Ingleside Precinct Rezoning - Riparian Corridors Assessment

Cox Architecture

ecological AUSTRALIA
A TETRA TECH COMPANY

1300 646 131
www.ecoaus.com.au

DOCUMENT TRACKING

Project Name	Ingleside Precinct Rezoning - Riparian Corridors Assessment
Project Number	20SYD-17161
Project Manager	Claire Wheeler
Prepared by	Claire Wheeler
Reviewed by	Ian Dixon
Approved by	David Bonjer
Status	**Final**
Version Number	**3**
Last saved on	**3 March 2021**

This report should be cited as 'Eco Logical Australia 2020. *Ingleside Riparian Assessment*. Prepared for Cox Architecture.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from Cox Architecture

Template 2.8.1

Contents

List of Figures

List of Tables

Abbreviations

Abbreviation	Description
BC Act	NSW *Biodiversity Conservation Act 2016*
BCAA	Biodiversity Certification Assessment Area
BCAM	Biodiversity Certification Assessment Methodology
BCAR	Biodiversity Certification Assessment Report
DoE	Commonwealth Department of the Environment
DPIE	NSW Department of Planning, Industry and Environment (formerly NSW Department of Planning)
DPI	Department of Primary Industries
DPI Water	Department of Primary Industries, Water
EEC	Endangered Ecological Community
ELA	Eco Logical Australia Pty Ltd
EP&A Act	NSW *Environmental Planning and Assessment Act 1979*
EPBC Act	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*
FM Act	NSW *Fisheries Management Act 1994*
LGA	Local Government Area
NW Act	NSW *Noxious Weeds Act 1993*
NRAR	Natural Resources Access Regulator
OEH	NSW Office of Environment and Heritage (now DPIE)
PLEP	Pittwater Local Environmental Plan (2010)
TS	Threatened Species
VRZ	Vegetated riparian zone
WSUD	Water Sensitive Urban Design
WM Act	NSW *Water Management Act 2000*

Executive Summary

Eco Logical Australia was engaged by the NSW Department of Planning, Industry and Environment to identify and assess the ecological values of riparian lands within the Ingleside Precinct. The purpose of assessment was to identify riparian constraints and opportunities within the Precinct, and to inform the Planning Proposal.

The site contains a number of tributaries of Mullet Creek, and the subcatchments for these watercourses are characterised by land previously cleared for a mix of uses including residential and rural-residential. These tributaries serve as the headwaters of larger reaches including Mullet and Narrabeen Lagoon. Significant conservation lands are immediately adjacent to the Precinct, including Ingleside Chase Reserve to the east. In addition, there are multiple areas of high conservation in the vicinity of the Precinct, including Ku-ring-gai Chase National Park to the north and northwest, Garigal National Park to the south and Katandra Bushland Sanctuary to the north east. In this regard, the water courses within the site serve as partial corridors linking these areas, while also influencing their environmental integrity with inflows of sediment, nutrients and other contaminants in the form of urban stormwater.

In order to protect and enhance the riparian values of the Precinct, individual water courses were mapped and appropriate riparian corridor widths applied to the respective watercourse. All streams within the Precinct were identified as either a 1st or 2nd order watercourse based on the Strahler stream classification methodology. Within or immediately adjacent to the Precinct there are six watercourse reaches in varying condition. The majority of these are in a degraded condition (five), with the remainder being in moderate condition. All reaches were evaluated in terms of their conservation and recovery potential which identified the majority (five) have moderate to high recovery potential and one with low recovery potential.

Broad recommendations have also been provided to guide the development of a Structure Plan and to afford adequate protection of the watercourses based on their position within the catchment, current condition, conservation and recovery potential, and legislative or agency requirements.

It will be important to ensure that key watercourses are protected and enhanced to prevent any increase in adverse environmental impacts on the adjoining sensitive environments as urban development intensifies within the Precinct. The layout and proposed land uses identified in the indicative Structure Plan seek to separate water and environmental land use from neighbouring development. All creeks have been assigned the mandatory riparian buffers. In most cases the buffer areas allowed for in the Structure Plan well exceed the minimum requirements, and vary from 24 m to almost 300 m in width.

Over 75% of the riparian corridors are protected and will be managed for environmental conservation including all those areas identified as high conservation priority in this report. A remaining 8% are in private recreation and 6% within specific infrastucture land uses. A summary of land uses applied to riparian areas is provided in Table 1.

There are no additional roads crossing riparian areas identified in the Structure Plan. Existing road alignments have been intentionally retained for this purpose. Online and offline flood detention and bioretention basins have been proposed in locations where they are compliant with Natural Resources Access Regulator (NRAR) guidelines. Stormwater will be detained prior to entering core riparian areas.

Table 1: Summary of the length of riparian corridor land uses

Land Use	Total Length of Watercourses (km)	Percent of Watercourse Length
Environmental Conservation (E2)	2.411	75.41%
Private Recreation (RE2)	0.263	8.23%
Rural Landscape (RU2)	0.297	9.29%
Low Density Residential (R2)	0.029	0.91%
Infrastructure (SP2)	0.198	6.19%
Total	**3.197 km**	**100.0%**

The Structure Plan supports the assessed importance of the riparian functions of this upper catchment area by exceeding buffer distances and complying with NRAR guidelines. As the current condition of the riparian corridors varies widely, but with many areas in the centre of the precinct in degraded condition, the proposed Structure Plan offers an opportunity to improve aquatic habitat and riparian connectivity.

1. Introduction

1.1 Project background

The Ingleside Rezoning Investigation Area (Ingleside Precinct) is located in the north of the Northern Beaches Local Government Area (LGA). In May 2016 Pittwater Council was merged into a new body, Northern Beaches Council, however the majority of the plans and strategies of the former council continue to apply until the Northern Beaches Local Environmental Plan is adopted.

The majority of the Precinct is zoned Rural Landscape (RU2) under Pittwater Local Environmental Plan (LEP) 2014, which has a range of permissible uses. Land tenure is a mix of public and private ownership.

The Minister for Planning and Public Spaces and Northern Beaches Council have agreed to undertake a Precinct Planning Process for the Ingleside Precinct to establish development controls to enable development consistent with that potential.

Eco Logical Australia Pty Ltd (ELA) has been engaged by the Department of Planning, Industry and Environment (DPIE) to prepare a Riparian Corridors Assessment to assist in a Planning Proposal for the Ingleside Precinct.

1.2 Study area description

The Ingleside Precinct is approximately 176 hectares (Figure 1). The Precinct is bounded by Mona Vale Road in the north as well as conservation areas and other lands.

Significant conservation lands are immediately adjacent to the Precinct, including Ingleside Chase Reserve to the east. In addition, there are multiple areas of high conservation in the vicinity of the Precinct, including Ku-ring-gai Chase National Park to the north and northwest, Garigal National Park to the south and Katandra Bushland Sanctuary to the north east.

The vegetation types within the Ingleside Precinct are strongly influenced by the topography of the area. Heath vegetation is associated with shallow soils and rocky outcrops and generally occur at higher elevations within the Precinct. The topography slopes down to the north and east where at times the terrain rapidly falls away to a series of steep moist gullies. Overall, topography within the Ingleside Precinct varies from steep slopes to gently undulating terrain.

There is one watercourse with multiple tributaries within the Precinct. There are first and second order tributaries of Mullet Creek flowing in a generally west-east direction through the Precinct (Figure 2). Downstream of the Precinct, Mullet Creek flows into Narrabeen Lagoon.

Riparian corridors are generally characterised by moist sclerophyll vegetation communities that have been partially cleared to varying degrees to accommodate a range of land uses including residential, light industrial, rural residential and public open space. Typically, most watercourses in the precinct boundary have been impacted by exotic weeds and stormwater runoff, although downstream there are some that remain in near intact condition.

1.3 Project objectives

The objectives of this report are to:

- Classify watercourses using the Strahler method and to identify riparian corridor boundaries
- Assess the ecological values and conservation and recovery potential of identified watercourses
- Identify recommendations for the protection of watercourses and riparian corridors, including those downstream of the Precinct
- Provide cross section drawings of the riparian zone.

The information from this report will be considered in protecting of aquatic animals and their habitats as part of the rezoning. A separate macroinvertebrate study was prepared by Cardno (2014).

Riparian corridors are considered in the Biodiversity Assessment as part of the development of ecological corridor connections.

