate, from the steep slopes of the Coxs River Valley to the thin, incised creek lines that ran into the Nattai River. From analysis of The Native Vegetation of the Warragamba Special Area (NPWS 2003a) and on-the-ground surveys it appears that this community is replaced by other rainforest communities such as PCT 769: Coachwood - Lilly Pilly warm temperature rainforest in moist sandstone gullies, Sydney Basin Bioregion, only when terrain becomes very steep and a semi-permanent water source is present. This PCT is broadly equivalent to two maps units described by NPWS (2003a), 'MU3 Grey Myrtle Dry Rainforest' and 'MU49 Dry Alluvial Paperbark Woodland'. Both these map units were recorded during the current survey. Of these, there is better correlation between the descriptions of MU3 and HN538 in terms of species composition and landscape position. MU48 is similar in structure to MU3, especially within narrow gullies, the dominant floristics are substantially different with MU3 being dominated by Backhousia myrtifolia and MU48 by Melaleuca stypheloides. MU48 has been included as part of this PCT because SMEC was unable to find a PCT which more accurately described the floristics and structure of MU48 mapped vegetation. While HN538 is a 'best fit' PCT for the vegetation observed, it does not fit the vegetation description particularly well. HN538 is broadly equivalent to 'RF p38 Grey Myrtle Dry Rainforest' in Tozer et al. (2010). A closed canopy dominated by *Backhousia myrtifolia* and *Melaleuca stypheloides* occurs throughout the community. In some areas, the species is dominated by only one of the species, and within some areas there is a mixture of both species. Emergent trees such as *Casuarina cunninghamiana, Angophora floribunda* and *Eucalyptus punctata* can occur on the edges of this community. A sparse sub-canopy was recorded that includes species such as *Ficus coronata, Pittosporum undulatum* and *Alphitonia excelsa*. A diverse assemblage of ferns was recorded including *Adiantum aethiopicum, Pellaea falcata, Pyrrosia rupestris, Doodia aspera* and *Pteris tremula*. Several vine species were also recorded; however, this observed assemblage of species did not differ greatly from					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
those found in other wet communities such as PCT 941: Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion. Such species include *Cissus antarctica, Cissus hypoglauca, Stephania japonica* and *Eustrephus latifolius*. The shrub and ground-cover layers are sparse due to the intermittent light reaching the forest floor. Recorded shrub species include *Notelaea longifolia, Melicytus dentatus* and *Pittosporum revolutum*. Ground-cover species common throughout the special area were also discovered throughout this community such as *Lomandra longifolia, Dichondra repens, Microleana stipodes*, and *Stellaria flaccida*. Epiphytic species such as Plectorrhiza tridentata also occurred in this community. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good).					
10) HN553 (PCT 941) **Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion**	**Forested Wetlands**	**Coastal Floodplain Wetlands**	**5**	**378.04**	**104.51**
Occurs on river flat alluvium in the Sydney Basin Bioregion was recorded in four areas of the study area; the Kedumba Valley, Nattai River Valley, Little River Valley, and Green Wattle Creek. These locations are within the river's riparian area and as such are supported by sandy alluvial soils. Variation between the three occurrences of this community was recorded, with the greatest difference being the presence of the threatened species *Eucalyptus benthamii* in the Kedumba Valley. The Mountain Blue Gum – Thin-leaved Stringybark open forest community occurs as a forest that can reach heights greater than 35 m. The characteristic tall canopy is dominated by *Eucalyptus deanei,* however in the Kedumba Valley *Eucalyptus benthamii* may be the dominant species. Other common canopy species include *Eucalyptus eugenioides, Casuarina cunninghamiana* and *Angophora floribunda*. The tall semi-open canopy allows for the development of a shrub-layer that can include species such as *Bursaria spinosa, Podocarpus spinulosus, Breynia oblongifolia* and *Elaeocarpus reticulatus*. Climbers and vines are common in this community, in some locations even being the dominant component of the ground-layer. Common species include *Cissus hypoglauca, Parsonsia straminea, Stephania japonica* and *Tylophora barbata*. Other common ground cover species include *Pratia purpurascens, Commelina cyanea, Microlaena stipoides, Entolasia marginata* and *Oplismenus imbecillis*. This PCT supports low levels of exotic species within areas and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU23: Burragorang River Flat Forest' as described in NPWS (2003a), and 'RF p40: Temperate Dry Rainforest' in Tozer et al. (2010).					
11) HN564 (PCT 1081) **Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion**	**Dry Sclerophyll Forest (shrubby sub-formation)**	**Sydney Hinterland Dry Sclerophyll Forest**	**40**	**7.37**	**1.92**
Occurs on moderately exposed, sloping sandstone terrain. This community was confirmed within the study area as occurring on sandy-clay soils. This PCT is equivalent to 'MU27 Burragorang Sandstone Dry Shrub Forest' in NPWS (2003a) 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 (2003a) as consisting of *Eucalyptus punctata, Angophora costata, Syncarpia glomulifera* subsp. *glomulifera* and *Corymbia gummifera*, growing to a mean height of 20 m. SMEC surveys found these species as occurring within the study area, as well as *Corymbia eximia* and *Eucalyptus pilularis*. The recorded shrub layer was composed 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 study area as one condition class (Moderate/Good).					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
12) HN566 (PCT 1083) **Red bloodwood -scribbly gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion**	**Dry Sclerophyll Forest (shrubby sub-formation)**	**Sydney Coastal Dry Sclerophyll Forest**	**17**	**25.14**	**6.57**
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' in NPWS (2003a) and 'DSF p131 Coastal Sandstone Ridgetop Woodland' in Tozer *et al*. (2010). The extent of this community across the study area includes ridgetops on skeletal soils, primarily within the north and south west of the study area. The canopy within the study area 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 study area is variable across the area, dependent upon seral stage and fire frequency. The stratum is composed 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. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good).					
13) HN568 (PCT 1086) **Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion**	**Dry Sclerophyll Forest (shrubby sub-formation)**	**Sydney Hinterland Dry Sclerophyll Forest**	**20**	**100.01**	**25.72**
Occurs primarily on the southern side of the Warragamba Gorge within the study area, although small areas were mapped occurring on the northern side of the gorge also. 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' in NPWS (2003a). In Tozer et al. (2010) it is equivalent to 'DSF p144: Wingecarribee-Burragorang Sandstone Forest'. Within the study area, the canopy of this community is open and between 15 to 25 m tall, consisting of species such as *Corymbia gummifera, Corymbia eximia, Angophora costata* and *Syncarpia glomulifera* subsp. *glomulifera* and stringybark species like *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 study area as one condition class (Moderate/Good).					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
14) HN574 (PCT 1105) **River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion**	**Forested Wetlands**	**Eastern Riverine Forests**	**40**	**368.15**	**84.23**
Borders major watercourses and creek lines such as the Wollondilly River, Nattai River, Kowmung River and Coxs River. Vegetation grows in alluvial sediments that have settled amongst the boulders and pebbles of these rivers and creeks. The soils in this community are dominated by sands which begin to intergrade with a clay loam as they extend away from the water's edge. The canopy is dominated by *Casuarina cunninghamiana* subsp. *cunninghamiana* with *Angophora floribunda* occurring less frequently. In areas where this community occurred adjacent to HN533, *Eucalyptus deanei* could also occur infrequently. Of note was the presence of *Grevillea robusta*, a rainforest species native to Northern NSW and Queensland, in a section of River Oak open forest along Sheehys Creek. In this circumstance, the recorded *G. robusta* had most likely naturalised from planted individuals in Western Sydney. A variable sub-canopy was recorded throughout the extent of this community in the study area. In areas adjacent to dry rainforest, *Backhousia myrtifolia* occurred as a sub-canopy species while in areas adjacent to HN533, *Pittosporum undulatum* and *Acacia decurrens* were present. *Melaleuca styphelioides* and *Brachychiton populneus* occurred sporadically in this community. The species recorded in the lower stories varied across the study area. While the shrub layer was generally sparse, commonly recorded species include Bursaria spinosa, Melicytus dentatus and *Phyllanthus gunnii*. Species such as *Breynia oblongifolia, Trema aspera* and *Clerodendrum tomentosum* were common in some areas but did not consistently occur in this community across the Special Area. Common native climbers include *Stephania japonica* and *Cissus hypoglauca*, while the exotic climber *Araujia sericifera* was prevalent. The native ground-cover species include *Cheilanthes sieberi, Pellaea falcata, Geranium homeanum* and *Microlaena stipoides* which would often be present in large swathes. Weed and exotic species where uncommon in this community most likely through the transport of seeds and other plant material through the adjacent watercourses. The most common exotic species were *Bidens pilosa, Sida rhombifolia* and *Tradescantia fluminensis*. This PCT supports low levels of exotic species within areas and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU39: Tablelands River Oak Forest' as described in NPWS (2003a), and 'FoW p32: Riverbank Forest' in Tozer *et al*. (2010).					
15) HN598 (PCT 1246) **Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains, Sydney Basin Bioregion**	**Dry Sclerophyll Forest (shrubby sub-formation)**	**Sydney Hinterland Dry Sclerophyll Forest**	**10**	**33.10**	**9.71**
Occurs in two locations, along the flootslopes of the Tonalli Range between Irish Bay and Lacys Creek, and along the Nattai River close to where the Nattai River joins the Wollondilly River. This PCT occurs on colluvial soils derived from Hawkesbury Sandstone. Dominant canopy species within this PCT include *Eucalyptus punctata and Eucalyptus agglomerata*, with occasional presence of *Eucalyptus piperita*, and a typical canopy height of 25 m. The sandy soils observed in this community support *Leptospermum polygalifolium* subsp. *polygalifolium, Banksia spinulosa* var. *spinulosa* and *Hakea sericea* throughout the sclerophyll shrub layer. The ground cover commonly consists of *Dianella caerulea, Entolasia stricta, Gonocarpus tetragynus* and *Lomatia silaifolia*. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU: Tonalli Escarpment Dry Shrub Forest' as described within NPWS (2003a), and 'DSF p244: Megalong-Tonalli Sandstone Forest' within Tozer *et al*. (2010).					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
16) HN606 (PCT 1284) **Turpentine - smooth-barked Apple moist shrubby forest of the lower Blue Mountains, Sydney Basin Bioregion**	**Wet Sclerophyll Forests (Shrubby sub-formation)**	**North Coast Wet Sclerophyll Forest**	**5**	**84.24**	**20.82**
Composed of two communities that were mapped and identified in The Native Vegetation of the Warragamba Special Area (NPWS 2003a); MU08 Sandstone Moist Blue Gum Forest and MU09 Sheltered Sandstone Intermediate Blue Gum Forest. This PCT was recorded from within Warragamba Gorge where it occurred on both sides of the gorge walls in relatively sheltered positions. In areas that were more exposed, the PCT community graded into HN564 and HN556. When conditions became wetter and more protected, this community was occasionally found adjacent to HN517. The community is a tall to very tall (≥50 m) eucalypt forest with a variable canopy that depends on the protection and aspect a particular site receives. Less exposed sites of this community are characterised by the canopy reaching heights over 50 m. *Eucalyptus deanei* and *Syncarpia glomulifera* subsp. *glomulifera* are the dominant canopy species under these conditions. As this community occupied more exposed locations two species of Angophora were recorded; *Angophora costata* and *Angophora floribunda*. A diverse assemblage of sub-canopy species was recorded by SMEC including, *Allocasuarina torulosa, Pittosporum undulatum, Acmena smithii* and *Glochidion ferdinandi* var. *ferdinandi*. Due to the dense canopy cover, the ground cover was primarily made up of ferns and vines. Recorded fern species include *Adiantum aethiopicum, Blechnum cartilagineum* and *Blechnum parrisiae*. The recorded vine assemblage was highly diverse compared to other communities in the catchment, comprising of species such as *Cissus hypoglauca, Gynochthodes jasminoides, Eustrephus latifolius, Stephania japonica* and *Smilax australis*. Areas of this community which were more exposed typically had a less dense canopy but a more divers shrub layer and sub-canopy. Species that would occur in these exposed areas include *Clerodendrum tomentosum, Notelaea longifolia* and *Astrotricha latifolia*. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good).					
17) HN607 (PCT 1292) **Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion**	**Forested Wetlands**	**Eastern Riverine Forests**	**10**	**36.58**	**14.66**
Occurs within in the predominantly dry sections of river bed in the Nattai and Little Rivers. Large sandstone boulders and course alluvial sands are interrupted by sections of river that still contain water and sections of beach marking where the river would flow after times of heavy precipitation. The community that SMEC has surveyed and mapped is different to what has been described in The Native Vegetation of the Warragamba Special Area (NPWS 2003a) as it occurs in flatter, wider and sandier river beds compared to the incised, rocky gullies provided in the mapping methodology. This community occurs as a distinct low scrub or low forest, less than 5 m tall. Emergent species such as *Casuarina cunninghamiana* subsp. *cunninghamiana* and *Eucalyptus deanei* are rare and reflect the dominant canopy species of the surrounding communities. The canopy is composed of small trees or tall shrubs such as *Tristaniopsis laurina, Melaleuca linariifolia* and *Stenocarpus salignus*. A diverse assemblage of smaller shrubs was observed in the community, composed of species such as *Correa reflexa, Grevillea arenaria, Dodonaea triquetra* and *Persoonia linearis*. The ground-cover only occurs in small sections that are slightly elevated from the river's high water mark or where small patches of higher nutrient soil have collected. Ground-cover species that were recorded in this community include *Lomandra longifolia, Pimelea linifolia, Adiantum aethiopicum* and *Oplismenus imbecillis*. This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). This PCT is broadly equivalent to 'MU6: Sandstone Riparian Scrub' as described in NPWS (2003a), and 'FoW p58: Sandstone Riparian Scrub' in Tozer *et al*. (2010).					

Biometric vegetation types (BVT) code Plant community types (PCT) name	Vegetation formation	Vegetation class	PCT cleared within HN catchment (%)	Area within study area (ha)[1]	Area within upstream impact area (ha)
18) HN557 (PCT 1401) **Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion**	**Grassy Woodlands**	**Western Slopes Grassy Woodlands**	**55**	**957.26**	**302.81**

Occurs across the study area from the Lower Wollondilly River Valley and along the Nattai and Little River, northwards to the confluence of the Kedumba River and Coxs River. This PCT typically occurs on loamy soils derived from a combination of fertile Porphyry sediments and Permian geology.

Meets the Final Determination for White Box Yellow Box Blakey's Red Gum Woodland under the BC Act, and White Box-Yellow Box-Blakey's Red Gum Grassy Woodland and Derived native Grassland under the EPBC Act. Consists of an open grassy eucalypt woodland with a variable understorey of shrubs, grasses, forbs and graminoids. There are three variants within this PCT which are broadly equivalent to three map units described within NPWS (2003a):

- Components of MU52 Devonian Red Gum-Ironbark Woodland
- MU50 Douglas Scarp Woodland
- MU32 Permian Footslopes Grassy Grey Box Forest.

The most common variant of the PCT is the one which is broadly equivalent to components of MU52 Devonian Red Gum-Ironbark Woodland. This variant mostly occurs around Lake Burragorang, especially towards the mouth of the Wollondilly River. This variant of the community is dominated by *Eucalyptus tereticornis, Eucalyptus glaucina, Eucalyptus albens-moluccana* intergrade, and occasional *Eucalyptus crebra* and *Eucalyptus melliodora* within the canopy. The midstorey is often open, containing *Acacia implexa, Bursaria spinosa*, and *Exocarpus strictus*. The understorey contains a variety of shrubs, grasses, and forbs including *Astroloma humifusum, Lissanthe strigosa, Chielanthes sieberii, Cymbopogon refractus, Aristida vagans*, and *Wahlenbergia gracilis*.

Another variation of the PCT is also common near the mouth of the Wollondilly River, however, small patches occur up along the Coxs River. This variant is broadly equivalent to MU50 Douglas Scarp Woodland. This variant is distinctive in the dominance *Eucalyptus crebra* and *Callitris endlicheri* in the canopy, with *Eucalyptus tereticornis, Eucalyptus punctata*, and *Eucalyptus moluccana* occurring as minor associates. The midstorey is dominated by *Acacia binervia*. The understorey consists of *Persoonia linearis, Lissanthe strigosa, Astroloma humifusum, Chielanthes sieberii*, and *Cymbopogon refractus*.

The third variant of HN557 is broadly equivalent to MU32 Permian Footslopes Grassy Grey Box Forest and is found widely around Lake Burragorang and along within the Nattai River valley. This variant is dominated by *Eucalyptus moluccana*, with *Eucalyptus tereticornis, Eucalyptus fibrosa* and *Eucalyptus crebra* occurring occasionally. The midstorey is open, consisting of *Acacia falcata* and *Exocarpus cupressiformis*, while the understorey contains a variety of shrubs and grasses including *Lissathe strigosa, Bossiaea buxifolia, Cymbopogon refractus*, and *Aristida vagans*.

This PCT is almost entirely weed free and occurs within the study area as one condition class (Moderate/Good). Much of the grassy understorey of this PCT had dried off due to lack of rain prior to and during field surveys.

This PCT is broadly equivalent to 'DSF p202: Burragorang Rocky Slopes Woodland' in Tozer *et al*. (2010).

Note 1: Total area of PCTs is 5,214 hectares. The study area is 5,280 hectares and the difference (66 hectares) is related to measuring accuracy, topography changes and cleared areas.

8.4.2 Vegetation zones

The PCTs occurring within the study area 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 21 vegetation zones. These are described and mapped in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 4.5, Figure 4-5) and summarised in Table 8-23.

All PCTs identified within the study area were assessed as being in Moderate/Goodcondition in line with the broad condition definitions outlined in the FBA. Seventeen of the 18 PCTs were assessed as being within one broad condition state and consisted of largely homogenous tracts of vegetation. The other PCT consisted of two varying condition classes, and thus split into two vegetation zones. Hence, a total of 19 vegetation zones were identified within the study area. Detailed maps are provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Appendix L). Vegetation zones were mapped and delineated to the survey area only, not to the boundary of the study area.

Note that Vegetation Zone 4 and Vegetation Zone 5 fall wholly within the development site (construction area, see Table 8-4), and therefore impacts to these vegetation zones are addressed in Chapter 10 and Appendix F3 (Construction BAR).