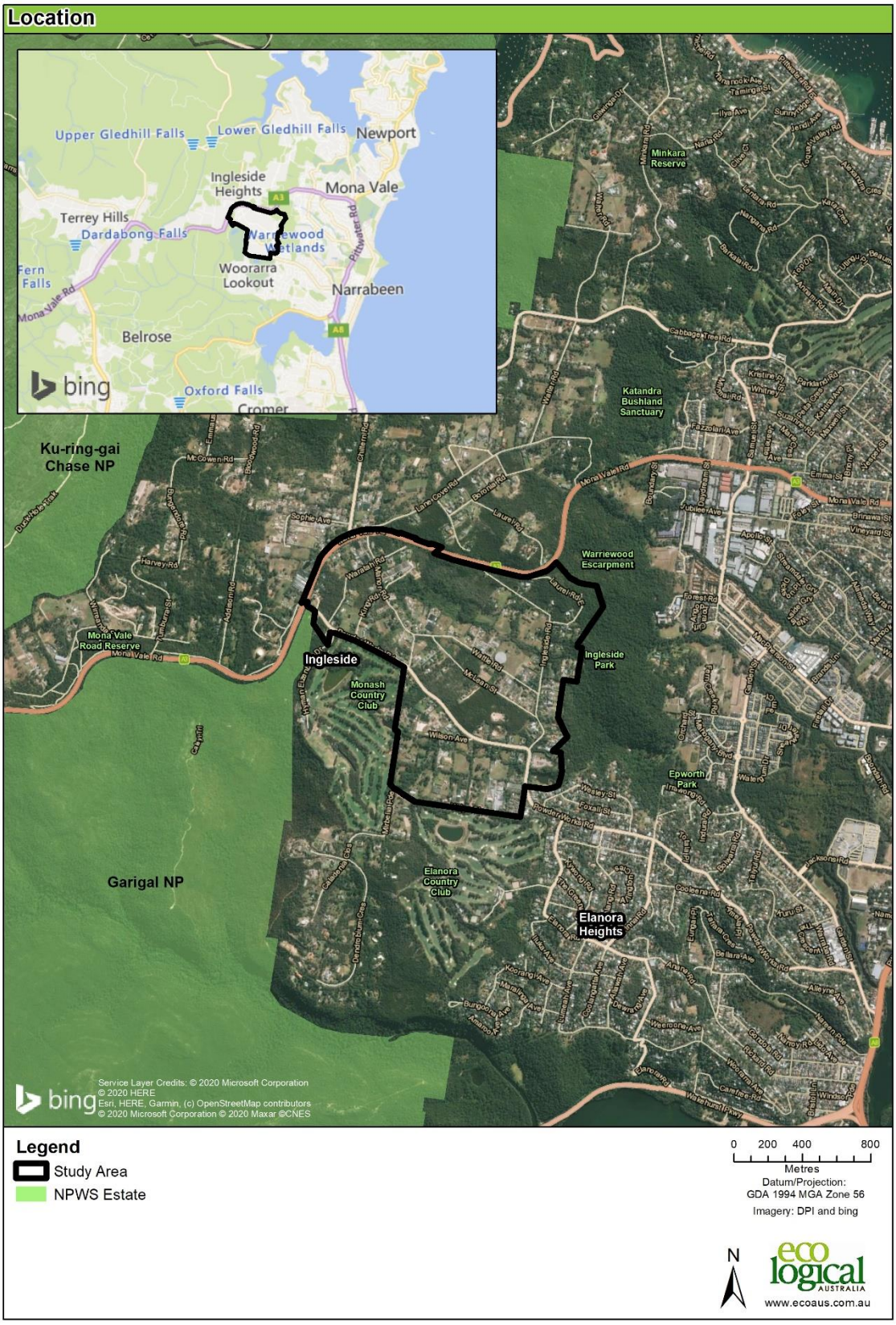


Figure 1: Ingleside Precinct locality map

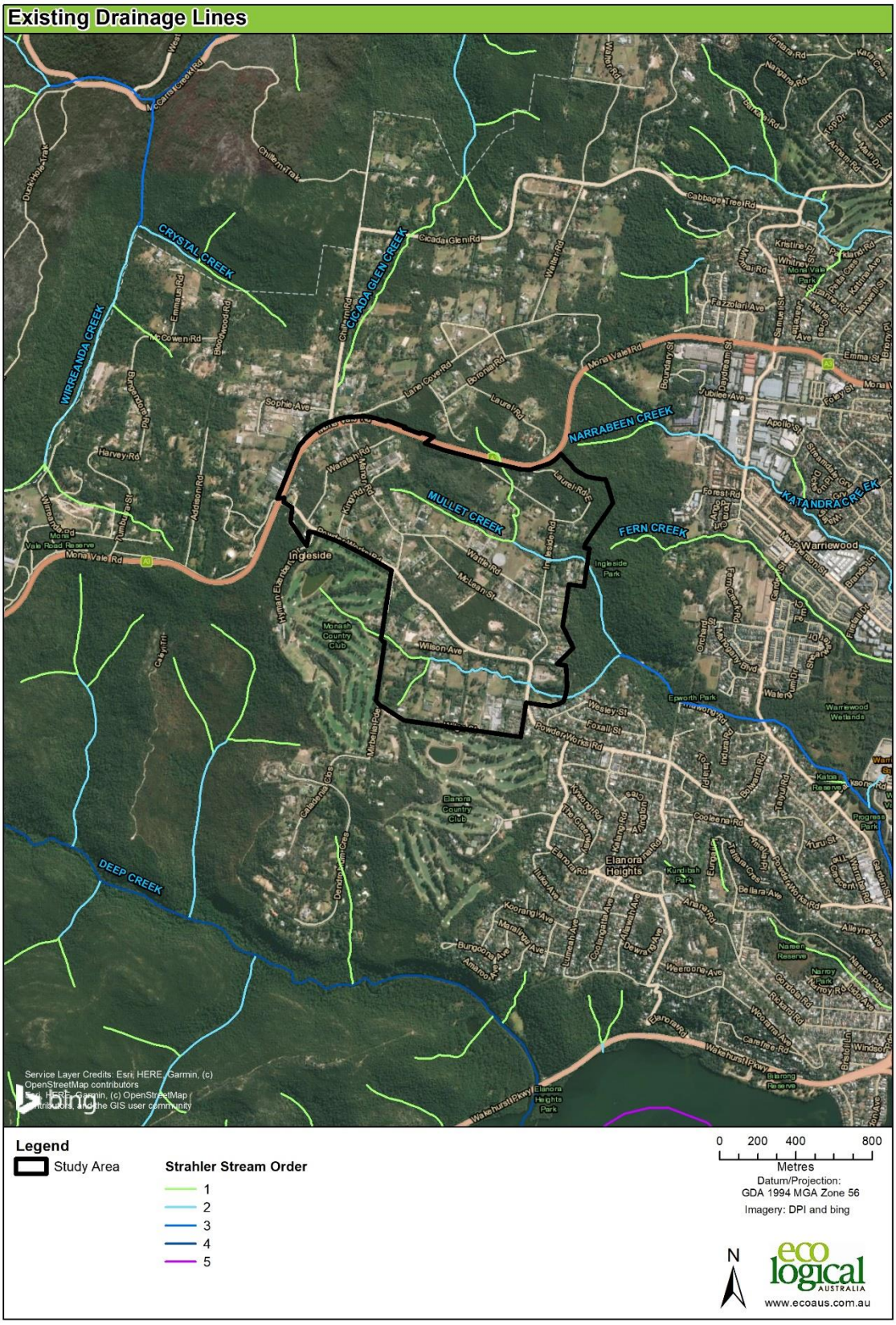


Figure 2: Ingleside Precinct drainage lines map (Source: Water Management (General) 2018 Hydroline Spatial Data)

2. Statutory framework

A variety of Commonwealth, State and local legislation are relevant to the Precinct and are briefly described below.

2.1 Commonwealth

2.1.1 Environment Protection and Biodiversity Conservation Act 1999

The Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) provides a national scheme for protecting the environment and conserving biodiversity values. The EPBC Act stipulates that approval from the Commonwealth Environment Minister is required if a development is likely to have a significant impact on matters considered to be Matters of National Environmental Significance (MNES).

For the Ingleside Precinct, there are a number of threatened species that are listed under the EPBC Act and therefore considered as MNES. However, relevant species will be addressed in the separate Biodiversity Assessment.

2.2 State

2.2.1 Environmental Planning and Assessment Act 1979

The NSW Environmental Planning and Assessment Act 1979 (EP&A Act) is the principal planning legislation for the state, providing a framework for the overall environmental planning and assessment of development proposals. Various legislation, such as the NSW Biodiversity Conservation Act 2016 (BC Act), are integrated with the EP&A Act and have been reviewed separately.

2.2.2 Biodiversity Conservation Act 2016

The BC Act aims to protect and encourage the recovery of threatened species, populations and communities listed under the Act. The BC Act is integrated with the EP&A Act and requires consideration of whether a development (Part 4 of the EP&A Act 1974) or an activity (Part 5 of the EP&A Act) is likely to significantly affect threatened species, populations and ecological communities or their habitat.

The schedules of the Act list species, populations and communities as endangered or vulnerable. New species, populations and communities are continually being added to the schedules of the BC Act. All developments, land use changes or activities need to be assessed to determine if they will have the potential to significantly impact on species, populations or communities listed under the Act.

2.2.3 Fisheries Management Act 1994

The *Fisheries Management Act 1994* (FM Act) governs the management of fish and their habitat in NSW. The FM Act applies to waterways defined as 'key fish habitat' and threatened fish species, and therefore requires a separate assessment from the NSW *Biodiversity Conservation Act 2016* (BC Act). The objectives of the FM Act are to conserve fish stocks and key fish habitats, conserve threatened species, populations and ecological communities of fish and marine vegetation and to promote ecologically sustainable development. The FM Act also regulates activities involving dredging and / or reclamation of aquatic habitats, obstruction of fish passage, harming marine vegetation and use of explosives within

a waterway. To assess impacts to aquatic habitats, the regulatory framework of the FM Act and associated guidelines have been applied for this assessment.

For this assessment, none of the species listed under the FM Act are considered likely to occur in the Precinct (refer to Section 3.2.1).

2.2.4 Water Management Act 2000

The main objective of the WM Act is to manage NSW water in a sustainable and integrated manner that will benefit current generations without compromising future generations' ability to meet their needs. The WM Act is administered by the Natural Resources Access Regulator (NRAR) and establishes an approval regime for activities within waterfront land, defined as the land 40 m from the highest bank of a river, lake or estuary.

Under the WM Act framework, activities and works proposed on waterfront land are regulated. These activities include:

- the construction of buildings or carrying out of works
- the removal of material or vegetation from land by excavation or any other means
- the deposition of material on land by landfill or otherwise
- any activity that affects the quantity or flow of water in a water source.

NRAR's Guidelines for Controlled Activities on waterfront land—Riparian corridors (NRAR 2018) outline the need for a Vegetated Riparian Zone (VRZ) adjacent to the channel to provide a transition zone between the terrestrial environment and watercourse. This vegetated zone helps maintain and improve the ecological functions of a watercourse whilst providing habitat for terrestrial flora and fauna. The VRZ plus the channel (bed and banks of the watercourse to the highest bank) constitute the 'riparian corridor' (Figure 3). NRAR recommends a VRZ width based on watercourse order as classified under the Strahler System of ordering watercourses and using Hydroline Spatial Data which is published on the department's website (Table 2).

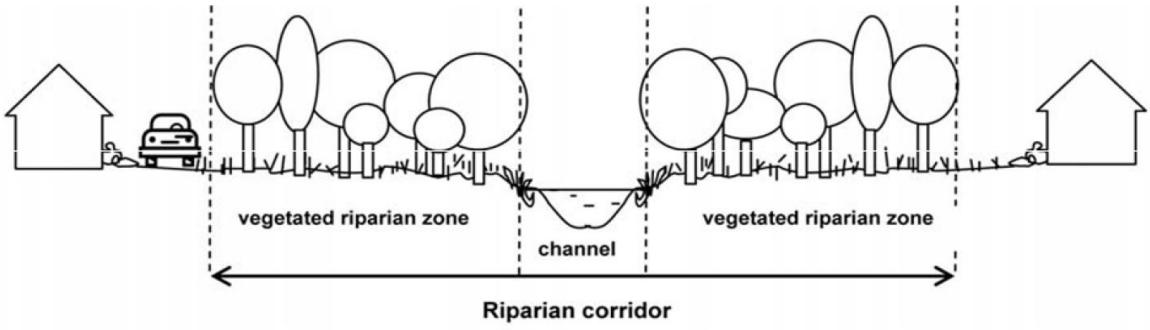


Figure 3: Vegetated riparian zone and watercourse channel comprising the riparian corridor (NRAR 2018)

Table 2: Recommended riparian corridor widths relative to Strahler stream order (NRAR 2018)

Watercourse type	VRZ width (each side of watercourse)	Total riparian corridor width
1st order	10 m	20 m + channel width
2nd order	20 m	40 m + channel width
3rd order	30 m	60 m + channel width
4th order and greater (includes estuaries, wetlands and any parts of rivers influenced by tidal waters)	40 m	80 m + channel width

Certain works are permissible within the riparian zone (Table 3). Non-riparian uses are consistent with NRAR's guidelines in the outer 50% of the VRZ as long as compensation (1:1 offset) is achieved within the site. The outer VRZ that is impacted must be offset elsewhere on site using the 'averaging rule' (Figure 4Figure 4).

Table 3: Riparian corridor (RC) matrix of permissible uses (NRAR 2018)

Stream order	Vegetated Riparian Zone (VRZ)	RC off-setting for non RC uses	Cycleways and paths	Detention basins		Stormwater outlet structures and essential services	Stream realignment	Road crossings		
				Only within 50% outer VRZ	Online			Any	Culvert	Bridge
1st	10m	●	●	●	●	●	●	●		
2nd	20m	●	●	●	●	●		●		
3rd	30m	●	●	●		●			●	●
4th +	40m	●	●	●		●			●	●

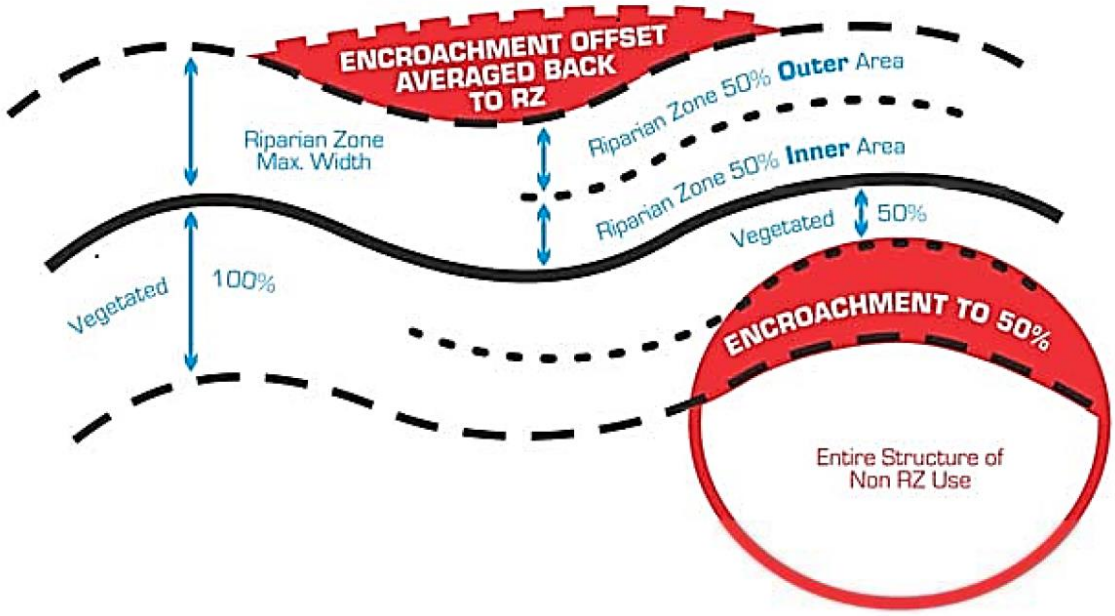


Figure 4: Riparian 'averaging rule' for offsetting encroachment into the outer 50% of the VRZ (NRAR 2018).

2.2.5 Biosecurity Act 2015

The *Noxious Weed Act 1993* was repealed and replaced with the *Biosecurity Act 2015*. Under the *Biosecurity Act 2015* all plants are regulated with a general biosecurity duty to prevent, eliminate or minimise any biosecurity risk they may pose. Any person who deals with any plant, who knows (or ought to know) of any biosecurity risk, has a duty to ensure the risk is prevented, eliminated or minimised, so far as is reasonably practicable.

Specific legal requirements apply to State determined priorities under the Greater Sydney Regional Strategic Weed Management Plan 2017-2022. Weeds listed as 'other weeds of regional concern' warrant resources for local control or management programs and are a priority to keep out of the region. Inclusion in this list may assist Local Control Authorities and/or land managers to prioritise action in certain circumstances where it can be demonstrated the weed poses a threat to the environment, human health, agriculture etc. Some noxious aquatic weeds were identified within the study area and are discussed in Section 3.2.3.

2.3 Local

2.3.1 Pittwater Local Environmental Plan 2014

The Pittwater Local Environmental Plan 2014 (PLEP) is the principal planning instrument for the Ingleside Precinct. The LEP sets out the current planning framework and establishes the requirements for the use and development of land in the LGA, including the Ingleside Precinct.

2.4 Relevant policy

2.4.1 Policy and guidelines for fish habitat conservation and management

The Policy and guidelines for fish habitat conservation and management (Fairfull 2013) (herein referred to as the 'Policy') is a supplementary document that outlines the requirements and obligations under the FM Act and the *Fisheries Management (General) Regulation 2010* and was developed to maintain and enhance fish habitat and assist in the protection of threatened species. The Policy provides a definition of key fish habitat (KFH) and guidance for assigning a rating for fish habitat sensitivity (Table 4), the classification of KFH (Table 5), which informs the types of crossing infrastructure suitable for the creek line (Table 6).

Table 4: Key Fish Habitat and associated sensitivity classification scheme (Fairfull 2013)

Key fish habitat and associated sensitivity classification scheme (for assessing potential impacts of certain activities and developments on key fish habitat types)	
TYPE 1 – Highly sensitive key fish habitat:	**TYPE 2 – Moderately sensitive key fish habitat:**
Posidonia australis (strapweed)	*Zostera, Heterozostera, Halophila* and *Ruppia* species of seagrass beds <5 m^2 in area
Zostera, Heterozostera, Halophila and *Ruppia* species of seagrass beds >5 m^2 in area	Mangroves
Coastal saltmarsh >5 m^2 in area	Coastal saltmarsh <5 m^2 in area
Coral communities	Marine macroalgae such as *Ecklonia* and *Sargassum* species
Coastal lakes and lagoons that have a natural opening and closing regime (i.e. are not permanently open or artificially opened or are subject to one off unauthorised openings)	Estuarine and marine rocky reefs
Marine park, an aquatic reserve or intertidal protected area	Coastal lakes and lagoons that are permanently open or subject to artificial opening via agreed management arrangements (e.g. managed in line with an entrance management program)
SEPP 14 coastal wetlands, wetlands recognised under international agreements (e.g. Ramsar, JAMBA, CAMBA, ROKAMBA wetlands), wetlands listed in the Directory of Important Wetlands of Australia	Aquatic habitat within 100 m of a marine park, an aquatic reserve or intertidal protected area
Freshwater habitats that contain in-stream gravel beds, rocks greater than 500 mm in two dimensions, snags greater than 300 mm in diameter or 3 metres in length, or native aquatic plants	Stable intertidal sand/mud flats, coastal and estuarine sandy beaches with large populations of in-fauna
Any known or expected protected or threatened species habitat or area of declared 'critical habitat' under the FM Act	Freshwater habitats and brackish wetlands, lakes and lagoons other than those defined in TYPE 1
Mound springs	Weir pools and dams up to full supply level where the weir or dam is across a natural waterway
	TYPE 3 – Minimally sensitive key fish habitat may include:
	Unstable or unvegetated sand or mud substrate, coastal and estuarine sandy beaches with minimal or no in-fauna

Key fish habitat and associated sensitivity classification scheme (for assessing potential impacts of certain activities and developments on key fish habitat types)	
	Coastal and freshwater habitats not included in TYPES 1 or 2
	Ephemeral aquatic habitat not supporting native aquatic or wetland vegetation

Table 5: Classification and characteristics of waterway class

Classification	Characteristics of waterway class
CLASS 1 **Major key fish habitat**	Marine or estuarine waterway or permanently flowing or flooded freshwater waterway (e.g. river or major creek), habitat of a threatened or protected fish species or 'critical habitat'.
CLASS 2 **Moderate key fish habitat**	Non-permanently flowing (intermittent) stream, creek or waterway (generally named) with clearly defined bed and banks with semi-permanent to permanent waters in pool or in connected wetland areas. Freshwater aquatic vegetation is present. TYPE 1 and 2 habitats present.
CLASS 3 **Minimal key fish habitat**	Named or unnamed waterway with intermittent flow and sporadic refuge, breeding or feeding areas for aquatic fauna (e.g. fish, yabbies). Semi-permanent pools form within the waterway or adjacent wetlands after a rain event. Otherwise, any minor waterway that interconnects with wetlands or other CLASS 1-3 fish habitats.
CLASS 4 **Unlikely key fish habitat**	Waterway (generally unnamed) with intermittent flow following rain events only, little or no defined drainage channel, little or no flow or free-standing water or pools post rain events (e.g. dry gullies or shallow floodplain depressions with no aquatic flora present).

Table 6: Watercourse crossings (Fairfull 2013)

Preferred waterway crossing type in relation to waterway class		
Waterway classification	**Minimum Recommended Crossing Type**	**Additional Design Information**
CLASS 1 **Major key fish habitat**	Bridge, arch structure or tunnel	Bridges are preferred to arch structures.
CLASS 2 **Moderate key fish habitat**	Bridge, arch structure, culvert[1] or ford	Bridges are preferred to arch structures, box culverts and fords (in that order).
CLASS 3 **Minimal key fish habitat**	Culvert[2] or ford	Box culverts are preferred to fords and pipe culverts (in that order).
CLASS 4 **Unlikely key fish habitat**	Culvert[3], causeway or ford	Culverts and fords are preferred to causeways (in that order).

[1] High priority given to the 'High Flow Design' procedures presented for the design of these culverts—refer to the "Design Considerations" section of Fairfull and Witheridge (2003).

[2] Minimum culvert design using the 'Low Flow Design' procedures; however, 'High Flow Design' and 'Medium Flow Design' should be given priority where affordable—refer to the "Design Considerations" section of Fairfull and Witheridge (2003).

[3] Fish friendly waterway crossing designs possibly unwarranted. Fish passage requirements should be confirmed with NSW DPI.

3. Methods

This riparian assessment follows the methods outlined by NRAR. This method assigns a Vegetated Riparian Zone (VRZ) width relative to the stream's corresponding Strahler stream order classification.

Specifically, this riparian assessment includes:

- Mapping of Top of Bank using a differential GPS
- Classification of the condition of stream reaches within the study area
- Categorisation of each stream using the Strahler stream order methodology
- Application of VRZ widths based on stream order
- Identification of Groundwater Dependent Ecosystems within the Precinct
- Identification of key riparian areas recommended for protection and rehabilitation.