Table 8-23. Vegetation zones within the study area

Vegetation zone	PCT name	Condition*
1.	HN564: Red Bloodwood – Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	Moderate/Good
2.	HN566: Red Bloodwood – scribbly gum heathy woodland on sandstone plateaux of the Sydney Basin Bioregion	Moderate/Good
3.	HN568: Red Bloodwood – Sydney Peppermint – Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	Moderate/Good
4.	Development site (construction area). See Chapter 10 and Appendix F3 (Construction BAR)	N/A
5.	Development site (construction area). See Chapter 10 and Appendix F3 (Construction BAR)	N/A
6.	HN553: Mountain Blue Gum – Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion	Moderate/Good
7.	HN538: Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East corner Bioregion	Moderate/Good
8.	HN537: Grey Myrtle - Lilly Pilly dry rainforest in dry gullies of the Sydney Basin Bioregion and South East Corner Bioregion	Moderate/Good
9.	HN536: Grey Gum shrubby open forest on gorge slopes of the Blue Mountains Sydney Basin Bioregion	Moderate/Good
10.	HN535: Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges Sydney Basin Bioregion	Moderate/Good
11.	HN533: Grey Gum - Hard Leaved Scribbly Gum woodland of the Coxs River Valley	Moderate/Good
12.	HN532: Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains Sydney Basin Bioregion	Moderate/Good
13.	HN527: Forest Red Gum - Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion	Moderate/Good
14.	HN527: Forest Red Gum – Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands Bioregion	Moderate/Good DNG

Vegetation zone	PCT name	Condition*
15.	HN525: Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges Sydney Basin Bioregion	Moderate/Good
16.	HN517: Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies Sydney Basin Bioregion	Moderate/Good
17.	HN557: Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion	Moderate/Good
18.	HN607: Water Gum - Coachwood riparian scrub along sandstone streams Sydney Basin Bioregion	Moderate/Good
19.	HN606: Turpentine - smooth-barked Apple moist shrubby forest of the lower Blue Mountains Sydney Basin Bioregion	Moderate/Good
20.	HN598: Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains Sydney Basin Bioregion	Moderate/Good
21.	HN574: River Oak open forest of major streams Sydney Basin Bioregion and South East Corner Bioregion	Moderate/Good

* Condition names reflect options available within the BioBanking Credit Calculator rather than on-ground condition

8.4.3 Threatened ecological communities

Based on the VIS Classification Database, six PCTs identified within the study area have the potential to be a component of six different threatened ecological communities (TEC) listed under both the BC Act and EPBC Act. These are:

- White Box Yellow Box Blakely's Red Gum Woodland listed as Critically Endangered under the BC Act and Critically Endangered under the EPBC Act
- Western Sydney Dry Rainforest in the Sydney Basin Bioregion listed as Endangered under the BC Act and Critically Endangered under the EPBC Act
- River-Flat Eucalypt Forest on Coastal Floodplains listed as Endangered under the BC Act and Critically Endangered under the EPBC Act
- Sydney Turpentine Ironbark Forest listed as Critically Endangered under the BC Act and Critically Endangered under the EPBC Act
- Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion listed as Endangered under the BC Act and Critically Endangered under the EPBC Act.

PCTs were 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. In addition, the vegetation within the study area 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 six TECs are provided in Table 8-24. The distribution of TECs across the study area is shown on Figure 8-16.

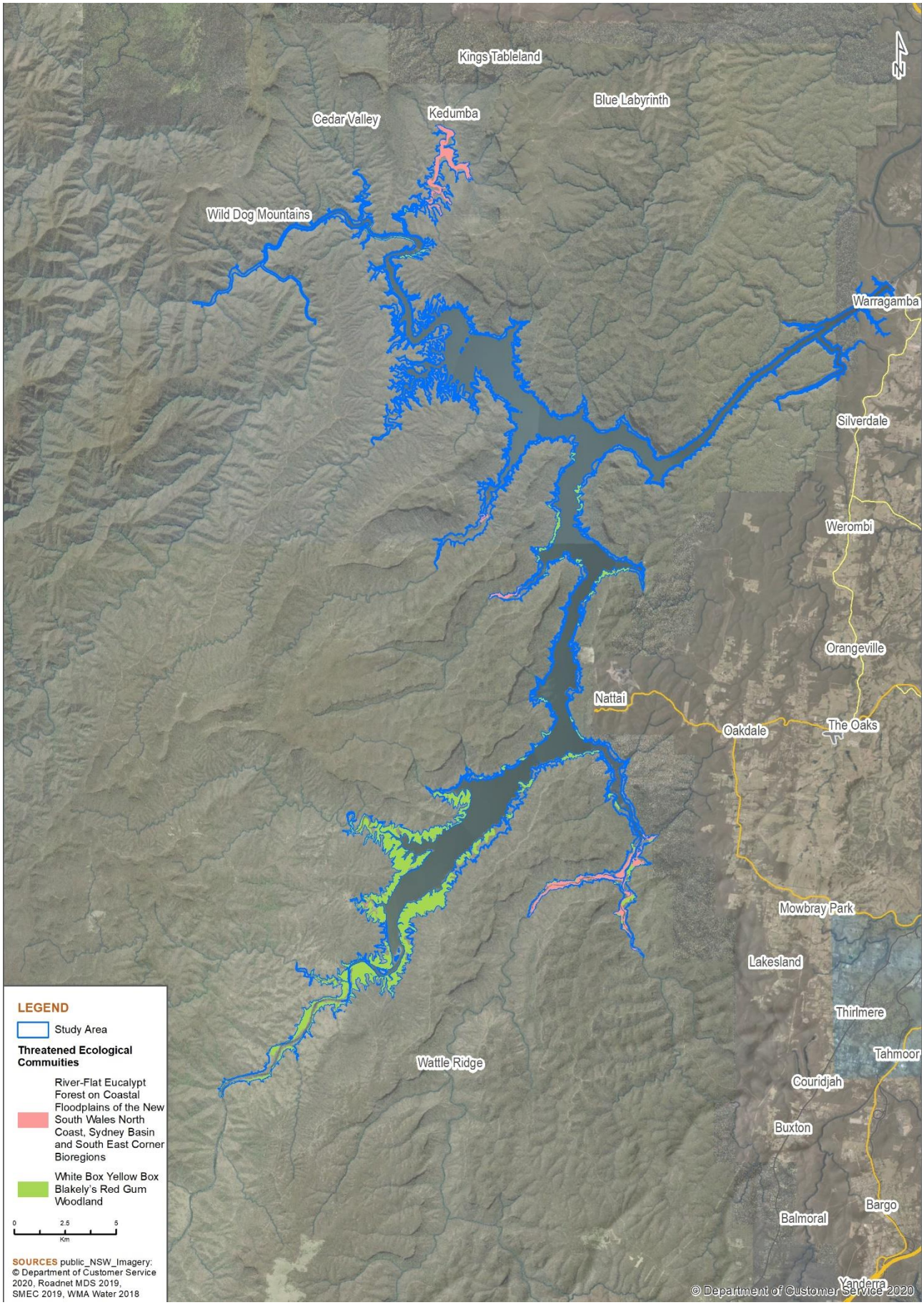
Further discussion and detailed maps are provided in Appendix F1 (Biodiversity Assessment Report – Upstream).

Table 8-24. TECs associated with PCTs occurring within the study area

BVT Code	PCT Name	TEC Name	BC Act status	EPBC ACT status	Assessed as TEC
HN527	Forest Red Gum - Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands	White Box Yellow Box Blakely's Red Gum Woodland	Critically Endangered	Critically Endangered	Yes (Both BC and EPBC Acts)
HN538	Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East Corner Bioregion	Western Sydney Dry Rainforest in the Sydney Basin Bioregion	Endangered	Critically Endangered	No
HN553	Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion	River-Flat Eucalypt Forest on Coastal Floodplains	Critically Endangered	Critically Endangered[1]	Yes
HN557	Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion	White Box Yellow Box Blakely's Red Gum Woodland	Critically Endangered	Critically Endangered	Yes (Both BC and EPBC Acts)
HN606	Turpentine - smooth-barked Apple moist shrubby forest of the lower Blue Mountains, Sydney Basin Bioregion	Blue Mountains Shale Cap Forest	Endangered	Critically Endangered	No
		Sydney Turpentine-Ironbark Forest	Critically Endangered	Critically Endangered	No

1. Gazetted 6 December 2020

Figure 8-16. Distribution of TECs across the study area



8.5 Threatened species and populations

8.5.1 Overview

Threatened species potentially occurring within the study area were assessed in accordance with the FBA and site surveys. The FBA process is outlined in Section 8.2.3, while definitions for ecosystem credit species and species credit species are provided in Section 8.2.8. The type and occurrence of threatened species and communities that could potentially be impacted by the Project are detailed in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5).

8.5.2 Predicted ecosystem credit species

The BioBanking Credit Calculator (BBCC) generates a list of predicted ecosystem credit species from numerous inputs. The FBA defines values as the ability of a species to respond to improvement in site value or other habitat improvement at a biobanking site with management actions, and is based on an assessment of effectiveness of management actions, life history characteristics, naturally rare species, and poorly known species.

Predicted fauna ecosystem credit species were determined using the BBCC and the criteria listed in Table 8-25. Each species was associated with relevant vegetation zones (19 Zones), which are described in Section 8.4.2.

A list of predicted ecosystem credit species is provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5.2, Table 5.1).

Table 8-25. FBA criteria used to predict ecosystem credit species within the study area

Criterion	IBRA subregion			
	Burragorang	**Bungonia**	**Kanangra**	**Wollemi**
Associated PCTs	HN536; HN525; HN553; HN538; HN532; HN535; HN557; HN566; HN568; HN533; HN517; HN598; HN607; HN527; HN574; HN606; HN537	HN574; HN527; HN538; HN557; HN553	HN574; HN536; HN525; HN535; HN538; HN557; HN532; HN553; HN537	HN568; HN536; HN566; HN532; HN533; HN606; HN517; HN564; HN607
Percent native vegetation in the linear assessment buffer[1]	64%	51%	85%	78%
Condition of vegetation	Moderate to good (all vegetation zones)	Moderate to good (all vegetation zones)	Moderate to good (all vegetation zones)	Moderate to good (all vegetation zones)
Patch size (ha)	1001+	1001+	1001+	1001+
Credit type	Ecosystem	Ecosystem	Ecosystem	Ecosystem

1: Linear assessment buffer used in FBA landscape assessment

8.5.3 Candidate species credit species

The BBCC generates a list of candidate species credit species from numerous inputs including classification of the species as a species credit species, the distribution of the species within the same IBRA subregion as the study area and the presence of habitat features or components associated with the species. The habitat features that have been assessed as present within the study area are as follows:

- land within 40 metres of heath, woodland or forest with sandy or friable soils.

- land within 250 metres of termite mounds or rock outcrops
- rainforest or tall open wet forest with understory and/or leaf litter and within 100 metres of streams
- swamps, swamp margins or creek edges
- land within 100 metres of emergent aquatic or riparian vegetation
- land containing bark or leaf litter accumulation
- 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
- rainforest or tall open wet forest with understory and/or leaf litter and within 100 metres of streams
- land containing escarpments, cliffs, caves, deep crevices, old mine shafts or tunnels
- 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 100 metres of stream or creek banks
- land within 1 km of rock outcrops or cliff lines
- land below 1,000 metres altitude and within 40 metres of rainforest or eucalypt forest with deep litter.

Species credit species that have been generated by the BBCC as candidate species for this assessment are listed in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 5.3.1, Table 5.5). This includes 88 flora species or populations and 35 fauna species. 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 study area on *Atlas of NSW Wildlife* Database
- are known or predicted to occur within the IBRA subregions within which the study area is located
- have been confirmed as occurring within the study area 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 Threatened Species Profile Database or OEH Threatened Species Profile do not occur, or have been substantially degraded such that the species is unlikely to occur, on the study area
- an expert report has stated that the species is unlikely to occur
- the species is a vagrant species and unlikely to occur within the study area.

In addition, three species, *Callistemon linearifolius, Eucalyptus glaucina* and *Grammitis stenophylla*, not predicted within the BBCC or recorded in the database searches were observed by SMEC in the study area so have been added to the number of Species Credit Species requiring consideration.

8.6 Biodiversity requiring further consideration

Biodiversity requiring further consideration is outlined in Attachment C of OEH's input into the SEARs (see Table 8-1). Table 8-26 outlines the species included within the SEARs, applicable IBRA subregion, whether it was recorded within the current surveys, and justification for inclusion as a matter for further consideration.

Table 8-26. Biodiversity requiring further consideration recorded within the study area

Genus species	Species/ population/EEC	TSC 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
White Box Yellow Box Blakely's Gum Woodland	EEC	CE	CE	N	N/A	Yes – recorded within the Burragorang, Bungonia, and Kanangra IBRA subregion	Species is listed as Critically Endangered thus meets the requirements for inclusion as per Section 9.2.4.1 of the FBA.
Ancistrachne maidenii	Species	V	-	Y	Wollemi	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Anthochaera phrygia	Species	CE	CE	N	N/A	Yes – recorded within Bungonia and Burragorang IBRA subregions	Species is listed as Critically Endangered thus meets the requirements for inclusion as per Section 9.2.5.1 of the FBA.
Bossiaea oligosperma	Species	V	V	Y	Bungonia, Burragorang	Yes – recorded within Bungonia and Burragorang IBRA subregions	Threatened species has been specifically nominated in Attachment C of the SEARs.
Callistemon linearifolius	Species	V	-	N	N/A	Yes – recorded within the Burragorang IBRA subregion	Species has not been previously recorded within the Burragorang subregion.
Dillwynia tenuifolia	Species	V	-	Y	Wollemi	Yes	Threatened species has been specifically nominated in Attachment C the SEARs.
Epacris purpurascens var. *purpurascens*	Species	V	-	Y	Wollemi, Burragorang	Yes	Threatened species has been specifically nominated in Attachment C of the SEARs.
Epacris sparsa	Species	V	V	Y	Wollemi	Yes	Threatened species has been specifically nominated in Attachment C of the SEARs
Eucalyptus benthamii	Species	V	V	Y	Burragorang, Kanangra	Yes – recorded within Burragorang and Kanangra IBRA subregions	Threatened species has been specifically nominated in Attachment C of the SEARs.

Genus species	Species/ population/EEC	TSC 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
Eucalyptus glaucina	Species	V	V	N	N/A	Yes	Species has not been previously recorded within the Bungonia, Burragorang, and Kanangra IBRA subregions.
Genoplesium baueri	Species	E	E	Y	Burragorang	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Gyrostemon thesioides	Species	E	-	Y	Burragorang	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Hakea dohertyi	Species	E	E	Y	Burragorang	Yes – recorded within Burragorang IBRA subregion	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.
Melaleuca deanei	Species	V	V	Y	Wollemi	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.
Pomaderris brunnea	Species	E	V	Y	Yengo	Yes – recorded within Bungonia and Burragorang IBRA subregions	Species has not been previously recorded within the Bungonia and Burragorang IBRA subregions.
Solanum armourense	Species	E	-	Y	Bungonia	Yes – recorded within Bungonia and Burragorang IBRA subregions	Threatened species has been specifically nominated in Attachment C of the SEARs.
Tetratheca glandulosa	Species	V	-	Y	Burragorang	Assumed present	Threatened species has been specifically nominated in Attachment C of the SEARs.

[1] TSC 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.

8.7 Avoid and minimise impacts

8.7.1 Avoid impacts

8.7.1.1 Project alternatives and FBA considerations

Chapter 4 of the EIS discusses the proposed 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.

Under the FBA (Section 8.3.1.3), a proponent must seek to avoid the impacts of a Major Project on all biodiversity values at the study area, 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 8-27.

Table 8-27. Avoidance of impacts on biodiversity values

FBA section	FBA criterion	Avoidance mechanism proposed
8.3.1.3 (a)	*Impacts to endangered ecological communities (EECs) and critically endangered ecological communities (CEECs)*	The Project allows for the provision of a 14 metre dam raising, which provides an optimum balance between effective downstream flood mitigation and minimising, as much as possible, impacts associated with upstream temporary inundation. The scale and nature of the Project means that options to avoid impacts to EECs and CEECs are limited.
8.3.1.3 (b)	*Impacts to PCTs that contain threatened species habitat*	The Project allows for the provision of a 14 metre dam raising, which provides an optimum balance between effective downstream flood mitigation and minimising, as much as possible, impacts associated with upstream temporary inundation. The scale and nature of the Project means that options to avoid impacts to PCTs that contain threatened species habitat are limited
8.3.1.3 (c)	*Impacts to areas that contain habitat for vulnerable, endangered or critically endangered threatened species or populations*	The Project allows for the provision of a 14 metre dam raising, which provides an optimum balance between effective downstream flood mitigation and minimising, as much as possible, impacts associated with upstream temporary inundation. The scale and nature of the development type means that options to avoid impacts to areas which contain habitat for vulnerable, endangered or critically endangered threatened species or populations are limited.

FBA section	FBA criterion	Avoidance mechanism proposed
8.3.1.3 (d)	*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 study area.
8.3.1.3 (e)	*Impacts to the riparian areas of 4th order or higher streams and rivers, important wetlands and estuaries*	The Project is situated at Warragamba Dam with operational impacts occurring on land surrounding Lake Burragorang, which is a 9th order stream at points along its extent. As such, any impacts to the riparian buffers of a 4th order stream or higher cannot be avoided.
8.3.1.3 (f)	*Impacts to state significant biodiversity links*	The Project is situated at Warragamba Dam with operational impacts occurring on land surrounding Lake Burragorang, which is a 9th order stream at points along its extent. As such, any impacts to the riparian buffers of a 4th order stream or higher cannot be avoided.

8.7.1.2 Site selection and planning

The Project proposes to raise the wall of Warragamba Dam to create an FMZ. As such, this site is fixed and there are no options for an alternative site. The selection of suitable flood mitigation options was informed though the consideration of various factors including social and environmental impacts and economic considerations. The layout for the Project has been refined through the consideration of various alternatives that have reduced the potential for adverse impacts to the environment, including specific impacts on threatened ecological communities.

FBA (section 8.3.2.8) considerations are summarised in Table 8-28.

Table 8-28. FBA considerations: site selection assessment

FBA section	FBA criterion	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, operational impacts to White Box Yellow Box Blakey's Red Gum Woodland CEEC and River Flat Eucalypt Forest on Coastal Floodplains cannot be avoided.
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, scale and nature of the development, operational impacts to White Box Yellow Box Blakey's Red Gum Woodland CEEC and River Flat Eucalypt Forest on Coastal Floodplains cannot be avoided. The final spillway heights have been optimised through design development and the interaction between the central and auxiliary spillway raised levels to minimise impacts upstream while maintaining the downstream benefits.
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*	The operational impacts of the Project would occur around Lake Burragorang and its tributaries. The vegetation within and surrounding the study area is intact with very high levels of connectivity. The operational impacts of the Project would not prevent movement of individuals through the landscape.