3.1 Riparian corridor mapping and condition assessment

The riparian categorisation was based on the Strahler stream dataset appearing on the 1:25,000 topographic map series (Figure 2), combined with field assessment data and analysis of top of bank results. Although higher definition stream mapping was conducted by Pittwater Council in 2013, NRAR require the 1:25,000 stream mapping to be assessed and validated under the WM Act. Therefore, additional drainage lines mapped in the Pittwater Stream Mapping Project do not contribute to the stream order numbering of this assessment. Although the Council mapping shows additional drainage lines within the study area, these are only small tributaries feeding the dominate streams used in this study (for example, see map in Pittwater Council 2013, Volume 2, Fig. 2.8). Updated mapping from Northern Beaches Council was not available for review at the time this assessment was completed.

A survey of the Top of Bank (ToB) for all accessible watercourses in the Precinct was conducted by an experienced aquatic/riparian ecologist and ecological assistant with a differential GPS (accuracy 50 – 70 cm) on the 4th, 5th and 6th of December 2013. The ToB mapping completed in the field was verified by cross-checking with recent high-resolution satellite imagery, and where necessary ToB data were manually amended. Where access was restricted (Figure 5), reaches were visually assessed from adjoining properties and/or from roadside verges. This approach was common to many of the reaches within the Precinct where access was not available (e.g. Reaches B and F). A brief reconnaissance was undertaken in September 2020 to determine if there had been significant condition change. The reconnaissance did not revisit all previously accessed properties, but was sufficient to determine that the catchment had not undergone significant change since the original survey.

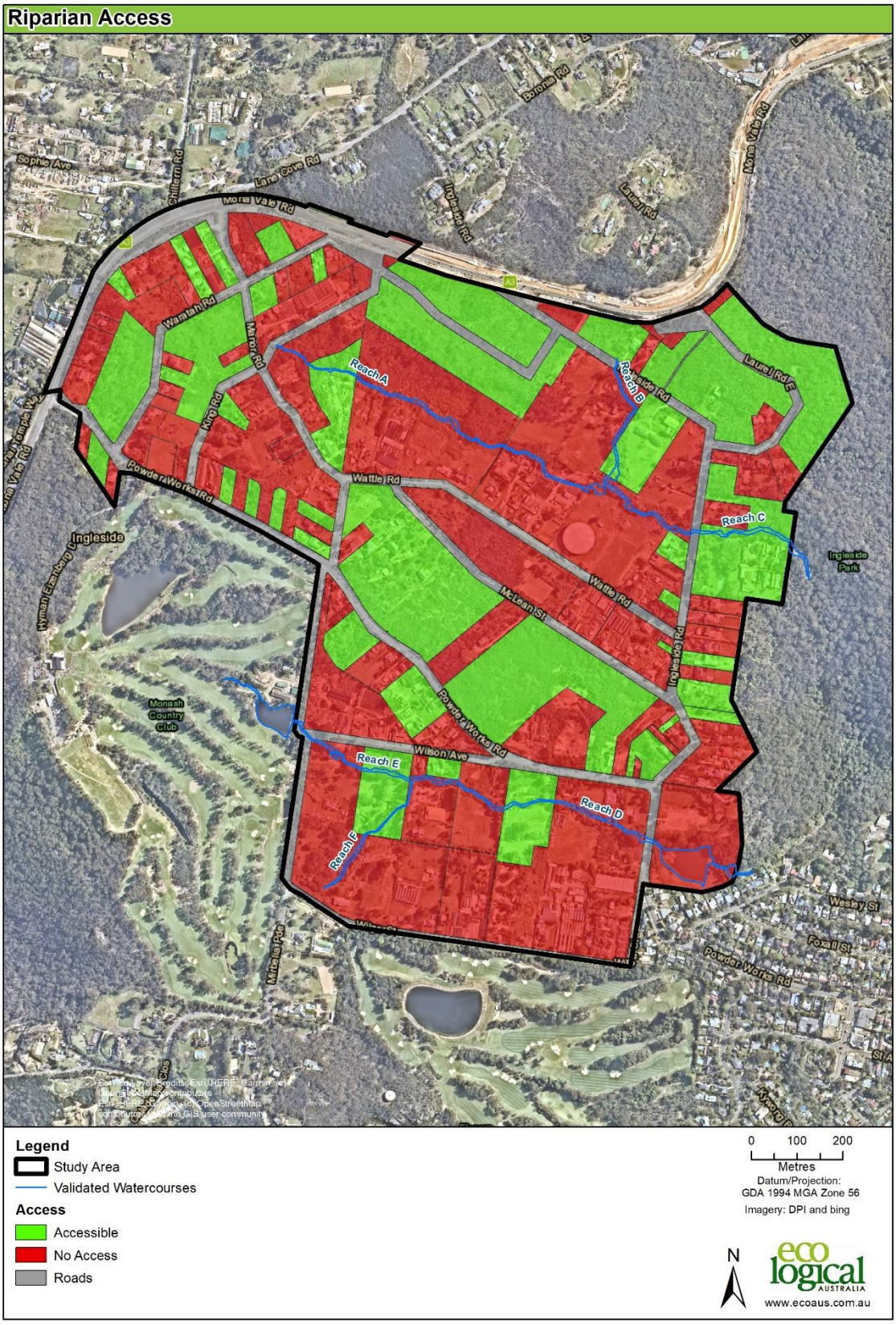


Figure 5: Access to drainage lines for field assessment

Watercourse reach labels have been assigned to enable clear identification and descriptions of the relevant sections of each watercourse. The condition of each reach was assessed for key characteristics related to hydrology, physical form, water quality, aquatic habitat and streamside vegetation. Each reach was given an overall condition rating of:

- Moderate condition
- Degraded condition.

3.2 Aquatic Assessment and Threatened Species

3.2.1 Threatened Species

Database searches were undertaken to identify threatened aquatic species that may occur within the Precinct. Given that the broader biodiversity assessment of the study area is being undertaken as part of the Biodiversity Assessment, searches were restricted to aquatic species listed under the Commonwealth EPBC Act and the NSW FM Act.

A review of listed threatened species dependant on in stream habitat revealed that two threatened species, Giant Burrowing Frog (*Heleioporus australiacus)* and Red-crowned Toadlet (*Pseudophrine australis),* may potentially occur, or are known to occur within the aquatic habitats present in the Precinct (Table 7). These species are considered under the BC Act and therefore will be addressed separately in the Biodiversity Assessment report.

Table 7: Listed aquatic and amphibious species recorded in the region

Species	FM Act status	BC Act status	EPBC Act status	Likelihood of occurrence
Macquarie Perch (*Macquaria australica*)	E		E	Unlikely, out of natural distribution
Adam's Emerald Dragonfly (*Arhaeophya adamsi*)	E			Unlikely, but potential habitat may occur downstream of the Precinct
Sydney Hawk Dragonfly (*Austrocordulia leonardi*)	E			Unlikely, out of natural distribution
Australian Grayling (*Prototroctes maraena*)	E		V	Unlikely. Not modelled to occur in catchment (Riches et al 2016)
Giant Burrowing Frog (*Heleioporus australiacus*)	-	V	V	Likely (recorded by former Pittwater Council)
Green and Golden Bell Frog (*Litoria aurea*)	-	E	V	Unlikely
Giant Barred Frog (*Mixophyes iterates*)	-	E	E	Unlikely
Red-crowned Toadlet (*Pseudophrine australis*)	-		V	Known (Council records)

3.2.2 Groundwater Dependent Ecosystems

Groundwater Dependent Ecosystems (GDEs) are defined as ecosystems whose current species composition, structure and function are reliant on a supply of groundwater (Eamus 2009) as opposed to surface water supplies from overland flow paths. The frequency of groundwater influence may range from daily to inter-annually, however it becomes clearly apparent when either the supply of groundwater or its quality (or both) is altered for a sufficient length of time to cause changes in plant function. Groundwater use by an ecological community or individual species does not necessarily imply groundwater dependence (Dressel et al 2010).

In Australia, the majority of ecosystems have little to no dependence on groundwater, although the full understanding of the role of groundwater in maintaining ecosystems is generally poor. The exception to this is wetland communities, for which it is thought that most have some level of dependence on groundwater resources (Hatton and Evans 1998).

GDEs are generally classified into six categories (SCCG 2006, SKM 2001):

- **Terrestrial vegetation** – forests and woodland which develop a permanent or seasonal dependence on groundwater, often by extending roots into the water table
- **Base Flow in streams** – aquatic and riparian ecosystems that exist in or adjacent to streams that are fed by groundwater base flow
- **Aquifer and cave systems** – aquatic ecosystems that occupy caves or aquifers
- **Wetlands** – aquatic communities and fringing vegetation that depend on groundwater fed lakes and wetlands
- **Estuarine and near shore marine ecosystems** – various ecosystems including mangroves, salt marsh and seagrass, whose ecological function has some dependence on groundwater discharge
- **Terrestrial fauna** – fauna species assemblages reliant on groundwater for drinking water.

A final category is also recognised – **not apparently dependent**. This category acknowledges that some ecosystems, particularly wetland and riparian vegetation, might superficially appear to be groundwater dependent while in fact they are dependent entirely on surface flows and or rainfall.

GDEs have varying degrees of dependency on groundwater. These range from total to occasional dependence and include (SCCG 2006, SKM 2001):

- **Entirely dependent** – ecosystems for which only a slight change in the groundwater regime will have catastrophic effects
- **Highly dependent** – ecosystems for which moderate changes in the groundwater regime will result in significant changes to ecosystem distribution, health and or diversity. These ecosystems utilise both ground and surface water resources.
- **Proportionally dependent** – ecosystems for which changes in the groundwater regime result in significant changes to the ecosystem characteristics
- **Opportunistically or minimally dependent** – ecosystems for which the reliance on groundwater is limited to seasonal or climatic variations. These ecosystems use surface water predominantly

and if access to groundwater is prolonged, declines in ecosystem distribution, health, species composition or diversity may result.

GDEs within the Precinct were identified and mapped during both the riparian and terrestrial biodiversity assessment and field inspection.

3.2.3 Noxious weeds

In NSW, Noxious weeds listed under the *Biosecurity Act 2015* are those class of plants that are required by law to be controlled by all landholders in the area in which it has been declared noxious (defined by LGA). In the Northern Beaches LGA, there are a number of declared priority weeds and of these, six are aquatic species:

- Alligator Weed (*Alternanthera philoxeriodes*)
- Longleaf Willow Primrose (*Ludwigia longifolia*)
- Ludwigia (*Ludwigia peruviana*)
- Salvinia (*Salvinia molesta*)
- Senegal Tea Plant (*Gymnocoronis spilanthoides*)
- Water Hyacinth (*Eichhornia crassipes*).

During the field surveys and ToB mapping, records were made of all declared noxious aquatic weeds that were observed.

4. Results

4.1 Top of bank mapping and condition assessment

The results of ToB mapping and initial delineation of riparian buffers are shown in Figure 6. Each stream was broken into reaches based on its general structure and clearly defined branches. The condition of each stream reach is summarised in Table 8. A photographic record of the accessible reaches of each stream was also made and is summarised in Appendix A .

The overall condition of the surveyed length of watercourses within the Precinct was generally degraded or moderate (Table 8). Streamside vegetation was modified to some extent along the length of each stream reach, with the majority of vegetation subject to moderate to substantial modification. Approximately half the assessed watercourses had one or more vegetative strata dominated by exotic vegetation, with little native vegetation remaining. There were large areas of dense weed infestation of the mid-storey and understorey vegetation. Remnant vegetation was often found in isolated small patches or strips. Within the total length of the watercourses a significant proportion had been modified with the inclusion of box culverts, piped sections and/or informal weirs for the extraction of water. A dam was also present within Reach E, a tributary of Mullet Creek providing storage for irrigation water within the Monash Country Club as well as Reach F. While some sections were subject to bank erosion, most were reasonably well stabilised by streamside vegetation, although highly modified by exotic species. Reach C, a tributary of Mullet Creek, which is located in an urbanised and disturbed sub-catchment, was assessed to be in moderate condition. This was largely the result of the lower portion of the reach below Ingleside Road having retained more than 50% native vegetation cover.

The field surveys mapped a total of six stream reaches: comprised of two 2nd order and four 1st order streams (Table 8).

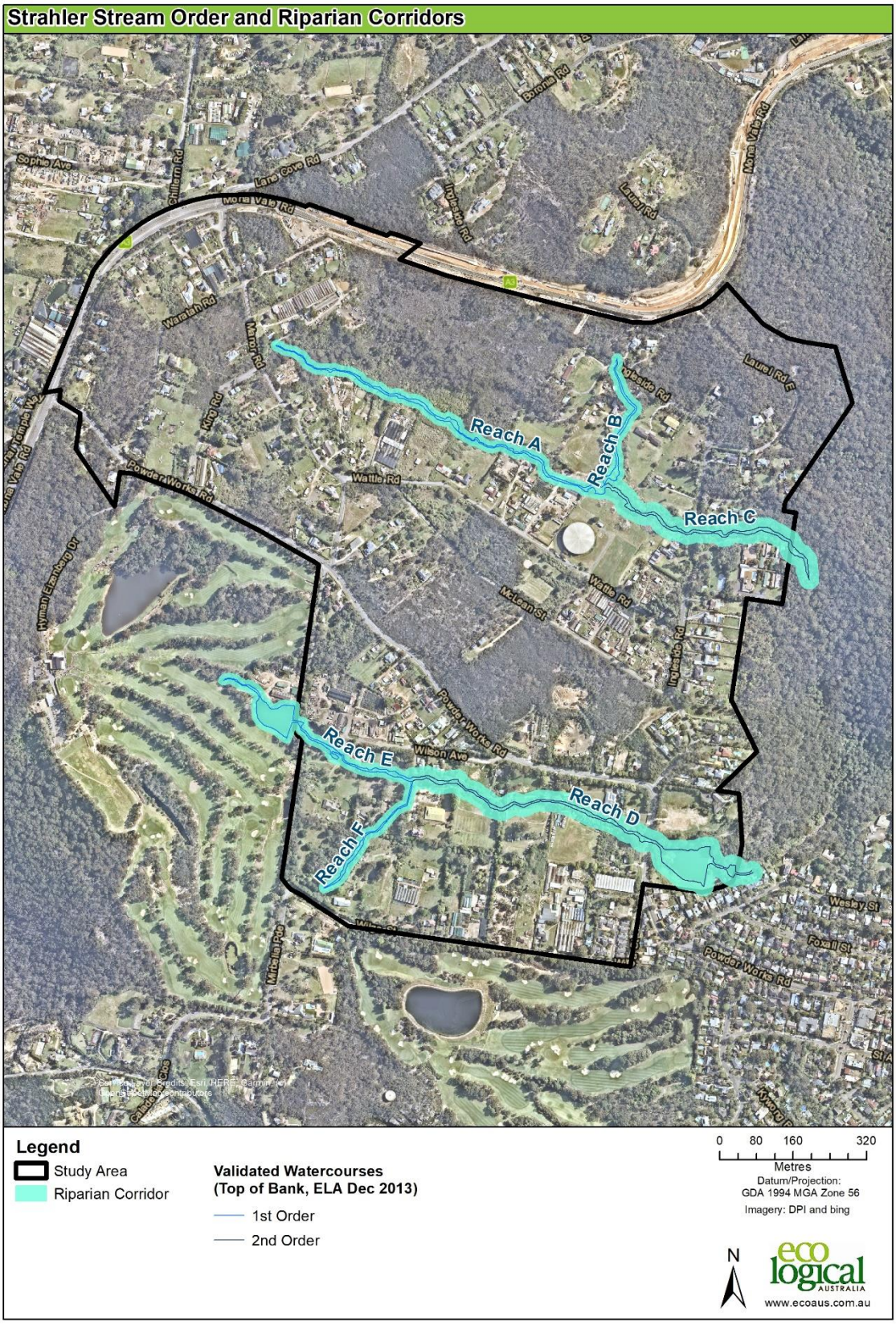


Figure 6: Strahler stream order and corresponding riparian corridors

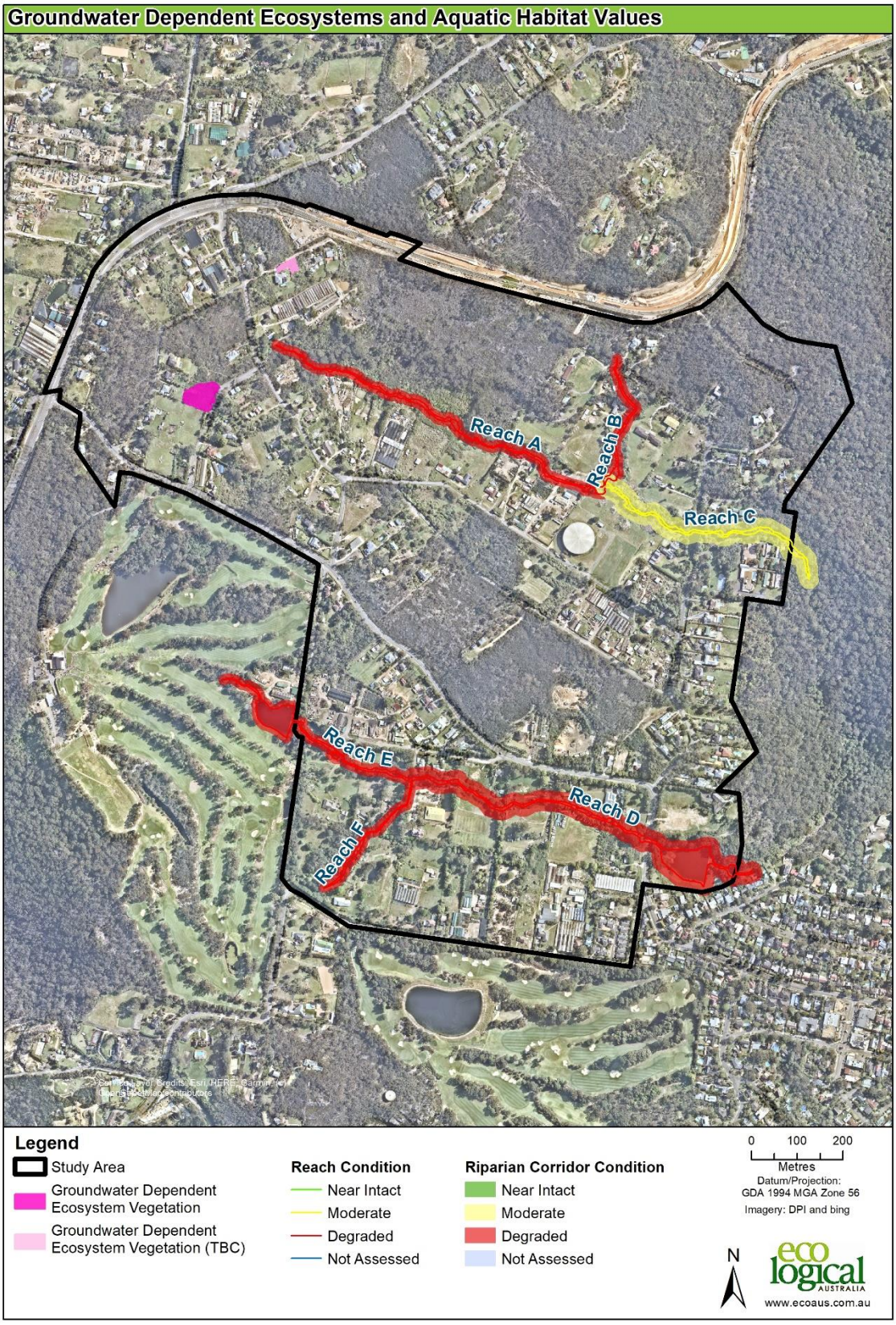


Figure 7: Groundwater Dependent Ecosystems and aquatic habitat values

Table 8: Watercourse condition assessment

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach A	Tributary of Mullet Creek	1st order stream (Strahler). Some modification to channel with partially cleared catchment.	Bank slope = 30-70 degrees. Banks generally well stabilised by streamside vegetation. Some slump (5-25%) and undercut erosion (1-5%)	Moderate habitat with average wetted channel width of 1-3 m. Slow flowing at the time of survey. Occasional in stream woody debris with dominant sandstone substrate and sand substrate. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Degraded Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Dominant strata mostly absent. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded
Reach B	Tributary of Mullet Creek	1st order stream (Strahler). Partially modified channel with upper reaches and the vicinity of Mona Vale Road no longer present. Partially cleared catchment.	Clay banks with slope = <30 degrees. Negligible erosion, with banks maintained by streamside vegetation dominated by weed species.	Limited habitat. Slow flowing mostly ponded water at time of survey. Dominant substrate clay with minimal in stream woody debris. Fish habitat = Class 4 - Unlikely fish habitat. Bird habitat = Poor. Frog habitat = Moderate.	Substantially modified Only small patches of well-separated native vegetation remain. One or more strata dominated by exotic species, high impact species present. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach D	Tributary of Mullet Creek	2nd order stream (Strahler). Some modification of channel. Culverts present. Partially cleared catchment.	Sandy banks with slope 30-70 degrees. Some gully (1-5%), slump (5-25%) and undercut (1-5%) erosion. Riparian trees and streamside vegetation dominated by weeds help maintain banks	Moderate habitat with an average wetted channel width 1-3 m with slow flowing water with an average depth 10-20 cm. Dominant substrate of bedrock with sandy subdominant substrate with common in stream vegetation. Moderate bird and frog habitat Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Substantially modified. Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded
Reach E	Tributary of Mullet Creek	1st order stream (Strahler). Partially modified channel. Dams within golf course represent major high-flow barrier. Culverts and crossings also present. Mostly cleared catchment.	Sandy bank with slope 30-70 degrees. Sections of bank with limited riparian trees exhibiting gully (1-5%), slump (5-25%) and undercut (1-5%) erosion.	Poor to moderate habitat. Dominant substrate sand with subdominant substrate of silt. Large pools (dams) upstream of Precinct within golf course. Elsewhere minimal flow at time of survey with common in stream vegetation. *Typha* spp. present in ponds/dams. Poor to moderate habitat. Fish habitat = Class 3 - Minimal fish habitat. Bird habitat = Poor. Frog habitat = Moderate.	Substantially modified Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded

Reach	Watercourse	Hydrology	Physical Form	Water Quality & Aquatic Habitat	Streamside Vegetation	Overall Condition
Reach F	Tributary of Mullet Creek	1st order stream (Strahler). Partially modified channel and cleared catchment.	Sandstone bedrock with bank slope 30-70 degrees. Banks generally stabilised by riparian vegetation dominated by weed species.	Moderate habitat with common in stream vegetation. Average wetted channel width 1-3 m with frequent pooling and low/stagnant flow. Occasional in stream vegetation. Fish habitat = Class 4 - Unlikely fish habitat. Bird habitat = Moderate. Frog habitat = Moderate.	Substantially modified Only small patches of well-separated native vegetation remain. Most strata dominated by exotic species, high impact species abundant. More than one stratum completely altered from reference (lost or <10% remaining). Reduced cover (<50%) of dominant strata, and only one age class present. Quantities and/or cover of debris 50% higher or lower than reference.	Degraded
Reach C	Tributary of Mullet Creek	2nd order stream (Strahler). Partially modified channel. Minor barriers present (culverts, piped culverts). Section above Ingleside Road more modified (channelised) than below. Partially cleared catchment.	Bank slope 30-70 degrees with some slump (1-5%) and undercut (5-25%) where in stream vegetation other than riparian trees is lacking.	Dominant and subdominant substrate bedrock and sand respectively. Pooling less frequent with relatively moderate stream velocity. Occasional in stream woody debris with rare native aquatic species (*Typha* sp., *Persicaria* sp.) Fish habitat = Class 2 - Moderate fish habitat. Bird habitat = Good. Frog habitat = Good.	Moderately modified About 50% of the native vegetation remains, either in strips or patches. One or more strata dominated by exotic species, high impact species present. Cover within one stratum up to 50% lower or higher than reference. Reduced cover (75-50%) of dominant strata, and only one age class present. Some evidence of unnatural loss of debris.	Moderate

4.2 Aquatic Habitat and Threatened Species

While many of the watercourses within the Precinct are disturbed and in a degraded condition, they still provide some degree of habitat for aquatic species. Typical of urban and semi urban streams, most of the watercourses demonstrate the effects of urban stormwater flows including sedimentation and nutrient accumulation, the later most evident in the prevalence of exotic weed species within the various creek lines.

Road and drainage works have also impacted on aquatic habitat in the form of culverts and other modifications, particularly in the vicinity of Mona Vale Road and Reach B. In this instance the watercourse has been modified to the extent that it no longer extends to or beyond Mona Vale Road.

Nevertheless, the majority of water courses within the study area are relatively stable and well vegetated and have value as part of a series of vegetated riparian corridors which provide habitat for local flora and fauna. The watercourses flow into reserved areas with conservation values create partial links to the reserves such as Ingleside Chase to the east.

Habitat for frogs and birds within the majority of the watercourses ranged between 'moderate' and 'good' with some parts exhibiting 'excellent' habitat (Table 8). In contrast, fish habitat was generally considered to be 'minimal' or 'unlikely' for all streams other than Reach C, which was assessed as having 'moderate' fish habitat. These results reflect the various barriers to fish passage within the area (culverts, dams, informal weirs etc.) and its position at the top of the catchment.

Regardless, there are a host of common aquatic species including eels, yabbies and macroinvertebrates that rely on the health of aquatic habitat for their ongoing survival. Aquatic habitat is an important component of overall ecosystem health and contributes to the diversity and viability of terrestrial habitat. It is recommended that future urban development considers the provision of good quality instream habitat, longitudinal connectivity and fringing riparian vegetation. In addition, erosion and sediment control should be a key requirement during construction, and Water Sensitive Urban Design (WSUD) principles applied to help protect important downstream, high quality bushland environments (Ingleside Chase Reserve and Narrabeen Lagoon).

4.2.1 Threatened Species

Relevant database searches identified two aquatic threatened species that are considered as 'likely' to occur within the Precinct, Red-crowned Toadlet (*Pseudophrine australis*) and Giant Burrowing Frog (*Heleioporus australiacus*) (Table 7). Northern Beaches Council has listed a record of Red-crowned Toadlet in the Precinct. These species are being considered under a separate Biodiversity Assessment. As a result, no further assessment of potential impacts on aquatic threatened species is required as part of this assessment.

4.2.2 GDE

GDEs mapped in the study area (Figure 7) are confined to the Coastal Upland Wet Heath Swamp and Coastal Upland Damp Heath Swamp vegetation types (SMCMA 2009). These vegetation types correlate to the Biometric Vegetation Type Needlebush Banksia Wet Heath on the Sandstone Plateaux of the Sydney Basin and were validated during field survey undertaken as part of the biodiversity assessment

for the Precinct. These vegetation types may utilise groundwater fed base flows associated with shallower aquifers linked to Reach A.

The dependence on groundwater varies greatly with each community and its position in the landscape. There is little available information on the level of groundwater dependency of theses patches of Heath Swamp vegetation within the Precinct. However, as a safeguard for future planning, freshwater GDEs such as streams, riparian zones and wetlands should be grouped as highly dependent, particularly during base flows.

4.2.3 Noxious weeds

Six species of aquatic noxious weeds were identified as having the potential to occur within the Precinct (Section 3.2.3). While none were detected during field investigations as part of this assessment in 2013, *Ludwigia* spp have been previously identified in the LGA (Pittwater Council 2013). Moreover, given that not all watercourses or sections of watercourse could be accessed, it is possible that these species may in fact occur more broadly within the Precinct. In this context, a precautionary approach should be taken during future riparian corridor works and or maintenance activities, and should any of the noxious species be identified their location should be accurately mapped and appropriate control techniques employed.

4.3 Conservation potential

A summary of conservation priority is provided in Table 9, and depicted graphically in Figure 8. High conservation potential streams include those that serve as a tributary for larger or less degraded watercourses beyond the study area. This includes the tributaries of Mullet Creek (Reaches C and D), which form the headwaters of these watercourses and flow though the adjacent Ingleside Chase Reserve and discharge to the Narrabeen Lagoon. In this context the conservation and recovery potential of these watercourses is further enhanced given their important role in maintaining and improving the environmental values of these downstream environments.

A number of watercourses (Reaches A, E and F) have been assessed as having moderate conservation and recovery potential. These streams are generally more degraded streams that serve as tributaries of higher value streams. The remaining stream (Reach B) has a lower conservation priority where the natural geomorphic condition has been completely altered as a result of being partially channelled, piped or realigned. Other lower impact modifications such culverts are also common throughout the study area.

In the context of the broader Precinct rezoning, where possible high value riparian corridors should be retained in public ownership, zoned and managed as conservation lands.

Table 9: Riparian corridor conservation priority

Reach	Conservation Priority
A	Moderate
B	Low
C	High
D	High
E	Moderate
F	Moderate

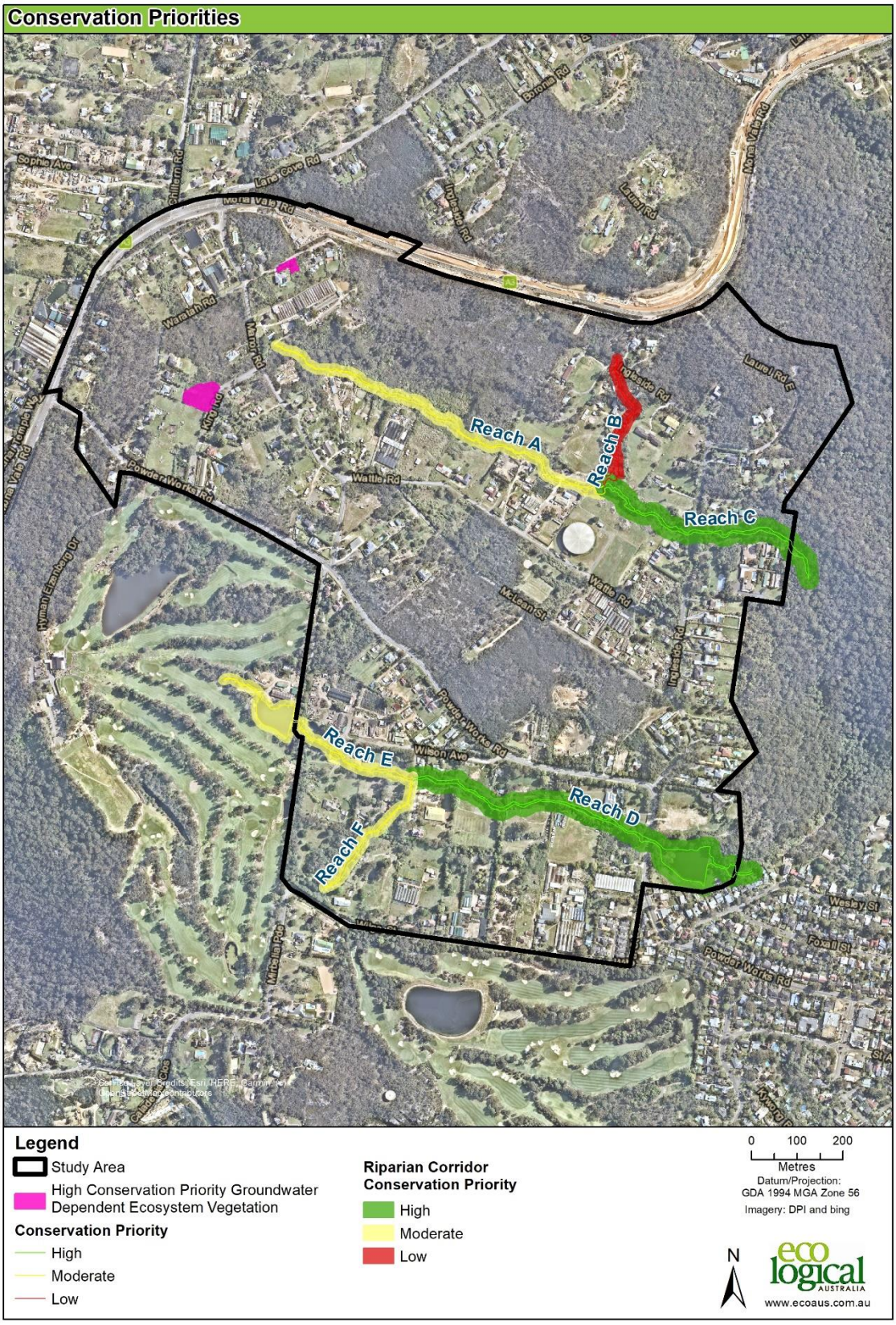


Figure 8: Watercourse conservation priority

5. Riparian Vegetation Management Study

This section of the report draws on the outcomes of the field assessment, identified conservation priorities, and recovery potential of the watercourses within the Precinct. This section does not provide detailed procedures for the ongoing rehabilitation and management of watercourses and riparian vegetation, but instead provides broad guidance with regard to future urban development within the Precinct. The guidance that is provided has been prepared recognising that many of the watercourses within the study area are located immediately adjacent to, or within, existing residential properties where the opportunities to establish recognised riparian corridors are more limited. The priorities for riparian corridor conservation are identified in Section 4.3 and depicted in Table 9 and Figure 8.