FBA section	FBA criterion	Considerations of the FBA guidelines at the site
	that allow movement of species across barriers or hostile gaps.	
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.

8.7.2 Measures to minimise impacts

8.7.2.1 Environmental Management Plan (EMP)

The Proponent will implement reasonable measures to avoid and minimise any impacts that may occur during the construction and operational phases of the Project that are additional to the impacts which occurred during the site selection and planning phases.

In 2018, an amendment to the *Water NSW Act 2014* (WaterNSW Act) was enacted which related specifically to the Project and the potential impacts of temporary inundation on national parks and state conservation areas in the Warragamba Dam catchment. Under previous legislation, inundation of national park land was not permitted, however, the amendment of the WaterNSW Act provided a special provision to allow the temporary inundation of national park and state conservation area land in the Warragamba Dam catchment. To ensure the mitigation of any impacts from temporary inundation, the special provisions also require:

- WaterNSW to prepare an Environmental Management Plan (EMP) in consultation with the Chief Executive of the OEH and NPWS if approval for the Project is given
- the NPW Minister to determine the matters that are to be addressed by an EMP
- the NPW Minister with the concurrence of the Minister for Water approve an acceptable EMP
- the NPW Minister with the concurrence of the Minister for Water require an approved EMP to be updated or reviewed
- the NPW Minister with the concurrence of the Minister for Water may direct Water NSW to take specified actions in relation to the temporary inundation of national park land resulting from the Warragamba Dam Project, including action relating to the monitoring of risks associated with the temporary inundation and relating to the rehabilitation or remediation of land
- WaterNSW to implement and monitor the EMPs
- Water NSW to notify the Chief Executive of the OEH if it believes a flood event that may affect national park land near Warragamba Dam is likely to occur.

While the exact content of the EMP has yet to be determined, it would address issues such as:

- rehabilitation and habitat restoration
- sediment and erosion control
- weed and feral animal management
- ecological monitoring
- responsibility for these actions (which would be negotiated between Water NSW and NPWS as part of development of the EMP).

It should be noted that the EMP will be separate to any other mitigation measures identified in this environmental assessment but would would complement and support these measures.

8.7.2.2 Minimising impacts during construction phase

Measures to minimise impacts related to the construction of the raised dam wall are outlined within the Chapter 10 of the EIS (Biodiversity – construction area).

8.7.2.3 Minimising impacts during operational phase

FBA considerations to avoid and minimise impacts on biodiversity values during the operational phase of the Project are described in Table 8-29.

Table 8-29. Considerations to minimise impacts of the proposed development during operation

FBA section	FBA criterion	Consideration of the FBA guidelines
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.*	Given the large extent of available habitat within the wider locality, no artificial habitats are proposed within the study area.
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 study area, migratory species or flight pathways because 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.*	The EMP required under the WaterNSW Act would contain mitigation measures for the operation of the Project.

8.7.2.4 Summary of measures

Project mitigation measures are summarised in Section 8.11 (Table 8-46). Note that offsetting requirements are discussed in Section 8.9.

8.8 Impact assessment

8.8.1 Potential flooding with the Project

Hydrology characteristics and potential Project impacts are addressed in detail in Chapter 15 (Flooding and Hydrology). The upstream impact area is discussed in Section 8.2.5 and defined in Table 8-4. The Project's operational impact would result in increased temporary inundation from large rainfall events in the study area. These impacts would involve changes to current temporary inundation extents, depths, durations and flooding frequency.

The following is a summary of the changes to flooding and hydrology in the catchment upstream of Warragamba Dam. It is stressed that these should not be considered in isolation and it is necessary to consider them holistically when assessing potential impacts of the Project.

It should also be noted that the PMF event is used principally as an input to design and, given the scale of the catchment of Lake Burragorang, is highly unlikely to occur in nature. Accordingly, more weight should be given to the flood events with a relatively greater chance of occurrence.

8.8.1.1 Depth and duration of temporary inundation

For upstream locations above the limit of the Project 1 in 100 year chance event:

- Increases in depth with the Project for all events would be half a metre or less
- Increases in duration of temporary inundation for all events for all locations would be less than half a day.

For locations approximating the limit of the Project 1 in 100 chance in a year event, increases in the depth of temporary inundation with the Project for all events up to the 1 in 100 chance in a year event would be half a metre or less.

Increases in the duration of temporary inundation for all events up to the 1 in 100 chance in a year event would be less than half a day on top of the existing duration of temporary inundation which for all four main rivers is around 5-7 days.

There is an increasing influence of the Project moving downstream with the increase in temporary depth and duration of temporary inundation, with locations within Lake Burragorang generally reflecting the pattern of changes in depth and duration of temporary inundation for the same flood events at the dam wall. This also holds generally for the upstream impact area.

8.8.1.2 Flood frequencies

- The Project would result in a shift in the flood frequency curves resulting in events of a specified depth occurring more frequently than currently occurs; this is most pronounced at the dam wall and in Lake Burragorang, and decreases moving up the tributaries
- Changes in flood frequencies for the upstream impact area are generally similar to Lake Burragorang
- There is no material difference in the existing and Project flood frequency curves at upstream locations that approximate the extent of the Project PMF (as would be expected).

8.8.1.3 Flood extents

- While the Project would increase the extent of any inundation with the use of the FMZ it is incremental to what already occurs. Based on modelling the likely incremental net increase in inundation area is around 1400 hectares.

8.8.2 Effects of temporary inundation

The potential impacts of alteration of natural flow regimes are wide-ranging but are also difficult to predict and quantify. The effects of temporary inundation are discussed in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 7.1.2) and summarised as follows.

8.8.2.1 Flood stress

Flooding is a compound stress composed of interacting changes within the plant cells induced by the flood water around the plant (Perata *et al*. 2011). Most terrestrial plant species cannot survive prolonged submergence or soil waterlogging and these stresses are collectively termed flood stress (Jackson and Colmer 2005, Loreti *et al*. 2016, Kozlowski 1997). Generally, plants are either intolerant to flooding and excluded from flood-prone habitats, or they are tolerant to flooding (Perata *et al*. 2011).

Once affected by flood stress, plants may be more susceptible to secondary biotic and abiotic impacts from the surrounding environment. When stressed or recovering from flood stress, plants may be less resilient to disease and pathogens, for example *Phytophthora cinnamomi* and Myrtle Rust, as well as to herbivory and parasitism. These supplementary biotic impacts may compound the flood stress, further reducing the vigour and health of the already stressed plant. Specific plant impacts are discussed as follows.

Flood tolerance

Flooding results in the inundation of part or all the above ground structures, while waterlogging is restricted to the soils and rhizosphere (Colmer and Pedersen 2008, Parolin and Wittmann 2010). Flood-tolerant plants, such as riparian or wetland species, typically possess traits that allow complex interactions of morphological, anatomical, and physiological adaptations to survive the physical and chemical effects of flooding (Catford and Jansson 2014). Such adaptions include, but are not limited to, the production of hypertrophied lenticels, aerenchym tissue, and adventitious roots (Kozlowski 1997). However, even within these flood-tolerant plants, tolerance levels are not universal with different species highly adapted and specialised for a narrow and restricted set of environmental

conditions, thus changes to baseline conditions can trigger stress responses (Parolin and Wittmann 2010, Catford and Jansson 2014, Voesenek and Bailey-Serres 2015). Notably, even mortality in *Casuarina cunninghamiana* has been observed on the Hawkesbury-Nepean River due to extended inundation and waterlogging (Howell and Benson 2000), and has been demonstrated to be sensitive to oxygen depletion in its root zone (Woolfrey and Ladd 2001).

Terrestrial plant species typically lack the suite of adaptations that enable tolerance to inundation, thus making them particularly susceptible to flood stress. The presence of adaptations may vary between species. Some species of eucalypt, such as *Eucalyptus camaldulensis*, possess the ability to form adventitious roots in waterlogged soils, while other species, such as *Eucalyptus globulus* do not (Bush and England 2019). Bush and England (2019) found that *Eucalyptus benthamii* may be tolerant to temporary inundation for up to six weeks duration to a depth of 30 centimetres, suggesting that the species may also possess similar morphological adaptions to enable some level of tolerance to flood stress.

Flood tolerance varies greatly among plant species, genotypes and environmentally induced development, and is influenced by plant age, time of year, duration, depth and frequency of flooding, condition of the floodwater, and current or historical environmental characteristics of the site. Therefore, the actual flood stress response to inundation and waterlogging may vary between each flood event (Howell and Benson 2000).

Biotic and abiotic impacts

Once affected by flood stress, plants are more susceptible to secondary biotic and abiotic impacts from the surrounding environment. When stressed or recovering from flood stress, plants are less resilient to disease and pathogens, for example *Phytophthora cinnamomi* and Myrtle Rust, as well as to herbivory and parasitism. These supplementary biotic impacts compound the flood stress, further reducing the vigour and health of the already stressed plant.

Gaseous exchange impacts

During periods of inundation, the concentration of oxygen, carbon dioxide, reactive oxygen species, and ethylene are altered within the plant's cells. Whilst the exact changes and combinations are dependent upon the flood duration, depth, and predominant environmental conditions at the time Perata *et al*. 2011, the overall affect is a change to plant metabolism which can detrimentally impact upon plant vigour and health. During a flood event, plants are likely to experience a reduction in respiration as gaseous exchange is considerably slower underwater, and photosynthesis and transport of carbohydrates is inhibited by a reduction in light availability which can lead to a deficit of energy (Kozlowski 1997, Catford and Jansson 2014). Changes to soil structure and chemistry such as depletion of oxygen, accumulation of carbon dioxide and reactive oxygen species, and changes in pH can also affect hormonal balance and metabolism typically by increasing the proportion of ethylene present within the cells (Kozlowski 1997).

Hormonal processes and metabolism impacts

Changes to plant hormonal processes and metabolism can induce changes to plant morphology and anatomy. Inundation and waterlogging causes death and decay of plant roots (Kozlowski 1997, Catford and Jansson 2014). Post-flood, root formation and branching, as well as existing root growth and formation of mycorrhizae association are inhibited. This in turn reduces absorption of macronutrients and ability to uptake water from the environment. Inundation and waterlogging can result in impacts upon plant growth by causing early leaf-drop, senescence and shoot dieback, as well as suppressing the formation and expansion of new leaves and stem (Kozlowski 1997).

Life history and abiotic impacts

Inundation and water logging may also result in disruptions to life-history processes such as flowering, fruit production and fruit set. These processes may be withheld (that is not occur at all), or proceed with reduced vigour and quality (Kozlowski 1997).

In addition, flood stressed plants may also be less resilient to abiotic impacts such as storms and intense wind, or bushfire. Stressed plants with damaged roots may suffer from windthrow and tree fall, especially after flooding where the substrate has been altered through erosional processes and changes in soil strength associated with saturation. Furthermore, fire response adaptations may be compromised in flood stressed plants due to reduced energy levels and altered hormonal processes.

Soil-stored seed impacts

Flood stress may also impact susceptible soil-stored seeds, as inundation may trigger germination for some species. This germination response would vary depending upon the current susceptibility of the soil stored seed to coupled

triggers, of which inundation may be only one input. For seed that is not triggered into germination, other impacts may affect seed's viability, predator interaction, physical arrangement within the soil, movement away from suitable habitat and metabolic stress. These impacts relate to the indirect impact of degradation and changes to terrestrial habitats.

8.8.2.2 Changes to vegetation structure, composition, and condition

Species composition within the study area has the potential to change within riparian, floodplain, and wetland communities, as well as for communities that are not strongly associated with fluvial, lacustral or wetland processes. However, the potential magnitude of change across the study area may vary depending on the depth, duration, and frequency of inundation. Important aspects are:

- Structure, species composition and overall condition are related, but changes to ecological inputs, including impacts, may see a variable response to these three physical aspects of ecological communities. Generally, vascular plants are either tolerant to inundation and waterlogging and are therefore present within flood-prone habitats, or they are intolerant to inundation and waterlogging and therefore excluded from these habitats (Catford and Jansson 2014). Notwithstanding, some species may be tolerant to inundation resulting from a stochastic or temporary event, depending on the specific environmental characteristics of that one-off event. Where the inundation results in waterlogging of soils, the distribution of many vascular plant species may be impacted through plant mortality, inhibited seed germination and growth, and altered plant anatomy (Catford and Jansson 2014). Consequently, there is generally a negative correlation between tolerance to inundation and waterlogging, and distance from rivers and riparian areas, wetlands, and waterbodies (Kozlowski 1997).
- Except for forested wetland communities occurring along the major tributaries, much of the vegetation surrounding Lake Burragorang is dry sclerophyll forest comprising of species that are generally not adapted to inundation or waterlogging (Keith 2004). These dry sclerophyll forest communities typically occur on infertile soils on steep terrain away from the fertile valleys and plains (Keith 2004). Temporary inundation events across the study area at differing frequencies may result in the loss of species with few adaptions to tolerate temporary inundation or waterlogging, although the actual response may vary depending on the depth and duration of temporary inundation. Even with the riparian vegetation communities, such as forested wetlands, community composition is shaped by adaptations to inundation, flood disturbance, and dispersal mechanisms of the component plant species, thus resulting in an assemblage determined by the dispersal, environmental and biotic constraints (Catford and Jansson 2014). Thus, alterations or modifications to these inputs may alter community composition in response.
- Areas disturbed by temporary inundation may be susceptible to weed invasion post-flood event due to germination triggers such as an increase in solar access, changes to soil nutrient levels, physical disturbance to soil, and deposition of weed propagules. Exotic species tend to have high propagule availability and greater dispersal capacity. Furthermore, as exotic plants tend to be generalist in their habitat requirements, and possess life history strategies suited to frequent disturbance, they would likely be able to out-compete native species poorly adapted to new environmental conditions (Catford and Jansson 2014). Modification to existing soil structure and a reduction in native community resilience would also favour the establishment of exotic species. The extent of impact may also depend on proximity to sources of weed propagules.

Overall, the vegetation in the study area typically has intact vegetation structure with high species diversity and in a high-quality condition for all plant communities. Some areas of PCT HN527, equivalent to White Box Yellow Box Blakely's Red Gum Woodland CEEC, have been modified by previous grazing and clearing. These modified areas of White Box Yellow Box Blakely's Red Gum Woodland CEEC are still in good condition even though they include areas of derived native grassland and have some structural change. All vegetation in the study area, including these areas of derived native grasslands, have been assessed as the highest of the broad FBA condition class classification as 'moderate to good' with no areas identified as being in 'low' condition.

Impacts to vegetation structure and composition may see a change in vegetation condition or site value, depending on the depth and duration of temporary inundation.

8.8.2.3 Physical damage to vegetation and habitat

The Project would result in changes in temporary inundation in the main reservoir area. Specifically, it would result in increased extent, duration and frequency of temporary inundation. Because the Project does not impact the volume and velocity of inflows, there would only be marginal changes to velocity profiles under the Project scenarios.

While the likelihood of impact from the temporary inundation is low some physical damage upon the vegetation may occur in some areas. Inundation can cause physical damage to plants, namely, scarring, bending, and uprooting (Kozlowski 1997, Lind *et al*. 2014). Riparian plant species typically possess resistance strategies such as stem, leaf, and root flexibility, brittle twigs to enable self-thinning, and widespread root systems to assist in surviving inundation (Kozlowski 1997, Lind *et al*. 2014). These adaptations may not be present within the terrestrial plant species occurring within the study area. A plant's morphology is in part driven by its phenotypic characteristics, but also by the environmental conditions. As such, it is unlikely that the vegetation within the study area possesses adaptive or acclimatised growth to withstand the physical forces of inundation. Consequently, the vegetation within the study area may be susceptible to physical damage from the increased temporary inundation associated with the Project.

Physical damage to plants would produce edge effects, both biotic (as weed establishment, native vegetation change and disturbance succession) and abiotic (changes to light, humidity and edaphic conditions), which may persist for periods of time, particularly with ongoing effects of recurring changed flood regimes.

8.8.2.4 Erosion and sedimentation

Potential changes to erosion and sedimentation are addressed in Appendix N2 (Geomorphology assessment report). An erosion hot spot model was developed and used to assess potential changes in erosion potential due to the Project. Model parameters were:

- soil type
- slope
- change in water velocity or wave height (erosional forces included water velocity in the upstream tributary areas and wave erosion in the main reservoir)
- change in vegetation cover.

Key findings are as follows:

- It was generally found that existing erosion potential of most of the catchment is relatively low, due to:
  - the catchment is well vegetated, which reduces erosion potential
  - water velocities and wave heights are generally low, which reduces the hydrological forces causing erosion.
- The small areas that currently have a high erosion potential are predominately steep slopes with erosive soils.
- Generally, the Project would result in a decrease in water velocities as there would be a larger backwater area behind the dam. This would result in a decrease in the erosive potential of flows in the tributaries where flows are generally the highest. An increase in erosion potential may occur where vegetation cover is reduced due flood stress.
- Deposition of sediments generally occurs when higher velocity sediment-laden water meets with a water area of lower velocity. As the Project would temporarily result in a larger ponded body of water (with a lower velocity), deposition zones would change and generally move upstream from their current locations along the tributaries. The tributaries that would be potentially be most affected would be the Wollondilly River and the Coxs River – as these two tributaries have the largest catchments and the highest proportion of cleared catchments upstream of the dam. They also have the highest sediment loads in comparison to other tributaries. While there may be some increase in sediment loads from the immediate catchment of the dam and tributaries due to the Project, most of the sediment would still originate from areas upstream of the dam.
- For most events (less than the 1 in 100 chance in a year flood event) there would only be marginal changes in the velocity profiles along the tributaries so there would be little or no change in the current sediment deposition zones. For the larger events, the sediment depositions zone may move upstream in the Wollondilly River and in the Coxs River, with the other rivers largely unaffected.
- The main potential impacts from changes in sediment deposition zones largely relate to smothering of vegetation and loss of soil stored seedbank. However, this impact is expected to be minimal at deposition locations in comparison to other potential impacts of the Project such as the increased depth, duration and extent of inundation.

8.8.2.5 Fauna mortality from inundation

The main potential impacts of the Project are on loss and modification of vegetation and the impacts of that on the habitat of threatened flora and fauna. Fauna mortality may also occur directly due to animals killed through injury or stress during flood events, particularly should the flood events occur during breeding periods where juveniles may

have limited ability to flee flood water and can be sensitive to disturbance. More mobile species with generalist habitat requirements could relocate to adjacent habitat during a flood event.

It should be noted that this is an existing risk albeit on a smaller scale.

8.8.2.6 Summary of potential impacts

Potential impacts of the Project during the ongoing operation could include:

- changes to the structure and condition of native vegetation communities including threatened ecological communities
- changes to the habitat of threatened and non-threatened flora and fauna species
- changes to erosion and sedimentation
- fauna and flora mortality from inundation
- other potential changes that could occur due to impacts to native vegetation including:
  - edge effects
  - weed invasion and encroachment
  - creating habitat conducive to invasive or over-abundant fauna
  - introduction or spread of diseases and pathogens
  - changes to natural fire regimes.

8.8.3 Identified impacts resulting from temporary inundation for flood mitigation

There is limited published information about the effects of flood mitigation and temporary inundation on terrestrial ecosystems. The assessment has drawn on various information sources, the key ones being as follows.

1. *A study commissioned by Infrastructure NSW to assess the environmental impacts of temporary inundation upstream of Queensland Flood Mitigation Dams (Hydrobiology 2020)*

Hydrobiology (2020) undertook a literature review and field assessment to investigate the effects of temporary flood inundation on flora and fauna surrounding flood mitigation dams in Queensland. The focus of the study was on the Hinze Dam on the Gold Coast; however additional investigations were undertaken on Wivenhoe Dam north-west of Brisbane. These dams include a flood mitigation function that results in temporary inundation of land upstream of the dam.

- The Hinze Dam is particularly relevant as it is predominantly surrounded by native vegetation and was subject to temporary inundation from a cyclone event in 2017. The study found that upstream of Hinze Dam the authors suggested there had been impacts on vegetation health between zero and one metres from the FSL from the inflow event. The event resulted in an elevated water level of around 5.7 metres above FSL that took more than two months to be released. The report was not conclusive as to whether vegetation impacts resulted from inundation or edge effects and limited evidence from one event did not suggest that temporary inundation would inevitably cause substantial environmental impact.
- For Wivenhoe Dam the flood event studies occurred in January 2011 where water levels remained above FSL for about 17 days, reaching 8.1 metres above FSL. For 50 percent of the time water levels were up to two metres above FSL. The results showed no change to woody vegetation cover or noticeable change to ground cover (including erosion, weed recruitment or evidence of sediment deposition).

The authors indicated that these were preliminary findings and further long-term monitoring would be required to determine if longer term changes to vegetation condition would ensue.

2. *A study commissioned by WaterNSW to examine the response to temporary inundation of* Eucalyptus benthamii *(Camden White Gum), which is a listed threatened species known to be potentially impacted by the Project*

The tolerance of *Eucalyptus benthamii* to temporary inundation was investigated in a research study carried out between September 2017 and February 2018 in Deniliquin by the CSIRO on behalf of WaterNSW. The paper is included in Appendix F1 (Biodiversity Assessment Report – Upstream, Appendix H). Specifically, the study examined the effects of temporary inundation for up to six weeks on the health and survival of a stand of 18-year-old *Eucalyptus benthamii* as well as the soil physical and chemical properties for up to one year after the initial flooding treatments (Bush and England 2019).

Two separate experiments (Experiment 1, Experiment 2) were conducted for the study.

- For Experiment 1, compartments of the trial site were temporarily flooded to a depth of 30 centimetres, commencing in March 2017, for durations of one, two, four, and six weeks. These treatments corresponded with flood scenarios determined by WaterNSW modelling. A control group of trees, which received no flooding treatment (Control A), was located adjacent to the flooded treatments. However, water from the flood treatments drained throughout the control site. As such, a second control site (Control B) was established.
- Experiment 2 was designed in the same way as Experiment 1 but commenced in August 2017.

Prior to the experiments commencing, baseline data was collected and then compared throughout the length of the study. Each tree was measured for growth and health traits such as, diameter at breast height (DBH), height to live growth, epicormic shoots, lignotuberous shoots, and general heath. Experiment 1 was monitored for two years while Experiment 2 was monitored for 18 months. In addition to tree health, soil physical and chemical properties were measured before, during, and after the flooding treatments. The soil at the trial sites was a Subnatric Brown Sodosol (Bush and England 2019). The A-horizon field texture was a silty clay loam and the B-horizon was a medium clay soil. The upper 100 centimetres of the soil was considered non-saline to slightly saline, whereas the 100-140 centimetres layer was moderately saline, meaning that salinity levels could adversely affect the growth of some plants. The soil from 0-40 centimetres was non-sodic, but from 40-140 centimetres depth the soil is sodic, meaning that there are excessive amounts of exchangeable sodium present. This portion of the study found that the tree stands in both experiments were subject to anaerobic conditions over the course of the flood treatment.

The study found that there was no statistical evidence that temporary inundation to a depth of 30 centimetres led to a decline in *Eucalyptus benthamii* health and survival over a period of 24 months after the application of flooding treatments which led to anaerobic soil conditions. While there was some evidence of stress within the stands, as well as some limited mortality, this was attributed to protracted hot and dry conditions in Deniliquin as demonstrated by similar stress and loss in control stands.

While it appears that *Eucalyptus benthamii* may be tolerant to temporary inundation for up to six weeks duration to a depth of 30 centimetres (Bush and England 2019), there are some key differences between the scenario within which the experiment was carried out and the modelled conditions expected to occur *in situ* within the Kedumba River population of *Eucalyptus benthamii*. Specifically, the depth of inundation is expected to be more variable and potentially greater than 30 centimetres. Under these circumstances the impacts on *Eucalyptus benthamii* may be greater than identified in the controlled study.

3. *Surveys undertaken as part of this assessment for sites that have been impacted by temporary inundation under the current operation of Warragamba Dam.*

As noted in Section 8.2.7, 95 plots were surveyed across the study area. Each of these plots were assessed for a range of factors (species richness, presence of weeds etc.) compared to a benchmark for the PCT, and a site value score generated for each vegetation zone. Notionally, the higher the score the closer to benchmark the plot is likely to be. All plots were assessed to be in moderate to good condition. Poor condition is a score 17 or below whereas the Warragamba plots ranged between 50-100. There was minimal difference in score between plots close to the FSL and therefore subject to existing temporary inundation, and plots not subject to existing temporary inundation. While this does not demonstrate that temporary inundation would not impact on vegetation, it does indicate that any change is likely to be difficult to measure and observe, and that change where it occurs will be transitional.

8.8.4 Assessment limitations

A precautionary approach has been adopted in assessing potential upstream biodiversity impacts including the adoption of the precautionary principle where sufficient information does not to exist to confidently assess potential impacts. Application of the precautionary principle requires that a lack of scientific certainty about the potential impacts of an action does not in itself justify a decision that the action is unlikely to have an impact.

The spatial and temporary impacts associated temporary inundation may be variable depending on future rainfall events, making the future impacts associated with the Project difficult to quantify. In addition to this, key uncertainties and issues in the impact assessment are noted as follows:

- The existing scientific literature has little definitive results confirming the extent of impacts of short-term inundation of flora and PCTs specific to the vegetation found in the study area. Any change is likely to occur over a long period of time subject to the large variability of the impact.
- While there is some research on inundation impacts for some vegetation found in the study area such as *Eucalyptus benthamii*, for most of the vegetation there is no scientific literature. The study area has specific environmental characteristics such as rapidly draining alluvial soils in many areas which may reduce certain

impacts of temporary inundation (or improve recovery) such as impacts from waterlogged soils. This has resulted in conservative assumptions of the impacts of temporary inundation.

- Biodiversity information within the study area and the broader locality – Up until the biodiversity surveys undertaken for the Project, there was very little ground-truthed vegetation mapping and other biodiversity information available for the study area and surrounding area. While the biodiversity survey works included a substantial portion of the study area, not all the study area was able to be visited due to its size and access constraints. Very few areas outside the study area were surveyed and therefore it was difficult to provide a context for some of the impacts with the regional presence of PCTs, flora and fauna.

The assessment takes into consideration and uses best available knowledge to input to the FBA. It takes a precautionary approach to impacts by assuming loss of all vegetation within the upstream impact area. However, because there will be no impact until the dam is raised and an actual flood occurs that fills the lake above FSL, there is an opportunity to refine the assessment by undertaking:

- further vegetation mapping and assessment to refine the extents of key threatened PCTs
- additional biodiversity surveys to confirm the presence/absence of threatened flora and fauna.

8.8.5 Assessment of impacts

8.8.5.1 Upstream impact area

As discussed in Section 8.2.5 the upstream impact area has been defined as the area between RL 119.5 mAHD and RL 126.97 mAHD. This area has been used to assess the impacts of the project and calculate offsetting.

It is assumed that the future site value of the native vegetation within the upstream impact area is zero (0). This is equivalent to the full clearance of the site and loss of all native vegetation and threatened species values within the area, and represents a very conservative approach to estimating impact and calculation of offsets for the Project.

8.8.5.2 Impacts on native vegetation

The Project's ongoing operation would result in potential impacts associated with temporary inundation to native vegetation across around 1,400 hectares. Native vegetation types within the upstream impact area includes areas of all 18 PCTs mapped in the study area. A summary of the PCT areas within the upstream impact area is given in Table 8-30.

Table 8-30. PCTs impacted within the upstream impact area

BVT code	PCT name	BC Act status	EPBC Act status	Upstream impact area (ha)
HN517 (PCT 769)	Coachwood - Lilly Pilly warm temperate rainforest in moist sandstone gullies, Sydney Basin Bioregion	–	–	0.53
HN525 (PCT 832)	Forest Red Gum - Narrow-leaved Ironbark open forest of the southern Blue Mountains gorges, Sydney Basin Bioregion	–	–	84.20
HN527 (PCT 840)	Forest Red Gum - Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands	Critically Endangered	Critically Endangered	127.75
HN532 (PCT 860)	Grey Gum - Broad-leaved Ironbark dry open forest on gorge slopes on the Blue Mountains, Sydney Basin Bioregion	–	–	226.04
HN533 (PCT 862)	Grey Gum - Hard Leaved Scribbly Gum woodland of the Cox River Valley	–	–	10.97
HN535 (PCT 870)	Grey Gum - Thin-leaved Stringybark grassy woodland of the southern Blue Mountain gorges, Sydney basin Bioregion	–	–	22.17

BVT code	PCT name	BC Act status	EPBC Act status	Upstream impact area (ha)
HN536 (PCT 871)	Grey Gum shrubby open forest on gorge slopes of the Blue Mountains, Sydney Basin Bioregion	–	–	212.92
HN537 (PCT 875)	Grey Myrtle - Lilly Pilly dry rainforest in dry gullies of the Sydney Basin Bioregion and South East Corner Bioregion	–	–	0.13
HN538 (PCT 877)	Grey Myrtle dry rainforest of the Sydney Basin Bioregion and South East corner Bioregion	–	–	28.09
HN553 (PCT 941)	Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion	Endangered	Critically Endangered	107.09
HN564 (PCT 1081)	Red Bloodwood - Grey Gum woodland on the edges of the Cumberland Plain, Sydney Basin Bioregion	–	–	2.51
HN566 (PCT 1083)	Red bloodwood -scribbly gum heathy woodland on sandstone plateaux of the Sydney basin Bioregion	–	–	28.63
HN568 (PCT 1086)	Red Bloodwood - Sydney Peppermint - Blue-leaved Stringybark heathy forest of the southern Blue Mountains, Sydney Basin Bioregion	–	–	31.21
HN574 (PCT 1105)	River Oak open forest of major streams, Sydney Basin Bioregion and South East Corner Bioregion	–	–	67.31
HN598 (PCT 1246)	Sydney Peppermint - Grey Gum shrubby open forest of the western Blue Mountains, Sydney Basin Bioregion	–	–	9.71
HN606 (PCT 1284)	Turpentine - smooth-barked Apple moist shrubby forest of the lower Blue Mountains, Sydney Basin Bioregion	–	–	37.73
HN607 (PCT 1292)	Water Gum - Coachwood riparian scrub along sandstone streams, Sydney Basin Bioregion	–	–	73.60
HN557 (PCT 1401)	Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion	Critically Endangered	Critically Endangered	302.81

8.8.5.3 Impacts on threatened ecological communities

Of the 18 PCTs potentially impacted by temporary inundation (see Table 8-30), three have been assessed as conforming to two BC Act listed TECs. The same PCTs have been assessed as an EPBC Act listed TEC.

- HN553 Mountain Blue Gum - Thin-leaved Stringybark open forest on river flat alluvium in the Sydney Basin Bioregion has been identified in the study area as a component of River-Flat Eucalypt Forest on Coastal Floodplains, which is listed as an endangered ecological community under the BC Act. All areas of this PCT mapped in the broader study area have also been assessed as the EEC. Within the study area, River-Flat Eucalypt Forest is distributed in two key locations: along the Kedumba River, and along the Nattai River. Impacts associated with temporary inundation would potentially result in loss of, and floristic and structural change to the threatened ecological community and its values.

  The area of the TEC within the upstream impact area is 107.09hectares.

- Two PCTs, **HN527 Forest Red Gum** - Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands and **HN557 Narrow-leaved Ironbark** - Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion have been identified within the study area as components of White Box Yellow Box Blakely's Red Gum Woodland which listed as a critically endangered ecological community under the BC Act.

  These two PCTs have also been identified within the study area as components of White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland, listed as a critically endangered ecological community (CEEC) under the EPBC Act.

  Within the study area, most of the White Box Yellow Box Blakely's Red Gum Woodland is distributed upstream from Higgins Bay, immediately surrounding Lake Burragorang and along the Wollondilly River. Impacts associated with temporary inundation would potentially result in loss of, and floristic and structural change to the threatened ecological community and its values

  The area of these TECs within the upstream impact area is 430.56 hectares.

8.8.5.4 Loss of threatened flora species and their habitat

The Project's ongoing operation would result in impacts associated with of temporary inundation of suitable habitat for threatened flora species

Generally, potential impacts to threatened flora species and their habitat associated with temporary inundation includes flood stress, physical damage to individual plants, and loss of soil stored seed bank.

As discussed in Section 8.3.3, the magnitude and extent of flooding will be variable depending on future rainfall events, making future impacts associated with the Project difficult to accurately characterise and quantify, particularly for the larger, less frequent events. While the threatened flora species considered within this assessment are unlikely to tolerate long term inundation, including waterlogging, and may be adversely impacted during an inundation event; there is uncertainly relating to the timing, duration, and depth of inundation. Therefore, the consequence of any given event is difficult to accurately quantify and describe in detail.

A description of the impacts of temporary inundation on each threatened flora candidate species and its habitat is provided in Table 8-31.

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
- associated PCTs described in Appendix C of NPWS (The Native Vegetation of the Warragamba Special Area 2003a)
- distribution patterns
- from field observations
- from records (Atlas of Living Australia, BioNet Wildlife Atlas, Australian Virtual Herbarium)
- 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).

A summary of the habitat impacted within the upstream impact area, and a description of how these areas were derived is given in Table 8-32.

Table 8-31. Description of Project impacts on flora species credit species

Species name	Common name	BC Act status	EPBC Act status	Description of potential impacts to species
Acacia baueri subsp. aspera	*Acacia baueri subsp. aspera*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Acacia bynoeana	Bynoe's Wattle	E	V	Temporary inundation resulting from the Project may adversely impact this species.
Acacia clunies-rossiae	Kanangra Wattle	V	-	During the current assessment, the species was recorded upstream of Green Wattle Creek, around the shores of Lake Burragorang and along the main tributaries, including Kedumba, Cox, and Kowmung Rivers, however suitable habitat for the species is found along the western shores of Lake Burragorang from the Wollondilly River to Coxs River. Temporary inundation resulting from the Project may adversely impact this species.
Acacia flocktoniae	Flockton Wattle	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Acacia gordonii	*Acacia gordonii*	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Acacia pubescens	Downy Wattle	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Acrophyllum australe	*Acrophyllum australe*	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Ancistrachne maidenii	*Ancistrachne maidenii*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Asterolasia buxifolia	*Asterolasia buxifolia*	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Asterolasia elegans	*Asterolasia elegans*	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Astrotricha crassifolia	Thick-leaf Star-hair	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Baloskion longipes	Dense Cord-rush	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Bossiaea oligosperma	Few-seeded Bossiaea	V	V	During the current assessment, the species was recorded upstream of Murphys Crossing on the Wollondilly River, around the shores of Lake Burragorang to around Higgins Bay. Temporary inundation resulting from the Project may adversely impact this species.
Caesia parviflora var. *minor*	Small Pale Grass-lily	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Callistemon linearifolius	Netted Bottle Brush	V	-	During the current assessment, the species was recorded in three locations: Little River, Tonalli Cove, and along Green Wattle Creek. . Temporary inundation resulting from the Project may adversely impact this species.
Callistemon megalongensis	Megalong Valley Bottlebrush	CE	CE	Temporary inundation resulting from the Project may adversely impact this species.
Calomnion complanatum	*Calomnion complanatum*	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Cryptostylis hunteriana	Leafless Tongue Orchid	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Cynanchum elegans	White-flowered Wax Plant	E	E	None – no habitat for this species within the study area.
Darwinia biflora	*Darwinia biflora*	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Darwinia peduncularis	*Darwinia peduncularis*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Dillwynia tenuifolia	*Dillwynia tenuifolia*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Epacris hamiltonii	*Epacris hamiltonii*	E	E	Temporary inundation resulting from the Project may adversely impact this species.