With the implementation of NRAR requirements for riparian corridor restoration, the aquatic and riparian habitat of the existing watercourses within the study area will improve over time as development works progress and more natural vegetation and flow regimes are re-established, particularly with the more disturbed watercourses of the Precinct. How this may be achieved with the inclusion of bioretention and other devices or management approaches is discussed below. Given the current state of some watercourses that have been highly modified and or channelised there may be opportunity for these reaches to be removed and replaced with suitable engineered water management solutions (Figure 8).

Future development will require stormwater detention areas and other WSUD features to maintain natural flow regimes and water quality outcomes within the study area and these have been discussed in the Ingleside Precinct Water Cycle Management and Flooding Assessment (Cardno 2020). Such features will serve an important role in re-establishing or enhancing habitat within the study area, particularly for those watercourses that have been more heavily modified by channelling or realignment in areas adjacent to existing urban development. Opportunities for such works will need to be considered in terms of the availability of suitable land and modelled flow regimes as the future development footprint is refined. Land ownership will be an important consideration in this regard, especially for those watercourses that are located immediately adjacent to existing residential development and where the opportunities to install WSUD features will be more limited.

Two dams exist within and adjacent to the study area, along Reaches D and E. While the dam within Reach E is located in the Monash Country Club, both dams should be considered with regard to their impact on natural flow regimes as well as the provision of aquatic habitat. Future stormwater/hydrology modelling within the Precinct should consider the role of these dams within the intended urban landscape (as defined by the Structure Plan) to ensure both that natural flow and habitat regimes are maintained at current levels as a minimum, or enhanced. In this regard, given the location of the dam on Reach E, which is located at the headwaters of Mullet Creek, there are likely to be opportunities to restore more natural flow regimes within this watercourse as urban development proceeds and the volume of surface runoff increases. Similarly, should the dam on Reach D be removed, dewatering should take place in accordance with detailed dewatering plans to manage and minimise impacts on the existing aquatic flora and fauna. Should this occur, it is recommended that any dewatering of the dam be staged so that any aquatic fauna utilising it have the opportunity to seek other habitat. Examples of compensatory habitat could include appropriately designed wet basins containing similar habitat features to the dams which are removed.

The patches of potential GDEs within the study area are generally isolated from existing watercourses. In this regard the role and function of these important ecosystems is somewhat less apparent within the study area. Nevertheless, the proposed rezoning presents an opportunity to recognise and enhance these important environmental features as a component of the broader riparian network of the Precinct. It is therefore recommended that where possible these areas of vegetation be retained and appropriately integrated with the Structure Plan and future urban development. If groundwater extraction is proposed as any part of future development proposals, impacts on these GDEs would need to be further assessed.

5.1.1 Riparian Ownership and Management Options

Land ownership within the study area is fragmented, and in some cases proposed riparian corridors would impact on existing residential properties and other forms of urban land use. Where it can be achieved riparian corridors should be in public ownership, which would increase the likelihood of achieving consistent environmental outcomes, and provide integrated uses and access for the community.

Where possible, drainage and detention structures should be owned and managed by Council. These areas can then be revegetated and managed as a naturalised feature. It is assumed that in accordance with the WM Act a Vegetation Management Plan will be required and prepared to the satisfaction of NRAR and Council for future development applications which impact on these areas.

Where public ownership cannot be achieved, consideration of suitable zoning and planning controls should be made in order to facilitate appropriate riparian land management outcomes.

5.1.2 Water Management Act

Further review of appropriate planning mechanisms (development controls) will need to be carried out by NRAR, Council and DPIE in order to determine a set of controls which will be appropriate for the Ingleside Precinct.

It is recommended that a Riparian Lands and Watercourses Map be included within the amended LEP and linked to the WM Act in a way that defines waterfront land within the Precinct as being limited to the extent of the Riparian Lands identified. It is noted that confirmation of stream locations and ToB may be a condition for areas of identified Riparian Lands where access was not possible for this project.

5.2 Management of Riparian Protected Areas

The NRAR has developed controlled activity guidelines that enable applicants to determine relevant approval requirements for controlled activities under the WM Act. The guidelines include a series of urban design principles and recommendations in relation to certain activities on waterfront land. The key elements of these guidelines in relation to the study area are presented below.

5.2.1 Urban Development Principles

The controlled activity guidelines do not encompass specific planning controls however they do contain objectives and a guide to works and activities generally allowable on waterfront land. The overarching objective of controlled activity provisions of the WM Act is to establish and preserve the integrity of riparian corridors.

NRAR does allow for a range of works and land uses within the outer VRZ of riparian corridors so long as they have minimal environmental harm. Activities which may be permissible are presented in Table 3.

5.2.2 Riparian Corridor Cross Sections

In determining the appropriate application of the riparian corridor management options described above, basic physical properties of individual watercourses such as channel width and invert are important factors for consideration, in that they help identify the suitability and potential scale of any works that may be required or under consideration.

For Mullet Creek, sections have been prepared based on the information collected during the December 2013 field survey and provide a general interpretation of the dimensions of the respective stream reach. Within the Precinct, watercourses have a channel width and invert that range from between 1 and 10, and 0.2 and 2.3 m respectively. The location of the cross sections for these watercourses are presented in Figure 9 and provided in Appendix B.

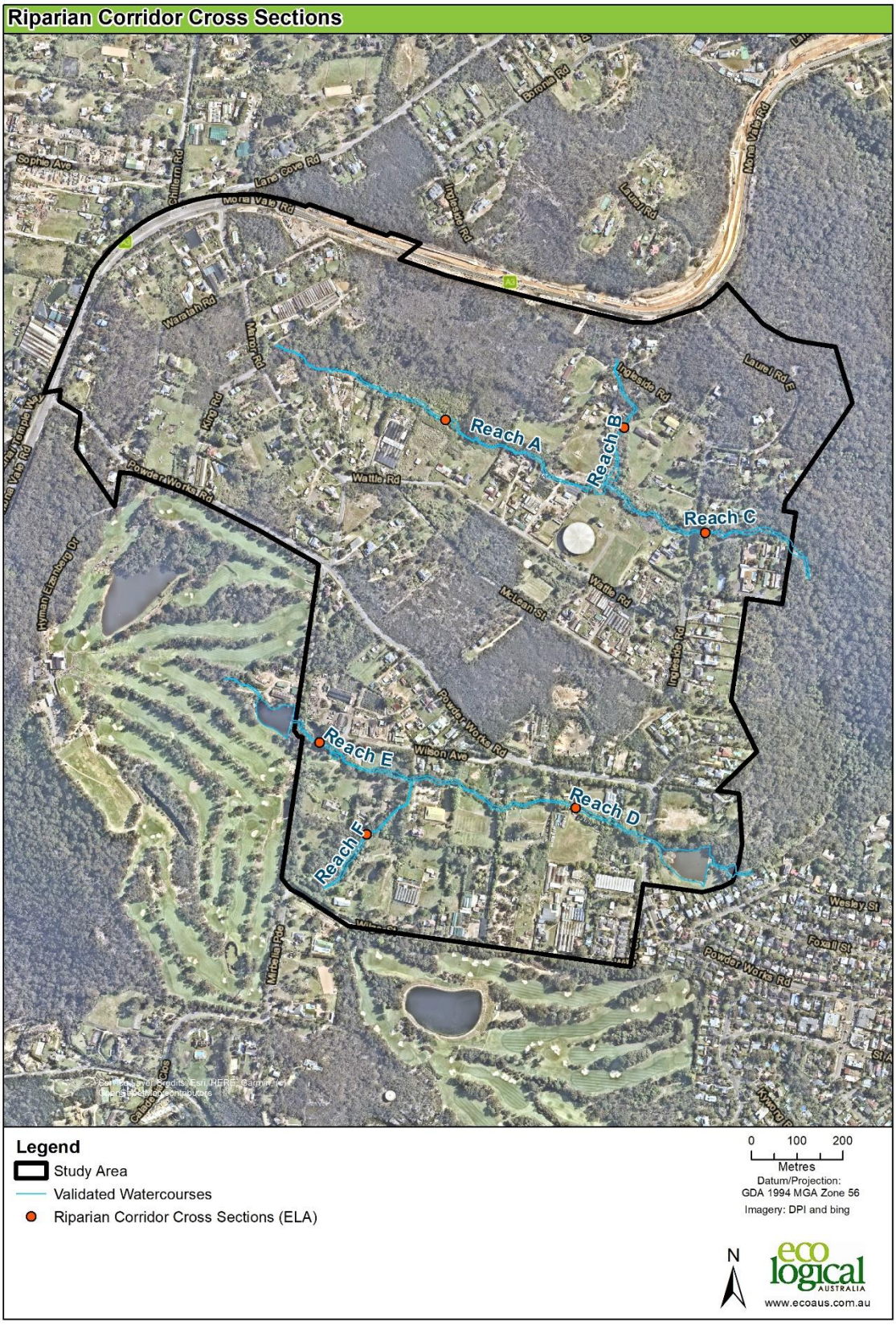


Figure 9: Location of riparian corridor cross sections

6. Conservation and management recommendations

The riparian corridors within the Precinct range from degraded to moderate condition. However, of the six watercourses identified, the majority have been assessed as having high or moderate recovery potential either because of their existing condition, function as part of a larger catchment, or potential to impact on sensitive environments. The remaining watercourse has been assessed as having a low recovery potential having already been substantially modified and located within a highly disturbed sub-catchment.