Species name	Common name	BC Act status	EPBC Act status	Description of potential impacts to species
Epacris purpurascens subsp. *purpurascens*	*Epacris purpurascens* subsp. *purpurascens*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Epacris sparsa	Sparse Heath	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Eucalyptus benthamii	Camden White Gum	V	V	During the current assessment, the species was recorded within the riparian area of the Kedumba River. Stands of 18 year-old *Eucalyptus benthamii* appear to be able to tolerate temporary inundation for up to 6 weeks to a depth of approximately 30 cm (CSIRO 2019). This suggests that the species has some tolerance to temporary inundation, which may be expected given its association with forested wetlands. However, impacts to the species due to inundation to greater depths, is unknown.
Eucalyptus glaucina	Slaty Red Gum	V	V	During the current assessment, the species was recorded across much of the study area, around the shores of Lake Burragorang and along the main tributaries, including Wollondilly, Nattai, Kedumba, Cox, and Kowmung Rivers. The species may possess some adaptions to flood stress including temporary water logging, however, the Project may still adversely impact this species.
Eucalyptus pulverulenta	Silver-leafed Gum	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Euphrasia bowdeniae	*Euphrasia bowdeniae*	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Genoplesium baueri	Bauer's Midge Orchid	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Genoplesium superbum	Superb Midge Orchid	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Grammitis stenophylla	Narrow-leaf Finger Fern	E	-	During the current assessment, the species was found along West Warragamba Wall, and along Werriberri Creek. Temporary inundation resulting from the Project may adversely impact this species.
Grevillea evansiana	Evans Grevillea	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Gyrostemon thesioides	*Gyrostemon thesioides*	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Hakea dohertyi	Kowmung Hakea	E	E	During the current assessment, *Hakea dohertyi* was recorded in one location: Tonalli Cove. . Temporary inundation resulting from the Project may adversely impact this species.
Haloragodendron lucasii	Hal	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Hibbertia puberula	*Hibbertia puberula*	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Hygrocybe anomala subsp. *ianthinomarginata*	*Hygrocybe anomala* subsp. *ianthinomarginata*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Hygrocybe aurantipes	*Hygrocybe aurantipes*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Hygrocybe reesiae	*Hygrocybe reesiae*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Isopogon fletcheri	Fletcher's Drumsticks	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Kunzea rupestris	*Kunzea rupestris*	V	V	Temporary inundation resulting from the Project may adversely impact this species.

Species name	Common name	BC Act status	EPBC Act status	Description of potential impacts to species
Lastreopsis hispida	Bristly Shield Fern	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Leionema lachnaeoides	*Leionema lachnaeoides*	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Lepidosperma evansianum	Evans Sedge	V	E	Temporary inundation resulting from the Project may adversely impact this species.
Leucopogon exolasius	Woronora Beard-heath	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Leucopogon fletcheri subsp. *fletcheri*	*Leucopogon fletcheri* subsp. *fletcheri*	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Melaleuca deanei	Deane's Paperbark	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Melaleuca groveana	Grove's Paperbark	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Micromyrtus blakelyi	*Micromyrtus blakelyi*	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Olearia cordata	*Olearia cordata*	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Persicaria elatior	Tall Knotweed	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Persoonia acerosa	Needle Geebung	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Persoonia bargoensis	Bargo Geebung	E	V	Temporary inundation resulting from the Project may adversely impact this species.
Persoonia glaucescens	Mittagong Geebung	E	V	Temporary inundation resulting from the Project may adversely impact this species.
Persoonia hirsuta	Hairy Geebung	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Pherosphaera fitzgeraldii	Dwarf Mountain Pine	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Phyllota humifusa	Dwarf Phyllota	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Pimelea curviflora var. *curviflora*	*Pimelea curviflora* var. *curviflora*	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Pomaderris brunnea	Brown Pomaderris	E	V	During the current assessment, the species was recorded along the Nattai River, at Tonalli Cover, Higgins Bay, and around Butchers Creek. Temporary inundation resulting from the Project may adversely impact this species.
Pterostylis saxicola	Sydney Plains Greenhood	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Pultenaea glabra	Smooth Bush-pea	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Pultenaea parviflora	*Pultenaea parviflora*	E	V	Temporary inundation resulting from the Project may adversely impact this species.
Pultenaea sp. Olinda	*Pultenaea sp. Olinda*	E	-	Temporary inundation resulting from the Project may adversely impact this species.
Pultenaea villifera – endangered population	*Pultenaea villifera* population in the Blue Mountains Local Government Area	EP	-	None – no habitat for this endangered population within the study area.
Rhizanthella slateri	Eastern Australian Underground Orchid	V	E	Temporary inundation resulting from the Project may adversely impact this species.
Rhodamnia rubescens	Scrub Turpentine	CE	-	Temporary inundation resulting from the Project may adversely impact this species.

Species name	Common name	BC Act status	EPBC Act status	Description of potential impacts to species
Solanum amourense	*Solanum armourense*	E	-	During the current assessment, the species was recorded upstream of Murphys Crossing on the Wollondilly River, around the shores of Lake Burragorang. Temporary inundation resulting from the Project may adversely impact this species.
Tetratheca glandulosa	*Tetratheca glandulosa*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Trachymene scapigera	Mountain Trachymene			Temporary inundation resulting from the Project may adversely impact this species.
Velleia perfoliata	*Velleia perfoliata*	V	V	Temporary inundation resulting from the Project may adversely impact this species.
Xanthosia scopulicola	*Xanthosia scopulicola*	V	-	Temporary inundation resulting from the Project may adversely impact this species.
Zieria covenyi	Coveny's Zieria	E	E	Temporary inundation resulting from the Project may adversely impact this species.
Zieria involucrata	*Zieria involucrata*	E	V	Temporary inundation resulting from the Project may adversely impact this species.
Zieria murphyi	Velvet Zieria	V	V	Temporary inundation resulting from the Project may adversely impact this species.

Table 8-32. Summary of species credit species habitat impacted by the Project

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Acacia baueri subsp. aspera	-	Associated PCTs: HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Wollemi IBRA subregion	7 ha
Acacia bynoeana	Bynoe's Wattle	Associated PCTs: HN564; HN566; HN568; HN604 Associated IBRA subregion: Burragorang and Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Burragorang and Wollemi IBRA subregions	35 ha
Acacia clunies-rossiae	Kanangra Wattle	Associated PCTs: HN525; HN527; HN532; HN535; HN536; HN537; HN538; HN557; HN574; HN598 Associated IBRA subregion: Burragorang, Kanangra, Bungonia Onsite distribution: Coxs River Catchment (above the confluence with the Wollondilly), western side of Wollondilly arm of Lake Burragorang north from Murphies Crossing	All associated PCTs in the Coxs River Catchment (above the confluence with the Wollondilly), western side of Wollondilly arm of Lake Burragorang north from Murphies Crossing - within Burragorang, Kanangra, Bungonia subregions	770 ha
Acacia flocktoniae	Flockton Wattle	Associated PCTs: HN525; HN527; HN533; HN535; HN536; HN564; HN568; HN598 Associated IBRA subregion: Burragorang, Bungonia, Kanangra and Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within all IBRA subregions	371 ha
Acacia gordonii	-	Associated PCTs: HN564; HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	8 ha
Acacia pubescens	Downy Wattle	Associated PCTs: HN564; HN566; HN568; HN604 Associated IBRA subregion: Burragorang and Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Burragorang and Wollemi IBRA subregions	35 ha
Acrophyllum australe	-	Associated PCTs: HN517; HN566; HN606 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present. Habitat constraint: within 500 m of south-facing cliff lines	All PCTs within 500m buffer of south-facing cliff-lines – within Wollemi IBRA subregion	13 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Ancistrachne maidenii	-	Associated PCTs: HN564; HN566; HN606 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	29 ha
Asterolasia buxifolia	-	Associated PCTs: HN574 Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Burragorang IBRA subregion	14 ha
Asterolasia elegans	-	Associated PCTs: HN517; HN566; HN606 Associated IBRA subregion: Wollemi Associated soil landscapes: Hawkesbury sandstone Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within study area that occur on mapped Hawkesbury sandstone soil landscape	6 ha
Astrotricha crassifolia	-	Associated PCTs: HN566; HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	8 ha
Baloskion longipes	Dense Cord-rush	Associated PCTs: HN574 Associated IBRA subregion: Burragorang and Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Burragorang and Kanangra IBRA subregions	31 ha
Bossiaea oligosperma	Few-seeded Bossiaea	Associated PCTs: HN525; HN527; HN532; HN536; HN557; HN574 Associated IBRA subregion: Burragorang, Bungonia Onsite distribution: Coxs River Catchment (above the confluence with the Wollondilly), western side of Wollondilly arm of Lake Burragorang north from Murphies Crossing	All associated PCTs in the Wollondilly River Catchment: from confluence of Nattai River, south to Murphy's Crossing – within Burragorang and Bungonia IBRA subregions	483 ha
Caesia parviflora var. minor	-	Associated PCTs: HN536; HN564; HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	15 ha
Callistemon linearifolius	Netted Bottle Brush	Associated PCTs: HN574; HN604; HN553 Associated IBRA subregion: Nil Onsite distribution: Nattai River and Little River Tonalli River Green Wattle Creek	All associated PCTs in three disjunct distributions: To the confluence of Nattai River and Little River Tonalli River Green Wattle Creek	1,968 ind

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Callistemon megalongensis	Megalong Valley Bottlebrush	Associated PCTs: HN533 Associated IBRA subregion: Burragorang and Wollemi Habitat constraint: within 300 m of creek lines Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within 300 m of 3rd order streams or larger - within Wollemi and Burragorang IBRA subregions	6 ha
Calomnion complanatum	-	Associated PCTs: HN517 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	1 ha
Cryptostylis hunteriana	Leafless Tongue Orchid	Associated PCTs: HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	7 ha
Cynanchum elegans	White-flowered Wax Plant	Associated PCTs: HN537; HN538 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	0 ha
Darwinia biflora	-	Associated PCTs: HN564; HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	80 ha
Darwinia peduncularis	-	Associated PCTs: HN536; HN566; HN607; HN598 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	15 ha
Dillwynia tenuifolia	-	Associated PCTs: HN564 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	2 ha
Epacris hamiltonii	-	Associated PCTs: HN517; HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	3 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Epacris purpurascens subsp. *purpurascens*	-	Associated PCTs: HN564; HN566; HN604; HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys, however, there are two records within the study area on Werriberri Creek. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	300 ind
Epacris sparsa	Sparse Heath	Associated PCTs: HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys, however. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	2 ind
Eucalyptus benthamii	Camden White Gum	Associated PCTs: HN533; HN532; HN536 Associated IBRA subregion: Burragorang, Wollemi Onsite distribution: species present within Kedumba River catchment.	All PCTs north of southern most *Eucalyptus benthamii* record – within Wollemi, Burragorang IBRA subregions	44 ha
Eucalyptus glaucina	Slaty Red Gum	Associated PCTs: HN557; HN525; HN527; HN532; HN535; HN536; HN538; HN553 Associated IBRA subregion: Burragorang, Kanangra, Bungonia, Wollemi Onsite distribution: species present around Lake Burragorang, plus along Nattai River/Little River area, Butchers Creek, Cox River including west of Kelpie Point, and Wollondilly River.	All PCTs within Wollemi, Burragorang, Kanangra, Bungonia IBRA subregions	10,970 ind
Eucalyptus pulverulenta	Silver-leafed Gum	Associated PCTs: HN533 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys, however. Assumed to be present.	All associated PCTs within Wollemi IBRA subregion	275 ind
Euphrasia bowdeniae	-	Associated PCTs: HN517; HN536 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present. Habitat constraint: within 500 m of south-facing cliff lines	All PCTs within 500 m buffer of south-facing cliff-lines – within Wollemi IBRA subregion	3 ha
Genoplesium baueri	Bauer's Midge Orchid	Associated PCTs: HN566 Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Burragorang subregion	223 ha
Genoplesium superbum	Superb Midge Orchid	Associated PCTs: HN566; HN532 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	10 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Grammitis stenophylla	Narrow-leaf Finger Fern	Associated PCTs: HN517; HN538; HN606; HN607; HN568 Associated IBRA subregion: Wollemi Onsite distribution: East Warragamba Wall and tributary to Werriberri Creek	All associated PCTs in Wollemi subregion	41 ha
Grevillea evansiana	Evans Grevillea	Associated PCTs: HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	7 ha
Grevillea parviflora subsp. *parviflora*	Small-flower Grevillea	Associated PCTs: HN564; HN566; HN604 Associated IBRA subregion: Burragorang and Wollemi Onsite distribution: not observed within the survey area during current surveys, however, the species was recorded within the construction area. Assumed to be present.	All associated PCTs in Burragorang and Wollemi subregion	9 ha
Gyrostemon thesioides	-	Associated PCTs: HN532; HN535; HN536; HN553; HN557; HN564; HN574; HN604; HN607; HN598 Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Burragorang subregion	886 ha
Hakea dohertyi	Kowmung Hakea	Associated PCTs: HN517; HN527; HN538; HN606; HN607; HN557 Associated IBRA subregion: Bungonia, Burragorang, Kanangra Onsite distribution: Tonalli Cove	All associated PCTs along western side of Wollondilly arm of Lake Burragorang north from Murphies Crossing, until just north of Higgins Bay – within Bungonia, Burragorang, Kanangra IBRA subregions	199 ha
Haloragodendron lucasii	-	Associated PCTs: HN566; HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	8 ha
Hibbertia puberula	-	Associated PCTs: HN564; HN566; HN568; HN604 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	35 ha
Hygrocybe anomala subsp. *ianthinomarginata*	-	Associated PCTs: HN517; HN536; HN566; HN606; HN607; HN598 Associated IBRA subregion: Burragorang, Wollemi, Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Burragorang, Wollemi, and Kanangra subregions	267 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Hygrocybe aurantipes	-	Associated PCTs: HN517; HN536; HN566; HN606; HN607; HN598 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	35 ha
Hygrocybe reesiae	-	Associated PCTs: HN517; HN536; HN566; HN606; HN607; HN598 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	35 ha
Isopogon fletcheri	-	Associated PCTs: HN536 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present. Habitat constraint: within 500 m of south-facing cliff lines.	All associated PCTs within 500 m buffer of south-facing cliff-lines – within Wollemi IBRA subregion	3 ha
Kunzea rupestris	-	Associated PCTs: HN564; HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	8 ha
Lastreopsis hispida	Bristly Shield Fern	Associated PCTs: HN517; HN606; HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs in Wollemi subregion	23 ha
Leionema lachnaeoides	-	Associated PCTs: HN517; HN598 Associated IBRA subregion: Burragorang and Wollemi Geology: Narrabeen sandstone Habitat constraint: within 200 m of cliff lines Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within 200 m of cliff lines on Narrabeen sandstone – within Wollemi and Burragorang IBRA subregions	1 ha
Lepidosperma evansianum	Evans Sedge	Associated PCTs: HN517 Associated IBRA subregion: Wollemi Habitat constraint: within 200 m of cliff lines Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs within 200 m of cliff lines– within Wollemi IBRA subregion	1 ha
Leucopogon exolasius	Woronora Beard-heath	Associated PCTs: HN564; HN566; HN568; HN607 Associated IBRA subregion: Burragorang and Wollemi Onsite distribution: not observed within the survey area during current surveys, however, there is one record immediately outside the survey area along Sheehy's Creek Road. Assumed to be present.	All associated PCTs – within Wollemi and Burragorang IBRA subregions	50 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Leucopogon fletcheri subsp. *fletcheri*	-	Associated PCTs: HN564; HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	8 ha
Melaleuca deanei	Deane's Paperbark	Associated PCTs: HN564; HN566 Associated IBRA subregion: Wollemi, Burragorang (observed) Onsite distribution: Not recorded within the survey area but approximately 2.5 km outside between the Kedumba River and Kelpie Point	All associated PCTs in Wollemi and Burragorang IBRA subregions	9 ha
Melaleuca groveana	-	Associated PCTs: HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	6 ind
Micromyrtus blakelyi	-	Associated PCTs: HN564; HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	8 ha
Olearia cordata	-	Associated PCTs: HN564; HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	8 ha
Persicaria elatior	Tall Knotweed	Associated PCTs: Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	Within 50 metres of Lake Burragorang and tributaries within Burragorang IBRA subregion	896 ha
Persoonia acerosa	Needle Geebung	Associated PCTs: HN566; HN568 Associated IBRA subregion: Burragorang and Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi and Burragorang IBRA subregions	33 ha
Persoonia bargoensis	Bargo Geebung	Associated PCTs: HN564; HN566; HN568; HN606; HN607 Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Burragorang IBRA subregion	22 ha
Persoonia glaucescens	Mittagong Geebung	Associated PCTs: HN564; HN566; HN568 Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Burragorang IBRA subregion	9 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Persoonia hirsuta	Hairy Geebung	Associated PCTs: HN564; HN566; HN568; HN604 Associated IBRA subregion: Burragorang and Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi and Burragorang IBRA subregions	35 ha
Pherosphaera fitzgeraldii	-	Associated PCTs: HN517 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	1 ha
Phyllota humifusa	Dwarf Phyllota	Associated PCTs: HN568 Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Burragorang IBRA subregion	8 ha
Pimelea curviflora var. curviflora	-	Associated PCTs: HN564; HN566; HN604 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	8 ha
Pomaderris brunnea	Brown Pomaderris	Associated PCTs: HN525; HN527; HN532; HN536; HN557; HN553; HN564; HN574; HN607 Associated IBRA subregion: Burragorang, Wollemi, Bungonia Onsite distribution: species recorded around Tonalli Cove, Higgins Bay, Nattai River, Butcher's Creek area	All associated PCTs within Wollemi, Burragorang, Bungonia IBRA subregions	1,146 ha
Pterostylis saxicola	Sydney Plains Greenhood	Associated PCTs: HN525; HN532; HN535; HN564 Associated IBRA subregion: Burragorang, Wollemi, Bungonia, Kanangra Habitat constraint: geology Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	HN525, HN532, HN535 on Lambie Group geology. HN564 on Hawkesbury sandstone. Within Wollemi, Burragorang, Bungonia, Kanangra IBRA subregions	111 ha
Pultenaea glabra	Smooth Bush-pea	Associated PCTs: HN566; HN568 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	33 ha
Pultenaea parviflora	-	Associated PCTs: HN566 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	7 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Pultenaea sp. Olinda	-	Associated PCTs: HN566; HN598 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	7 ha
Rhizanthella slateri	Eastern Australian Underground Orchid	Associated PCTs: HN517; HN606; HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	23 ha
Rhodamnia rubescens	Scrub Turpentine	Associated PCTs: HN517, HN537, HN538, HN606 Associated IBRA subregion: Burragorang, Bungonia, Wollemi, and Kanangra Onsite distribution: not observed within the survey area during current surveys, however, there are records at Yerranderie and Jenolan Caves. Assumed to be present.	All associated PCTs – within Burragorang, Bungonia, Wollemi, and Kanangra IBRA subregions	78 ind
Solanum amourense	-	Associated PCTs: HN525; HN527; HN532; HN535; HN536; HN538; HN557; HN568 Associated IBRA subregion: Burragorang, Kanangra, Bungonia Onsite distribution: east of Wollondilly River near Murphy's Crossing	All associated PCTs in the Wollondilly River Catchment: from confluence of Nattai River, south to extent of study area of Wollondilly River – within Burragorang, Kanangra, Bungonia subregions	470 ha
Tetratheca glandulosa	-	Associated PCTs: HN517; HN532; HN564; HN566; HN568; HN604; HN606; HN607; HN598 Associated IBRA subregion: Burragorang and Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Wollemi and Burragorang IBRA subregions	305 ha
Trachymene scapigera	-	Associated PCTs: HN553; HN557; HN574 Associated IBRA subregion: Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Kanangra IBRA subregion	19 ha
Velleia perfoliata	-	Associated PCTs: HN532; HN536; HN564; HN566; HN598 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys, however. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	18 ha
Xanthosia scopulicola	-	Associated PCTs: HN606; HN598 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys, however. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	21 ha

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha) or number of Individuals (Ind)
Zieria covenyi	Coveny's Zieria	Associated PCTs: HN566; HN598 Associated IBRA subregion: Burragorang Onsite distribution: not observed within the survey area during current surveys. Assumed to be present.	All associated PCTs – within Burragorang IBRA subregion	11 ha
Zieria involucrata	-	Associated PCTs: HN606 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys, however. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	21 ha
Zieria murphyi	Velvet Zieria	Associated PCTs: HN566; HN598 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys, however. Assumed to be present.	All associated PCTs – within Wollemi IBRA subregion	7 ha

8.8.5.5 Impacts on threatened fauna species and their habitat

The Project's ongoing operation would result in impacts associated with of temporary inundation to suitable habitat for threatened fauna species. Important fauna habitat features that may be impacted by the Project include:

- understorey vegetation: this includes 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: 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: 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.

As discussed in Section 8.8.1, the magnitude and extent of flooding will be variable depending on future rainfall events, making future impacts associated with the Project difficult to accurately characterise and quantify, particularly for the larger, less frequent events. Therefore, the consequence of any given event is difficult to accurately quantify and describe in detail.

A description of the potential impacts of temporary inundation on each threatened fauna candidate species and its habitat is provided in Table 8-33.

Threatened species polygons were derived for each of the threatened fauna 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
- from records (Atlas of Living Australia, BioNet Wildlife Atlas, Australian Virtual Herbarium)
- distribution 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).

A summary of the habitat impacted within the upstream impact area, and a description of how these areas were derived is shown in Table 8-34.

Table 8-33. Description of potential Project impacts on fauna species credit species

Species name	Common name	BC Act status	EPBC Act status	Description of potential impacts to species
Anthochaera phrygia	Regent Honeyeater	CE	CE	During the current assessment, a large breeding population of Regent Honeyeaters were recorded around Tonalli Cove. Impacts from temporary inundation may include loss of structural components of the vegetation (for example, *Amyema pendula* and *Amyema cambagei*) within areas of suitable breeding habitat, mortality of nestlings should a flood occur during a breeding event, and potential loss of suitable foraging habitat, specifically feed tree species such as *Eucalyptus melliodora, Eucalyptus albens, and Eucalyptus eugenioides.* Further consideration of the impacts to Regent Honeyeater can be found in Appendix F1 (Biodiversity Assessment Report – Upstream, Appendix K).
Cercartetus nanus	Eastern Pygmy-possum	V	-	Eastern Pygmy-possums were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area and across the study area may result in a reduction in the availability of foraging resources and breeding sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during a flood event, and loss of suitable foraging habitat.
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	During the current assessment, the species was recorded across much of the study area: around the shores of Lake Burragorang, along the main tributaries, including Wollondilly, Nattai, Kedumba, Cox, and Kowmung Rivers, and Warragamba Dam. Temporary inundation may modify the structure and composition of suitable foraging habitat. It is expected that limited roosting and breeding habitat occurs within the study area, however, it should be noted that t surveys did not specifically target this type of habitat during the current assessment. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during a flood event, and loss of suitable foraging habitat.
Heleioporus australiacus	Giant Burrowing Frog	V	V	Giant Burrowing Frogs were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and breeding sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during a flood event, and loss of suitable foraging habitat.
Hoplocephalus bungaroides	Broad-headed Snake	E	V	Broad-headed Snakes were not recorded during current surveys but are assumed to be present. Low quality habitat for Broad-headed Snake may be impacted. The affected habitat is confined to the lower reaches of Lake Burragorang and consists of small ledges with few exfoliated rocks and is moderately to well shaded. The most important areas of habitat in the study area occur along the top edges of the sandstone escarpments, where there are more extensive areas of rock shelf and little shading. These areas are well above the proposed inundation area. Impacts may include loss of habitat components such as exfoliated rocks and hollows, and potential mortality during flood events.
Isoodon obesulus subsp. *obesulus*	Southern Brown Bandicoot (eastern)	E	E	Southern Brown Bandicoots were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and breeding sites for the Southern Brown Bandicoot. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.

Species name	Common name	BC Act status	EPBC Act status	Description of potential impacts to species
Ixobrychus flavicollis	Black Bittern	V	-	Black Bitterns were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of roosting and sheltering sites for Black Bitterns. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.
Litoria littlejohni	Littlejohn's Tree Frog	V	V	Littlejohn's Tree Frog were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and breeding sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.
Macropus parma	Parma Wallaby	V	-	Parma Wallabies were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and shelter sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.
Myotis macropus	Southern Myotis	V	-	Temporary inundation may modify the structure and composition of suitable foraging habitat for Southern Myotis within the study area. Most of the habitat impacted comprises of suitable foraging habitat. It is expected that some roosting and breeding habitat occurs within the study area, however, it should be noted that surveys did not specifically target this type of habitat during the current assessment. Impacts may include loss of large areas of the structural components of the vegetation within areas of suitable foraging habitat, loss of suitable breeding and roosting habitat, and potential mortality of individuals during flood events.
Petaurus norfolcensis	Squirrel Glider	V	-	Squirrel Gliders were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and nesting sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	Brush-tailed Rock Wallabies were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and shelter sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.
Phascogale tapoatafa	Brush-tailed Phascogale	V	-	Brush-tailed Phascogale were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and nesting sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.

Species name	Common name	BC Act status	EPBC Act status	Description of potential impacts to species
Phascolarctos cinereus	Koala	V	V	Koalas were not recorded during current surveys but are assumed to be present. Modification of habitat within the study area may impact on koalas due to the potential reduction in the availability of foraging resources. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat- specifically suitable feed tree species.
Pseudophryne australis	Red-crowned Toadlet	V	-	Red-crowned Toadlet were recorded during current surveys, calling from East Warragamba Wall and West Warragamba Wall. Modification of habitat within the study area may result in a reduction in the availability of foraging resources and breeding sites. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.
Varanus rosenbergi	Rosenberg's Goanna	V	-	During the current assessment, Rosenberg's Goanna was recorded near the confluence of the Coxs and Kedumba Rivers. Modification of habitat within the study area may result in a reduction in the availability of breeding sites for Rosenberg's Goanna. Impacts may include loss of structural components of the vegetation within areas of suitable breeding habitat, potential mortality of individuals during flood events, and loss of suitable foraging habitat.

Table 8-34. Summary of species credit species habitat impacted by the Project

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha)
Anthochaera phrygia	Regent Honeyeater	Associated PCTs: HN525; HN527; HN532; HN533; HN535; HN536; HN537; HN538; HN553; HN557; HN564; HN566; HN568; HN574; HN604; HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Bungonia, Wollemi, Kanangra Onsite distribution: breeding population of minimum 21-25 individuals recorded around Tonalli Cove	All associated PCTs within Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	1,264.55
Cercartetus nanus	Eastern Pygmy-possum	Associated PCTs: HN517; HN525; HN527; HN532; HN533; HN535; HN536; HN537; HN553; HN557; HN564; HN566; HN568; HN604; HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Bungonia, Wollemi, Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	1,296.12
Chalinolobus dwyeri	Large-eared Pied Bat	Associated PCTs: HN517; HN525; HN527; HN532; HN533; HN535; HN536; HN537; HN538; HN553; HN557; HN564; HN566; HN568; HN574; HN604; HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Bungonia, Wollemi, Kanangra Habitat constraint: 2 kilometres of mapped cliff lines Onsite distribution: Nattai River, Wollondilly River, Tonalli Cove, Coxs River between Kelpie Point and Butcher's Creek, East and West Warragamba Walls	All associated PCTs within 2km of mapped cliff lines – in Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	1,203.02
Heleioporus australiacus	Giant Burrowing Frog	Associated PCTs: HN517; HN525; HN527; HN532; HN533; HN535; HN536; HN537; HN553; HN557; HN564; HN566; HN568; HN604; HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Wollemi, Kanangra Habitat constraint: all areas of native vegetation within 300 metres 2nd and 3rd order streams on sandstone or upland swamps Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All native vegetation within 300 metres of 2nd and 3rd order streams on sandstone – in Burragorang, Wollemi, Kanangra IBRA subregions	883.64
Hoplocephalus bungaroides	Broad-headed Snake	Associated PCTs: HN517; HN525; HN527; HN532; HN533; HN535; HN536; HN537; HN553; HN564; HN566; HN568; HN574; HN604: HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Wollemi, Kanangra Habitat constraint: land within 500 m of sandstone escarpments with hollow-bearing trees, rock crevices or flat sandstone rocks on exposed cliff edges and sandstone outcropping Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within 500 m of mapped cliff lines – in Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	124.71
Isoodon obesulus subsp. *obesulus*	Southern Brown Bandicoot (eastern)	Associated PCTs: HN525; HN527; HN532; HN533; HN535; HN536; HN553; HN557; HN566 Associated IBRA subregions: Burragorang, Wollemi, Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Burragorang, Wollemi, Kanangra IBRA subregions	1,167.29

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha)
Ixobrychus flavicollis	Black Bittern	Associated PCTs: HN553; HN574; HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Wollemi IBRA subregion	1.84
Litoria littlejohni	Littlejohn's Tree Frog	Associated PCTs: HN517; HN525; HN527; HN532; HN533; HN535; HN536; HN537; HN553; HN564; HN566; HN568; HN574; HN604: HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Wollemi Habitat constraint: all areas of native vegetation within 300 metres 3rd and 4th order streams with a rocky base on sandstone Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within 300 metres of 3rd and 4th order streams on sandstone – in Burragorang and Wollemi IBRA subregions	420.32
Macropus parma	Parma Wallaby	Associated PCTs: HN607 Associated IBRA subregion: Wollemi Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Wollemi IBRA subregion	1.84
Myotis macropus	Southern Myotis	Associated PCTs: HN517; HN525; HN527; HN532; HN533; HN535; HN537; HN538; HN553; HN564; HN568; HN574; HN598; HN606; HN607 Associated IBRA subregions: Burragorang, Bungonia, Wollemi, Kanangra Habitat constraint: Hollow-bearing trees, bridges, caves or artificial structures within 200 metres of riparian zone Onsite distribution: not observed within the survey area during current surveys, however, there are recent records within the study area. Assumed to be present	All associated PCTs within 200 m of riparian zone – in Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	863.70
Petaurus norfolcensis	Squirrel Glider	Associated PCTs: HN525; HN527; HN532; HN533; HN535; HN536; HN553; HN557; HN566; HN568; HN604; HN606; HN598 Associated IBRA subregions: Burragorang, Bungonia, Wollemi, Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	1,238.37
Petrogale penicillata	Brush-tailed Rock-wallaby	Associated PCTs: HN517; HN525; HN527; HN533; HN535; HN536; HN537; HN538; HN557; HN566; HN568; HN606; HN598 Associated IBRA subregions: Burragorang, Bungonia, Wollemi, Kanangra Habitat constraint: land within 1 km of rock outcrops or cliff lines Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within 1 kilometres of mapped cliff lines – in Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	411.70

Species name	Common name	Threatened species polygon filters	Decision	Upstream impact area (ha)
Phascogale tapoatafa	Brush-tailed Phascogale	Associated PCTs: HN532; HN533; HN564; HN566; HN604; HN606 Associated IBRA subregion: Burragorang, Wollemi, Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Burragorang, Wollemi, Kanangra IBRA subregions	32.98
Phascolarctos cinereus	Koala	Associated PCTs: HN517; HN525; HN527; HN532; HN533; HN535; HN536; HN537; HN538; HN553; HN557; HN564; HN566; HN568; HN574; HN604; HN606; HN607; HN598 Associated IBRA subregion: Burragorang, Bungonia, Wollemi, Kanangra Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All associated PCTs within Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	1,380.35
Pseudophryne australis	Red-crowned Toadlet	Associated PCTs: HN517; HN532; HN533; HN536; HN564; HN566; HN568; HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Wollemi, Kanangra Habitat constraint: all areas of native vegetation within 100 metres 1st and 2nd order drainage lines, swamps or soaks on sandstone geology Onsite distribution: not observed within the survey area during current surveys. Assumed to be present	All native vegetation within 100 metres of 1st and 2nd order drainage lines, swamps or soaks on sandstone geology – within the Burragorang, Wollemi, and Kanangra subregions	760.31
Varanus rosenbergi	Rosenberg's Goanna	Associated PCTs: HN525; HN527; HN533; HN535; HN536; HN553; HN557; HN564; HN566; HN568; HN574; HN604; HN606; HN607; HN598 Associated IBRA subregions: Burragorang, Wollemi, Kanangra, Bungonia Habitat constraint: land within 250 metres of termite mounds or rock outcrops Onsite distribution: Coxs River	All associated PCTs within Burragorang, Bungonia, Wollemi, Kanangra IBRA subregions	1,111.39

8.8.6 Cumulative impacts

Cumulative impacts on biodiversity values from the Project across the construction area, upstream operational area, and downstream area, as well as projects within the same IBRA subregions have been considered. These are discussed in Appendix F1 (Biodiversity Assessment Report – Upstream), Appendix F2 (Downstream BAR) and Chapter 28 (Cumulative impact assessment), and summarised in Table 8-35. The impacted areas encompass all types of impacts, including the impacts associated with temporary inundation and alterations to hydrological flows.

It should be noted that only key infrastructure projects have been included within the assessment. Therefore, this assessment is not a comprehensive assessment of all other proposed or determined projects within the IBRA subregions associated with the Project. Furthermore, for some projects, there is no publicly available information about the extent of the construction and operational impacts of the Project, or they are yet to be determined. Lastly, only impacts to threatened biota across multiple projects, or areas of the Project are included within the cumulative impact assessment.

Table 8-35. Past, present and future projects

Project	Construction impact	Operational Impact
Warragamba Dam Raising – Upstream ▪ upstream operational impacts associated within the Project.	▪ N/A	▪ flood stress of native vegetation due to temporary inundation of around two weeks ▪ long term erosion ▪ changes to vegetation structure and floristics ▪ physical damage to vegetation ▪ loss of threatened species and their habitat.
Warragamba Dam Raising – Construction ▪ Construction impacts associated within the Project.	▪ removal of 22.51 ha of native vegetation, including one CEEC ▪ removal of threatened flora and fauna habitat.	▪ N/A
Warragamba Dam Raising – Downstream ▪ Downstream operational impacts associated within the Project.	▪ N/A	▪ alterations of hydrological flows ▪ changes to vegetation structure and floristics ▪ long term erosion ▪ loss of threatened species and their habitat.
Western Sydney Airport ▪ Located approximately 8.5 km east of Warragamba Dam. ▪ Construction commenced.	▪ removal of 318.50 ha of native vegetation ▪ removal of 141.80 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 73.65 hectares of native vegetation, including one CEEC ▪ removal of 334.312 hectares of fauna habitat ▪ direct and indirect impacts to threatened biota.	▪ fauna injury and mortality from vehicle collisions ▪ changes to aquatic habitat and hydrology ▪ impacts on riparian corridors ▪ noise, light and vibration impacts.

Project	Construction impact	Operational Impact
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 39.61 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 54.10 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.

8.8.7 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, p11) 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 to the TSC Act provides a list of KTPs, with Schedule 4 to 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 upstream biodiversity assessment.

Impacts from KTPs associated with the FM Act are provided in Chapter 9 of the 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 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, may result in the operation of or increase the impact of two KTPs. These are presented in Table 8-36.

Table 8-36. Key threatening processes associated with the project

Key threatening process	BC Act	EPBC Act	EPBC Act equivalent	Details
Alteration to the natural flow regimes of rivers, streams, floodplains & wetlands	Yes	Yes	-	The change in the depth and duration of inundation, especially within forested wetland communities along the major tributaries of Lake Burragorang, would constitute an 'alteration to the natural flow regimes of rivers, streams, floodplains and wetlands' as defined within the Scientific Determination of the KTP.
Clearing of native vegetation	Yes	Yes	Land clearance	The change in the depth and duration of inundation as a result of the Project result in the loss of vegetation such that the structure and floristic composition of the PCTs would be modified.

Changes to vegetation community and structure that may result from temporary inundation may in turn create conditions more conducive to the operation of a range of additional KTPs, which are listed in Table 8-37. 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 8-37. Other key threatening processes

Key threatening process	BC Act	EPBC 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)*
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 of frogs by amphibian chytrid causing the disease chytridiomycosis	Yes	Yes	Infection of amphibians with chytrid fungus resulting in chytridiomycosis

Key threatening process	BC Act	EPBC Act	EPBC Act equivalent
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 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	-
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

8.8.8 Thresholds for assessing unavoidable impacts

Unavoidable impacts of the Project have been considered and a determination made of the assessment and offsetting requirements of such impacts. Table 8-38 summarises these requirements which include:

(i) Impacts that require further consideration by 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 by the assessor.

A discussion of each of these components is provided in the following table. The Biodiversity Credit Report generated by the Project is provided in Appendix F1 (Biodiversity Assessment Report – Upstream, Appendix A).

.

Table 8-38. Summary of areas impacted by the Project

Threshold	Biodiversity value	Criteria	Applicability to the Project
I. Impacts that require further consideration by consent authority	Landscape features	Impacts that would substantially reduce the width of vegetation in the riparian buffer zone bordering rivers and streams 4th order or greater	Yes- The Project may impact on 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	The Project may impact on a CEEC as a result of potential impacts to: White Box Yellow Box Blakely's Red Gum Woodland CEEC These impacts are unlikely to cause the extinction of the CEEC from the IBRA subregion or significantly reduce the viability of the CEEC.
		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)	Yes – the Project may impact on suitable breeding and foraging habitat for Regent Honeyeater.
		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.	Yes – the Project would potentially impact on the following species: ▪ *Hakea dohertyi* ▪ *Eucalyptus benthamii* ▪ *Solanum amourense.*
		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	Yes – the Project would potentially impact upon four threatened species that have not previously been recorded within the IBRA subregions within which the Project occurs. These species are: ▪ *Eucalyptus glaucina* ▪ *Callistemon linearifolius* ▪ *Grammitis stenophylla* ▪ *Pomaderris brunnea*.

Threshold	Biodiversity value	Criteria	Applicability to the Project
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
		Impacts on PCTs that are EECs not specifically nominated as requiring further consideration in the SEARs	The Project would potentially impact on three PCTs associated with EECs: HN553, HN527, HN557, that are not specifically nominated as requiring further consideration in the SEARs.
		Impacts on PCTs associated with threatened species habitat and which have a site value score ≥17	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 have been 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	The Project would potentially 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	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.	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	All PCTs within the study area 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 would potentially impact on 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	All PCTs have a site value score >17.
IV. Impacts that do not require further assessment by the assessor	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 as requiring assessment.
	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 as 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

8.8.9 Impacts that require further consideration

8.8.9.1 Landscape features

Consideration of 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.

Because the Project would potentially impact upon native vegetation within the 50-metre riparian buffer of a 6th order stream or higher, the matters outlined in Table 8-39 are to be considered.

Table 8-39. Further consideration of impacts to riparian buffers

FBA section 9.2.3.3 criterion	Consideration
(a) the name and stream order of the riparian buffer being impacted	The following rivers are greater than a 6th order stream at the point of its extent at which the impact would occur: ▪ Wollondilly River: 8th order Strahler stream ▪ Nattai River: 7th order Strahler stream ▪ Little River: 6th order Strahler stream ▪ Coxs River: 8th order Strahler stream ▪ Kowmung River: 7th order Strahler stream ▪ Kedumba River: 6th order Strahler stream.
(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 the size of the gaps being created or expanded	The total area of riparian buffer within the study area is 4,239.87 ha. The Project would increase the extent (in relation to width from the FSL), depth, and duration of temporary inundation within the riparian buffer from existing conditions. The additional width of impact is variable across the study area and will depend on the variability of the flood event. As discussed in Section 8.2.5.2 the upstream impact area has been defined as the area between RL 119.5 mAHD and RL 126.97 mAHD. Note that the riparian areas adjacent to the existing FSL of Warragamba are subject to temporary inundation from the existing dam however with the project, inundation would occur further up the reaches of a number of rivers and creeks.
(c) the PCT and condition of the vegetation in the riparian buffer being impacted.	The identified PCTs within the upstream impact area are detailed in Section 8.4.1.1. The condition of the PCTs has been assessed as moderate to good within the riparian buffer.
(d) any direct impacts on wetlands or watercourses downstream of the development site	N/A to the upstream biodiversity assessment report.
(e) mitigation measures proposed to minimise the impact on the biodiversity values of the riparian or downstream area.	The riparian area would be managed as part of an Environmental Management Plan. It is expected that the plan would include measures that would minimise erosion, bank slumping, and re-establish native vegetation within certain areas of the study area.

8.8.9.2 Native vegetation

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

1. Any CEEC, unless the CEEC is specifically excluded by the SEARs.

2. 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 SEARs exclude the following CEECs from matters for further consideration:

- Wollemi IBRA Subregion
  - Sun Valley Cabbage Gum Forest in the Sydney Basin Bioregion
- Burragorang IBRA subregion
  - Cumberland Plain Woodland in the Sydney Basin Bioregion
  - Robertson Basalt Tall Open-forest in the Sydney Basin and South Eastern Highlands bioregions.

However, the Project would impact upon two PCTs, considered to align with White Box Yellow Box Blakely's Red Gum Woodland (Critically Endangered – BC Act and EPBC Act). These are:

- PCT 840/HN527: Narrow-leaved Ironbark – Forest Red Gum on rocky slopes of the lower Burragorang Gorge, Sydney Basin Bioregion
- PCT 1401/HN557: Forest Red Gum – Yellow Box woodland of dry gorge slopes, southern Sydney Basin Bioregion and South Eastern Highlands.

White Box Yellow Box Blakely's Red Gum Woodland CEEC is not specifically listed in the SEARs as a matter requiring consideration. However, as it is listed as Critically Endangered under the BC Act, and listed as Critically Endangered under the EPBC Act, it meets the requirements for inclusion as per Section 9.2.4.1 of the FBA. As such, this CEEC has been considered further (based on the criteria in Section 9.2.4.2 of the FBA) in Table 8-40.

The SEARs did not specifically nominate any 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.

Table 8-40. Further consideration of impacts to White box yellow box Blakely's red gum CEEC

FBA section 9.2.4.2 criterion	Consideration
(a) the area and condition of the CEEC or EEC to be impacted directly and indirectly by the proposed development	The Project would impact 430.56 ha of White Box Yellow Box Blakely's Red Gum Woodland CEEC within the upstream impact area. The area comprises: ▪ 70.70 ha of HN527: Forest Red Gum - Yellow Box woodland of dry gorge slopes southern Sydney Basin Bioregion and South Eastern Highlands Bioregion (Moderate/Good condition) ▪ 57.05 ha of HN527 (Moderate/Good_DNG condition) ▪ 302.81 ha of HN557: Narrow-leaved Ironbark - Forest Red Gum on rocky slopes of the lower Burragorang Gorge Sydney Basin Bioregion (Moderate). Within the study area, the majority of White Box Yellow Box Blakely's Red Gum Woodland is distributed upstream from Higgins Bay, immediately surrounding Lake Burragorang and along the Wollondilly River.
(b) the extent and overall condition of the CEEC or EEC within an area of 1,000 ha and then 10,000 ha surrounding the proposed development footprint.	***Note**: It was not possible to derive an extent and overall condition of the CEEC within an area of 1,000 ha and then 10,000 ha of the Project due to it being a linear, large-scale extent. SMEC has instead derived an` extent and overall condition of the CEEC within a one kilometre and then a five kilometre buffer applied to the study area boundary.* The GIS layer '*Native vegetation of southeast NSW: a revised classification and map for the coast and eastern tablelands*' (Tozer, et al. 2010) was used to calculate the area of White Box Yellow Box Blakely's Red Gum Woodland CEEC within a one kilometre and then a five kilometre buffer of the study area. Using Tozer, et al. (2010), the map units considered equivalent to this CEEC are: ▪ GW p24: Tableland Grassy Box-Gum Woodland ▪ DSF p35: Wollondilly-Cox-Shoalhaven Gorge Woodland ▪ GW p420: Tableland Granite Grassy Woodland ▪ DSF p202: Burragorang Rocky Slopes Woodland. An analysis of this mapping estimated that there is approximately: ▪ 2,817.23 hectares of the EEC within a buffer of one kilometre of the study area ▪ 9,589.21 hectares of the EEC within a buffer of five kilometres of the study area. However, given the broad-scale nature of the Tozer, et al. (2010) GIS layer, it should be noted that it is possible that there are additional occurrences of the EEC not mapped within each one kilometre and 5 kilometre buffer. The mapping by Tozer, et al. (2010) does not provide information on the 'vegetation condition' for each mapped occurrence of the EEC. According to the Final Determination for White box Yellow Box Blakely's Red Gum Woodland CEEC '*the condition of remnants ranges from relatively good to highly degraded*' where '*less degraded remnants occur in Travelling Stock Routes, cemeteries and reserves*' (NSW Scientific Committee 2011d). A desktop analysis of the mapped occurrences of the CEEC within the one kilometre and five kilometre buffered areas identified many patches as occurring adjacent to the south-west portion of the study area along the Wollondilly River near Coleman's Bend, Douglas Flat, Bridge Point and Tonalli Cove with smaller extents mapped along the Little River and near to the confluence between the Kedumba River and Cox River. All mapped extents of the EEC occurring within the one kilometre and five kilometre buffered areas are likely to be in relatively good condition due to their isolation and reservation on National Park estate. However, historically these areas may have been subjected to light grazing by stock due to previously having been private landholdings.

FBA section 9.2.4.2 criterion	Consideration
(c) an estimate of the extant area and overall condition of the CEEC or EEC remaining in the IBRA subregion after the impact of the proposed development has been taken into consideration	Current mapping and literature do not provide an accurate estimate of the extant area of this CEEC in the Bungonia, Burragorang and Kanangra IBRA subregions. Due to the CEECs' occurrence on high fertility soils, much of the community is on privately owned land, existing as isolated patches within an agricultural matrix of cropping, improved pastures and/or disturbed vegetation communities (DECCW 2010b). Thomas, et al. (2000) estimated that in south-eastern NSW the extent of White Box Yellow Box Blakely's Red Gum Woodland EEC has been reduced to around five percent of its pre-1750 distribution totalling approximately 59,468 hectares. Further, it is considered that only 0.05 percent of the EEC in NSW remains in near to original condition (Prober & Thiele 2005). The map units equivalent to the CEEC as per Tozer, et al. were therefore considered for the purposes of estimating the extant area of the EEC within each IBRA subregion. According to this mapping (Tozer, et al. 2010), there is: ▪ 42,811.87 hectares of EEC within the Bungonia IBRA subregion ▪ 6,257.00 hectares of EEC within the Burragorang IBRA subregion ▪ 2,533.80 hectares of EEC within the Kanangra IBRA subregion. However, this mapping may contain inaccuracies in extent and does not provide an indication of the condition of the mapped occurrences of the EEC. Given the occurrence of the CEEC is predominantly on privately owned land, the quality of remnants remains largely unknown (DECCW 2010b). The Project would impact approximately 430.56 ha of White Box Yellow Box Blakely's Red Gum Woodland CEEC within the upstream impact area. Where the impacts associated with the Project have been taken into consideration (assuming that all extents of this EEC would cease to exist following inundation), it is estimated that there is: ▪ 41,364.24 hectares of the CEEC outside of the impact area within the Bungonia IBRA subregion ▪ 4,809.27 hectares of CEEC would remain within the Burragorang IBRA subregion ▪ 1,086.07 hectares would remain within the Kanangra IBRA subregion.
(d) the development proposal impact on: i) abiotic factors critical to the long-term survival of the CEEC or EEC. For example, will the impact lead to a reduction of groundwater levels or substantial alteration of surface water patterns?	Within the study area, the majority of White Box Yellow Box Blakely's Red Gum Woodland is distributed upstream of Higgins Bay, immediately surrounding Lake Burragorang and along the Wollondilly River The Project may alter abiotic factors that may impact on the long-term survival of the CEEC. Such abiotic factors include (but not limited to) changes to soil properties (such as the chemistry, structure etc.), hydrological processes (including surface water patterns) and nutrient cycling, with the extent to which the changes occurring dependent upon the depth and duration temporary inundation. However, there is little information available to understand the extent of changes to abiotic factors that would be required to consequently have a detrimental effect on the long-term survival of the CEEC. Therefore, in applying the precautionary principle it has been assumed that any change to abiotic factors may detrimentally affect the quality and integrity of the CEEC within the impact area.
ii) characteristic and functionally important species through impacts such as, but not limited to, inappropriate fire regimes, removal of understory species, or harvesting of plants	Temporary inundation from the Project would impact approximately 430.56 ha of moderate to good condition HN527 and HN557 equivalent to White Box Yellow Box Blakely's Red Gum woodland CEEC within the impact area. As discussed in Section 4.4.2.1, the EEC within the study area contains functionally important species such as *Cheilanthes distans, Themeda triandra*, and *Arthropodium milleflorum*, some of which may be intolerant to waterlogging and temporary inundation (Benson & McDougall 1993; Benson & McDougall 1996; Benson & McDougall 2005). The protected status of the catchment will remain unchanged and access will be restricted so it is not expected that the Project will result in inappropriate fire regimes, removal of understory species or harvesting of plants.

FBA section 9.2.4.2 criterion	Consideration
iii) the quality and integrity of an occurrence of the CEEC or EEC through threats and indirect impacts including, but not limited to, assisting invasive flora and fauna species to become established or causing regular mobilisation of fertilisers, herbicides or other chemicals or pollutants which may harm or inhibit growth of species in the CEEC or EEC.	The quality and integrity of White Box Yellow Box Blakely's Red Gum Woodland CEEC may be impacted by temporary inundation via various pathways following inundation events. The Project will not increase sources of invasive flora and fauna species or cause mobilisation of fertilisers, herbicides or other chemical or pollutants which may harm or inhibit growth of species. Flood stress may lead to increased risk of weed encroachment and susceptibly of flora and fauna species to diseases and pathogens. The CEEC within the study area was found to be high quality due to having high species diversity, structural intactness and a demonstrated resilience to past agricultural land use practices. However, additional pressures associated with the Project may potentially reduce the quality and integrity of remaining stands of the CEEC within the study area.
(e) direct or indirect fragmentation and isolation of an important area of the EEC.	The White Box Yellow Box Blakely's Red Gum Woodland within the study area is an important area of the TEC as defined by the FBA. An important area comprises an area of the TEC 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 EEC or occurrences of the CEEC or EEC at the limit of the community's range. The National Recovery Plan for White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland identifies habitat critical for the survival of the EEC, and states that given the highly degraded state of the ecological community, all areas of White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland which meet the minimum condition requirements under the EPBC Act should be considered critical for the survival of the TEC. Both HN527 and HN557 conform to the Final Determination of the CEEC under the EPBC . The areas of TEC that occur within the study area are contiguous with larger tracts of the TEC within the locality.
(f) the measures proposed to contribute to the recovery of the EEC in the IBRA subregion	White Box Yellow Box Blakely's Red Gum Woodland has been assigned to the threatened ecological community management stream under the Saving our Species (SoS) program. This SoS strategy aims to secure the ecological community in the long term. The proponent of the Project plans to compensate for the impacts to White Box Yellow Box Blakely's Red Gum Woodland within the upstream impact area in accordance with the steps outlined in the biodiversity offset strategy (BOS).

8.8.9.3 Threatened species and populations

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

- any impacts on critically endangered species, unless the critically endangered species is specifically excluded in the SEARs
- 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
- where the survey or expert report undertaken in accordance with Section 6.6 of the FBA confirms that the threatened species is present in the proposed study area, and the threatened species has not previously been recorded in the IBRA subregion according to records in the NSW Wildlife Atlas.

The Project may impact upon the following threatened species listed within Attachment C on OEH's input into the SEARs:

- *Ancistrachne maidenii*
- *Eucalyptus benthamii*
- *Bossiaea oligosperma*
- *Solanum amourense*
- *Hakea dohertyi*
- *Dillwynia tenuifolia*
- *Epacris purpurascens var. purpurascens*
- *Gyrostemon thesioides*
- *Hibbertia puberula*
- *Melaleuca deanei*
- *Genoplesium baueri*
- *Tetratheca glandulosa.*

The Project may also impact upon:

- suitable breeding and foraging habitat for the Critically Endangered Regent Honeyeater
- *Eucalyptus glaucina, Pomaderris brunnea*, and *Callistemon linearifolious*, all of which were found incidentally outside of their normal IBRA Subregion distribution.

One critically endangered species, the Regent Honeyeater, was recorded within the study area while another, *Rhodamnia rubescens*, is assumed to be present. These species were not listed in the SEARs as matters for further consideration, however, they meet the requirements for further consideration under Section 9.2.5 of the FBA.

The SEARs produced for the Project exclude the following matters for further consideration:

- Elusive Bush-pea (*Pultenaea elusa*) (excluded for Burragorang IBRA subregion only)
- Megalong Valley Bottlebrush (*Callistemon megalongensis*) (excluded for Burragorang IBRA subregion only)
- Wingecarribee Gentian (*Gentiana wingecarribiensis*) (excluded for Burragorang IBRA subregion only).

Species listed in the SEARs as matters for further consideration that were not listed in the upstream IBRA Subregions have been excluded.

Matters for further consideration for threatened species are found in Appendix F1 (Biodiversity Assessment Report – Upstream, Appendix K).

8.9 Impacts requiring offsetting

8.9.1 Native vegetation

The assessment has identified the ecosystem credits required to offset the potential native vegetation impacts using the FBA Calculator.

The offset requirement for each PCT was calculated using the BBCC across the four IBRA subregions as discussed in Section 8.3.5. The management zone impacted, loss in site value, and the number of ecosystem credits required for the impacts for each IBRA calculator are detailed in Appendix F1 (Biodiversity Assessment Report – Upstream, Section 8) and Appendix F6 (Biodiversity offset strategy), and summarised in Table 8-41, Table 8-42, Table 8-43 and Table 8-44.

Table 8-41. Ecosystem credit requirements within Bungonia IBRA due to the Project

Veg zone	PCT	Condition	Impact area (ha)	Current site value	Future site value	Credit requirement
6	HN553	Moderate/Good	2.58	68.12	0	150
7	HN538	Moderate/Good	0.92	84.44	0	65
13	HN527	Moderate/Good	6.43	72.22	0	392
14	HN527	Moderate/Good_DNGL	18.0	53.38	0	844
17	HN557	Moderate/Good	1.89	73.44	0	117
21	HN574	Moderate/Good	54.29	74.64	0	3,412
Total			**84.10**			**4,980**

Table 8-42. Ecosystem credit requirements within Kanangra IBRA due to the Project

Veg zone	PCT	Condition	Impact area (ha)	Current site value	Future site value	Credit requirement
1	HN564	Moderate/Good	0.59	68.12	0	34
2	HN566	Moderate/Good	22.07	84.44	0	1,549
3	HN568	Moderate/Good	5.49	100.00	0	449
9	HN536	Moderate/Good	1.52	86.28	0	109
11	HN535	Moderate/Good	5.90	100.00	0	483
12	HN532	Moderate/Good	0.62	59.42	0	32
16	HN607	Moderate/Good	3,058.94	76.09	0	3,767
18	HN557	Moderate/Good	0.53	73.44	0	33
19	HN606	Moderate/Good	16.92	74.64	0	1,063
Total			**112.58**			**7,519**

Table 8-43. Ecosystem credit requirements within Wollemi IBRA due to the Project

Veg zone	PCT	Condition	Impact area (ha)	Current site value	Future site value	Credit requirement
1	HN564	Moderate/Good	1.92	60.63	0	100
2	HN566	Moderate/Good	6.04	77.08	0	343
3	HN568	Moderate/Good	17.84	91.06	0	1,339
9	HN536	Moderate/Good	6.19	82.28	0	442
11	HN533	Moderate/Good	1.28	75.36	0	81
12	HN532	Moderate/Good	3.19	59.42	0	164
16	HN517	Moderate/Good	0.34	78.26	0	22
18	HN607	Moderate/Good	1.84	64.98	0	102
19	HN606	Moderate/Good	20.54	85.99	0	1463
Total			**59.19**			**4,056**

Table 8-44. Ecosystem credit requirements within Burragorang IBRA due to the Project

Veg zone	PCT	Condition	Impact area (ha)	Current site value	Future site value	Credit requirement
2	HN566	Moderate/Good	0.52	77.08	0	31
3	HN568	Moderate/Good	7.88	91.06	0	590
6	HN553	Moderate/Good	104.51	68.12	0	6,019
7	HN538	Moderate/Good	27.17	84.44	0	1,897
8	HN537	Moderate/Good	0.13			11
9	HN536	Moderate/Good	205.21	82.28	0	14,613
10	HN535	Moderate/Good	16.27	100.0	0	1,326
11	HN533	Moderate/Good	9.69	75.36	0	610
12	HN532	Moderate/Good	222.23	59.42	0	11,348
13	HN527	Moderate/Good	64.27	72.22	0	13,899
14	HN527	Moderate/Good_DNGL	39.05	53.38	0	1,818
15	HN525	Moderate/Good	84.20	76.09	0	5,352
16	HN517	Moderate/Good	0.19	78.26	0	11
17	HN557	Moderate/Good	300.39	73.44	0	18,499
18	HN607	Moderate/Good	12.82	64.98	0	710
19	HN606	Moderate/Good	0.27	85.99	0	20
20	HN598	Moderate/Good	9.71	83.51	0	670
21	HN574	Moderate/Good	13.02	74.64	0	813
Total			**1,117.54**			**68,236**

8.9.2 Species and populations

The assessment has identified the ecosystem credits required to offset the potential native vegetation impacts using the FBA Calculator. The Offset Package is detailed in Appendix F6 (Biodiversity offset strategy), which is based on establishing credits to offset the following impacts within the upstream impact area.

Ninety-one (91) species credit species require offsetting. Species and their threatened status, area to be removed and credit requirements are presented in Table 8-45. Note that *Acronychia littoralis* (Scented Acronychia) has been used as a surrogate for *Rhodamnia rubescens* as the latter species is not available in the BBCC.

Table 8-45. Species credit species requiring offsetting

Species name	Common name	BC Act status	EPBC Act status	Area to be removed (ha) or number of individuals (ind)	Credit requirement
Acacia baueri subsp. aspera	*Acacia baueri subsp. aspera*	V	–	7.00	280
Acacia bynoeana	Bynoe's Wattle	E	V	35.00	2,695
Acacia clunies-rossiae	Kanangra Wattle	V	–	770.00	10,010
Acacia flocktoniae	Flockton Wattle	V	V	371.00	6,678
Acacia gordonii	*Acacia gordonii*	E	E	8.00	208

Species name	Common name	BC Act status	EPBC Act status	Area to be removed (ha) or number of individuals (ind)	Credit requirement
Acacia pubescens	Downy Wattle	V	V	35.00	665
Acronychia littoralis	Scented Acronychia	–	–	78.00	3,878
Acrophyllum australe	*Acrophyllum australe*	V	V	13.00	234
Ancistrachne maidenii	*Ancistrachne maidenii*	V	–	29.00	638
Anthochaera phrygia	Regent Honeyeater	CE	CE	1,264.55	97,370
Asterolasia buxifolia	*Asterolasia buxifolia*	E	–	14.00	1,078
Asterolasia elegans	*Asterolasia elegans*	E	E	6.00	108
Astrotricha crassifolia	Thick-leaf Star-hair	V	V	8.00	616
Baloskion longipes	Dense Cord-rush	V	V	31.00	558
Bossiaea oligosperma	Few-seeded Bossiaea	V	V	483.00	7,245
Caesia parviflora subsp. minor	Small Pale Grass-lily	E	–	15.00	210
Callistemon linearifolius	Netted Bottle Brush	V		1,968.00 (ind)	13,252
Callistemon megalongensis	Megalong Valley Bottlebrush	CE	CE	6.00	462
Calomnion complanatum	*Calomnion complanatum*	E	–	1.00	77
Cercartetus nanus	Eastern Pygmy-possum	V	–	1,296.12	25,923
Chalinolobus dwyeri	Large-eared Pied Bat	V	V	1,203.02	15,640
Cryptostylis hunteriana	Leafless Tongue Orchid	V	V	7.00	280
Darwinia biflora	*Darwinia biflora*	V	V	8.00	160
Darwinia peduncularis	*Darwinia peduncularis*	V	–	15.00	270
Dillwynia tenuifolia	*Dillwynia tenuifolia*	V	–	2.00	36
Epacris hamiltonii	*Epacris hamiltonii*	E	E	3.00	54
Epacris purpurascens subsp. purpurascens	*Epacris purpurascens subsp. purpurascens*	V	–	300.00	5,100
Epacris sparsa	Sparse Heath	V	V	2.00	36
Eucalyptus benthamii	Camden White Gum	V	V	44.00	616
Eucalyptus glaucina	Slaty Red Gum	V	V	10,970.00 (ind)	23,505
Eucalyptus pulverulenta	Silver-leafed Gum	V	V	170.44 275 (ind)	30
Euphrasia bowdeniae	*Euphrasia bowdeniae*	V	V	3.00	231
Genoplesium baueri	Bauer's Midge Orchid	E	E	223.00	2,899
Genoplesium superbum	Superb Midge Orchid	E	–	10.00	770
Grammitis stenophylla	Narrow-leaf Finger Fern	E	–	41.00	533
Grevillea evansiana	Evans Grevillea	V	V	7.00	105
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	V	V	9.00	126
Gyrostemon thesioides	*Gyrostemon thesioides*	E	–	886.00	68,222
Hakea dohertyi	Kowmung Hakea	E	E	199.00	3,781
Haloragodendron lucasii	*Haloragodendron lucasii*	V	V	8.00	616
Heleioporus australiacus	Giant Burrowing Frog	V	V	883.64	11,487
Hibbertia puberula	*Hibbertia puberula*	E	–	35.00	1,400
Hoplocephalus bungaroides	Broad-Headed Snake	E	V	124.71	4,116
Hygrocybe anomala subsp. ianthinomarginata	*Hygrocybe anomala subsp. ianthinomarginata*	V	–	267.00	20,559

Species name	Common name	BC Act status	EPBC Act status	Area to be removed (ha) or number of individuals (ind)	Credit requirement
Hygrocybe aurantipes	*Hygrocybe aurantipes*	V	–	35.00	1,400
Hygrocybe reesiae	*Hygrocybe reesiae*	V	–	35.00	1,400
Isoodon obesulus subsp. obesulus	Southern Brown Bandicoot (Eastern)	E	E	1,167.29	30,348
Isopogon fletcheri	Fletcher's Drumsticks	V	V	3.00	69
Ixobrychus flavicollis	Black Bittern	V	–	1.84	24
Kunzea rupestris	*Kunzea rupestris*	V	V	8.00	208
Lastreopsis hispida	Bristly Shield Fern	E	–	23.00	1,771
Leionema lachnaeoides	*Leionema lachnaeoides*	E	E	1.00	77
Lepidosperma evansianum	Evans Sedge	V	E	1.00	77
Leucopogon exolasius	Woronora Beard-heath	V	V	50.00	392
Leucopogon fletcheri subsp. fletcheri	*Leucopogon fletcheri subsp. fletcheri*	E	–	8.00	128
Litoria littlejohni	Littlejohn's Tree Frog	V	V	420.32	10,935
Macropus parma	Parma Wallaby	V	–	1.84	48
Melaleuca deanei	Deane's Paperbark	V	V	9.00	693
Melaleuca groveana	Grove's Paperbark	V	–	6.00	84
Micromyrtus blakelyi	*Micromyrtus blakelyi*	V	V	8.00	208
Myotis macropus	Southern Myotis	V	–	863.79	19,004
Olearia cordata	*Olearia cordata*	V	V	8.00	104
Persicaria elatior	Tall Knotweed	V	V	896.00	11,648
Persoonia acerosa	Needle Geebung	V	V	33.00	429
Persoonia bargoensis	Bargo Geebung	E	V	22.00	1,694
Persoonia glaucescens	Mittagong Geebung	E	V	9.00	693
Persoonia hirsuta	Hairy Geebung	E	E	35.00	2,695
Petaurus norfolcensis	Squirrel Glider	V	–	1,238.37	27,244
Petrogale penicillata	Brush-tailed Rock-wallaby	E	V	411.70	10,706
Phascogale tapoatafa	Brush-tailed Phascogale	V	–	32.98	660
Phascolarctos cinereus	Koala	V	V	1,380.35	35,890
Pherosphaera fitzgeraldii	Dwarf Mountain Pine	E	E	1.00	26
Phyllota humifusa	Dwarf Phyllota	V	V	8.00	144
Pimelea curviflora subsp. curviflora	*Pimelea curviflora subsp. curviflora*	V	V	8.00	616
Pomaderris brunnea	Brown Pomaderris	E	V	1,146.00	17,190
Pseudophryne australis	Red-crowned Toadlet	V	–	760.31	9,874
Pterostylis saxicola	Sydney Plains Greenhood	E	E	111.00	4,440
Pultenaea glabra	Smooth Bush-Pea	V	V	33.00	495
Pultenaea parviflora	*Pultenaea parviflora*	E	V	7.00	105
Pultenaea sp. Olinda	*Pultenaea sp. Olinda*	E	–	7.00	280
Rhizanthella slateri	Eastern Australian Underground Orchid	V	E	23.00	1,771
Solanum amourense	*Solanum amourense*	E	–	470.00	6,110
Tetratheca glandulosa	*Tetratheca glandulosa*	V	–	305.00	4,880

Species name	Common name	BC Act status	EPBC Act status	Area to be removed (ha) or number of individuals (ind)	Credit requirement
Trachymene scapigera	Mountain Trachymene	E	E	19.00	760
Varanus rosenbergi	Rosenbergs Goanna	V	–	1,111.39	36,676
Velleia perfoliata	*Velleia perfoliata*	V	V	18.00	306
Xanthosia scopulicola	*Xanthosia scopulicola*	V	–	21.00	315
Zieria covenyi	Coveny's Zieria	E	E	11.00	1,100
Zieria involucrata	*Zieria involucrata*	E	V	21.00	315
Zieria murphyi	Velvet Zieria	V	V	7.00	105

8.10 Impacts that do not require further assessment

The study area includes 5.23 hectares of cleared and modified land that is not considered to contain 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

8.11 Environmental management measures

Although the Project would seek to avoid and minimise impacts, not all biodiversity impacts can be avoided for many aspects of the Project as have been detailed above. The measure described in Table 8-46 would be implemented to effectively manage and mitigate impacts during operation.

Table 8-46. Summary of measures to minimise upstream biodiversity impacts

Impact		Mitigation measure	Outcome	Timing	Responsibility
General flora and fauna impacts	BUS1	Offset strategy to mitigate potential impacts on biodiversity (see Appendix F6 - Biodiversity Offset Strategy)	Offset strategy	Operation	WNSW

8.12 Risk assessment

An environmental risk assessment was carried out in accordance with the SEARs, using the methodology provided in Appendix C (Risk assessment procedure). A Project risk matrix was developed and risk ranking evaluated by considering:

- the likelihood (L) of an impact occurring
- the severity or consequence (C) of the impact in a biophysical and/or socio-economic context, with consideration of:
  - whether the impact will be in breach of regulatory or policy requirements
  - the sensitivity of receptors
  - duration of impact, that is, whether the impact is permanent or temporary
  - the areal extent of the impact and/or the magnitude of the impact on receptors.

The likelihood and consequence matrix is shown on Figure 8-17.

Once the consequence and likelihood of an impact are assessed, the risk matrix provides an associated ranking of risk significance: **Low**; **Medium**; **High** or **Extreme,** as shown in Table 8-47**.** The residual risk was determined after the application of proposed mitigation measures.

The risk analysis for potential upstream biodiversity impacts is provided in Table 8-48. This includes the residual risk of the potential impact after the implementation of mitigation measures.

Table 8-47. Risk ranking definitions

Risk definitions	
Extreme 21 – 25	Widespread and diverse primary and secondary impacts with significant long-term effects on the environment, livelihood, and quality of life. Those affected will have irreparable impacts on livelihoods and quality of life.
High 15 – 20	Significant resources and/or Project modification would be required to manage potential environmental damage. These risks can be accommodated in a Project of this size, however comprehensive and effective monitoring measures would need to be employed such that Project activities are halted and/or appropriately moderated. Those impacted may be able to adapt to change and regain their livelihoods and quality of life with a degree of difficulty.
Medium 9 – 14	Risk is tolerable if mitigation measures are in place, however management procedures will need to ensure necessary actions are quickly taken in response to perceived or actual environmental damage. Those impacted will be able to adapt to changes.
Low 1 – 8	On-going monitoring is required however resources allocation and responses would have low priority compared to higher ranked risks. Those impacted will be able to adapt to change with relative ease.

Figure 8-17. Risk matrix

		Consequence				
		Negligible	Minor	Medium	Major	Extreme
	LEGAL	No legal consequences	No legal consequences	Incident potentially causing breach of licence conditions	Breach of licence conditions	Breach of licence conditions resulting in shutdown of Project operations.
	SOCIO-ECONOMIC	Impacts that are practically indistinguishable from the social baseline or consist of solely localised or temporary/short-term effects with no consequences on livelihoods and quality of life.	Short-term or temporary impacts with limited consequences on livelihoods and quality of life. Those affected will be able to adapt to the changes with relative ease and regain their pre-impact livelihoods and quality of life.	Primary and secondary impacts with moderate effects on livelihoods and quality of life. Will be able to adapt to the changes with some difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with significant long-term effects on livelihoods and quality of life. Those affected may be able to adapt to changes with a degree of difficulty and regain their pre-impact livelihoods and quality of life.	Widespread and diverse primary and secondary impacts with irreparable impacts on livelihoods and quality of life and no possibility to restore livelihoods.
	HEALTH	No health consequences	Accident or illness with little or no impact on ability to function. Medical treatment required is limited or unnecessary.	Accident or illness leading to mild to moderate functional impairment requiring medical treatment.	Accident or illness leading to permanent disability or requiring a high level of medical treatment or management.	Accident, serious illness or chronic exposure resulting in fatality.
	ENVIRONMENT	Localised (on-site), short-term impact on habitat, species or environmental media	Localised or widespread medium-term impact to habitat, species or environmental media	Localised degradation of sensitive habitat or widespread long-term impacts on habitat, species or environmental media. Possible contribution to cumulative impacts.	Widespread and long-term changes to sensitive habitat, species diversity or abundance or environmental media. Temporary loss of ecosystem function at landscape scale. Moderate contribution to cumulative impacts.	Loss of a nationally or internationally recognised threatened species or vegetation community. Permanent loss of ecosystem function on a landscape scale. Major contribution to cumulative effects
		A - negligible	**B** - minor	**C** - medium	**D** - major	**E** - extreme
Expected to occur during the Project or beyond the Project	**a** - expected	**13**	**14**	**20**	**24**	**25**
May occur during the Project or beyond the Project	**b** - may	**8**	**12**	**19**	**22**	**23**
Possible under exceptional circumstances	**c** - possible	**6**	**7**	**11**	**18**	**21**
Unlikely to occur during the Project	**d** - unlikely	**4**	**5**	**10**	**16**	**17**
Rare or previously unknown to occur	**e** - rare	**1**	**2**	**3**	**9**	**15**

Risk Definition (see Table 8-47)	**Low**	**Medium**	**High**	**Extreme**

Table 8-48. Biodiversity upstream: risk assessment

Biodiversity: upstream								
Key impacts	Risk before mitigation			Mitigation and management	Risk after mitigation			Residual risk
	L	C	R		L	C	R	
Upstream								
The Project's operational impact would result in increased temporary inundation from mitigating large rainfall events in the study area. These impacts would involve changes to current temporary inundation extents, depths and durations, and rates of rising and receding flows. The upstream impact area covers an area of around 1400 ha. This area reflects the difference between the likely inundation level with the Project (10.25 m above FSL, RL 126.97 mAHD) and the likely inundation level for the existing dam (2.78 m above FSL, RL 119.5 mAHD). Potential impacts include: ▪ flood stress of native vegetation due to temporary inundation of around two weeks ▪ long term erosion ▪ changes to vegetation structure and floristics. ▪ physical damage to vegetation ▪ loss of threatened species and their habitat. Specific impacts are: ▪ **Impacts on native vegetation:** The Project's ongoing operation would result in potential impacts associated with temporary inundation to native vegetation across around 1400 ha. Native vegetation types within the upstream impact area includes areas of all 18 PCTs mapped in the study area. Endangered or critically	a	D	24	BUS1	a	C	20	Areas around Lake Burragorang are already subject to temporary inundation and there is a high likelihood that the Project may result in more prolonged and extensive temporary inundation. A biodiversity offset strategy (BOS) has been prepared to address the potential impacts of the Project resulting from upstream temporary inundation. The BOS assumes that there would be 100 percent loss of ecosystem and species values within the upstream impact area, however, in practice, this may not necessarily fully eventuate. The EMP required to be prepared and implemented in accordance with the *Water NSW Act 2014* to address temporary inundation of national parks estate is a separate management measure to the Project but would support the BOS. The EMP would provide a range of measures to monitor and minimise potential inundation impacts on affected areas. This would marginally reduce the consequence; however, the likelihood of inundation and potential biodiversity impacts remain. The residual risk has been assessed as High and will require appropriate resources to prevent and manage potential environmental damage. Comprehensive and effective monitoring measures will need to be employed to gauge the effectiveness of management measures and, if necessary, operational activities would need to be modified.

Biodiversity: upstream								
Key impacts	Risk before mitigation			Mitigation and management	Risk after mitigation			Residual risk
	L	C	R		L	C	R	
endangered under the BC and/or EPBC Acts include: ○ HN527 (PCT 840): Forest Redgum-Yellow Box = 127.8 ha ○ HN553 (PCT 941): Mountain Blue Gum - Thin-leaved Stringybark open forest = 104.5 ha ○ HN557 (PCT 1401): Narrow-leaved Ironbark - Forest Red Gum = 14.7 ha ▪ **Loss of threatened flora species and their habitat** ○ 75 flora species credit species ○ 16 fauna species credit species								

local people
global experience

SMEC is recognised for providing technical excellence and consultancy expertise in urban, infrastructure and management advisory. From concept to completion, our core service offering covers the life-cycle of a project and maximises value to our clients and communities. We align global expertise with local knowledge and state-of-the-art processes and systems to deliver innovative solutions to a range of industry sectors.

www.smec.com