In this context, the majority of the watercourses within the Precinct should be afforded suitable protection, and the application of appropriate riparian buffers. Integration of the riparian corridors as part of recognised biodiversity corridors within the Precinct should also be considered.

The placement and management of detention/bioretention basins and public open space will be important in helping to maintain and improve the ecological condition of riparian areas. Proposed detention basins should be placed in sections of land which are preferably adjacent to riparian corridors, vegetated with local provenance species, and retained in public ownership. Where possible, open space areas, and water quality and flood detention devices should be located in degraded stream reaches to minimise the loss of existing or better quality habitat across the Precinct.

Where the public ownership of riparian corridors cannot be achieved, opportunities to maximise aquatic ecological values across the site should be considered through the rehabilitation of remnant vegetation in areas zoned for public or private open space, drainage and education infrastructure, and possibly environmental conservation and environmental living.

Specific riparian and aquatic design considerations include:

- Adequate Riparian Protection Areas along Mullet Creek (or their tributaries with moderate conservation and recovery potential), with co-location of water treatment/detention facilities to maintain or increase the effective riparian corridor width
- Integration of GDEs as part of the broader riparian and/or biodiversity corridor network within the Precinct.
- Embellishment of existing native riparian and aquatic vegetation and restoration of the aquatic habitat of the watercourses as part of a riparian corridor management plan
- Where possible, incorporation of new wetlands and the rejuvenation of aquatic habitat within areas of open space and or conservation lands to replace areas lost for infrastructure
- Use of local provenance wetland species for detention basin design, with specific consideration given to establishing or enhancing suitable wetland/aquatic habitat
- Appropriate use of large woody debris to re-introduce in stream habitat
- Control of peak flows to reduce erosion impacts and improve water quality through the implementation of WSUD.
- Design and placement of sewer infrastructure to reduce the potential impact of overflows within riparian environments
- Perimeter roads to separate development areas from the riparian corridor VRZ.

7. Assessment of Structure Plan

This section provides a brief analysis of the zoning plan (Figure 10), including components of the Draft Water Cycle Management and Flooding Assessment (Cardno 2020). NRAR controlled activity guidelines, whilst not directly applicable to a rezoning, have been considered during the development of the Structure Plan. The structure plan achieves the objectives of NSW policy settings in the following manner:

- All waterways contain riparian buffers that comply with NRAR guidelines.
- The Structure Plan protects all riparian corridor VRZ reaches identified as 'high riparian corridor conservation priority' (Figure 8) on site by assigning appropriate environmental land uses areas. This appropriate application of land use areas is broken down in Table 10 below.
- The majority of riparian areas are zoned E2 Environmental Conservation and will also be subject to the Biodiversity overlay in the LEP.
- The widths allowed for riparian buffers in the Structure Plan often exceed NRAR guidelines minimum widths. Figure 10 shows a series of measured riparian and ecological corridors widths, within the portion of the Ingleside Precinct proposed for development. These widths are based only on proposed Environmental Conservation land use, and do not include stormwater basins, parks, or other land uses). These are:
  - On the northern branch of Mullet Creek widths are 24 m – 296 m.
  - For the proposed ecological corridor located between the northern and southern branches of Mullet Creek (and not associated with a riparian corridor), widths are 25 m – 296 m.
  - On the southern branch of Mullet Creek widths are 27 m – 61 m.
- Creek crossings have been restricted to existing crossings only. Those being:
  - On Mullet Creek via Powderworks Rd (Reach D) & Ingleside Rd (Reach C).
- Three offline detention basins have been located outside the inner 50% VRZ as per NRAR guidelines.
- One online detention basin has been located at the confluence of Reaches A and B on a 2nd order stream which is in accordance with NRAR guidelines. Note that the NRAR guidelines also stipulate that online basins are to be dry and vegetated, be for temporary flood detention only, have an equivalent VRZ for the corresponding watercourse order and not be used for water quality treatment purposes.
- Where stormwater detention is required outside the riparian corridor but within the VRZ a water management land use has been assigned.
- All stormwater run-off will be detained prior to discharging into the riparian corridor VRZ. Thirteen bioretention basins, designed for water quality improvement prior to discharge into the tributaries of Mullet Creek, have been located outside of the riparian corridors.
- Native vegetation within the environmental conservation landuse areas will be retained and there are significant corridors established as a result.
- Reach B is located within land zoned as RU2 Rural Landscape. Reach B has been assessed as in a degraded condition. This area will be subject to a Biodiversity overlay and future development on the waterfront land of Reach B will be subjected to the normal Development Application process and require a Controlled Activity Approval under the WM Act.

- Vegetation Management Plan(s) and DCPs for the environmental conservation land use areas have not yet been prepared, but there is the opportunity for areas mapped as cleared and exotic vegetation, to be revegetated, and for disturbed areas to be rehabilitated and/or used for passive recreational opportunities appropriate for the setting. Specific riparian and aquatic design considerations are outlined in the previous chapter.

Table 10: Land uses applied to riparian corridors (km)

Reach	Environmental Conservation (E2)	Private recreation (RE2)	Rural Landscape (RU2)	Low Density Residential (R2)	Infrastructure (SP2)	Total (km)
Reach A	0.803	0	0	0.008	0.059	0.870
Reach B	0	0	0.275	0	0.053	0.329
Reach C	0.380	0	0.022	0	0.085	0.488
Reach D	0.568	0.263	0	20	0	0.851
Reach E	0.337	0	0	0	0	0.337
Reach F	322	0	0	0	0	0.322
Total (km)	**2.411**	**0.263**	**0.297**	**0.029**	**0.198**	**3.197**

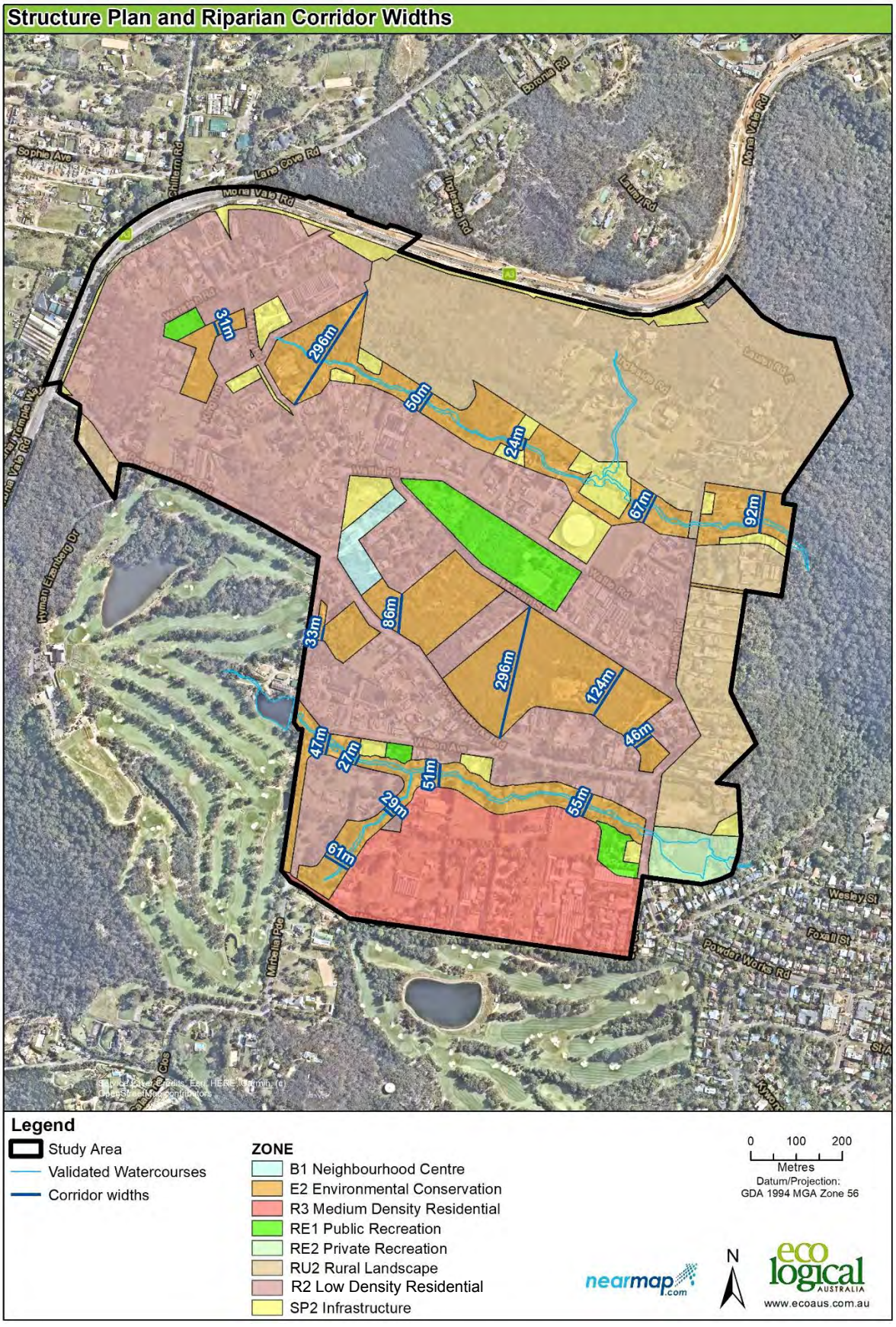


Figure 10: Structure plan and corridor widths

8. References

Cardno (2014). *Ingleside Water Management Strategy*. [Includes macroinvertebrate study].

Cardno (2020). *Ingleside Precent Water Cycle Management and Flooding Assessment – South Ingleside.* Prepared for Cox Architecture

Fairfull, S. (2013). *Fisheries NSW Policy and Guidelines for Fish Habitat Conservation and Management (2013 update*). Available online: http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0005/634694/Policy-and-guidelines-for-fish-habitat.pdf

Natural Resources Access Regulator (NRAR) (2018). *Guidelines for controlled activities on waterfront land – Riparian corridors*. Available online: https://www.industry.nsw.gov.au/__data/assets/pdf_file/0004/156865/NRAR-Guidelines-for-controlled-activities-on-waterfront-land-Riparian-corridors.pdf

Riches, M., Gilligan, D., Danaher, K. and Pursey, J. (2016). *Fish Communities and Threatened Species Distributions of NSW.* NSW Department of Primary Industries

Appendix A : Watercourse images recorded in the field

Mullet Creek

Reach A

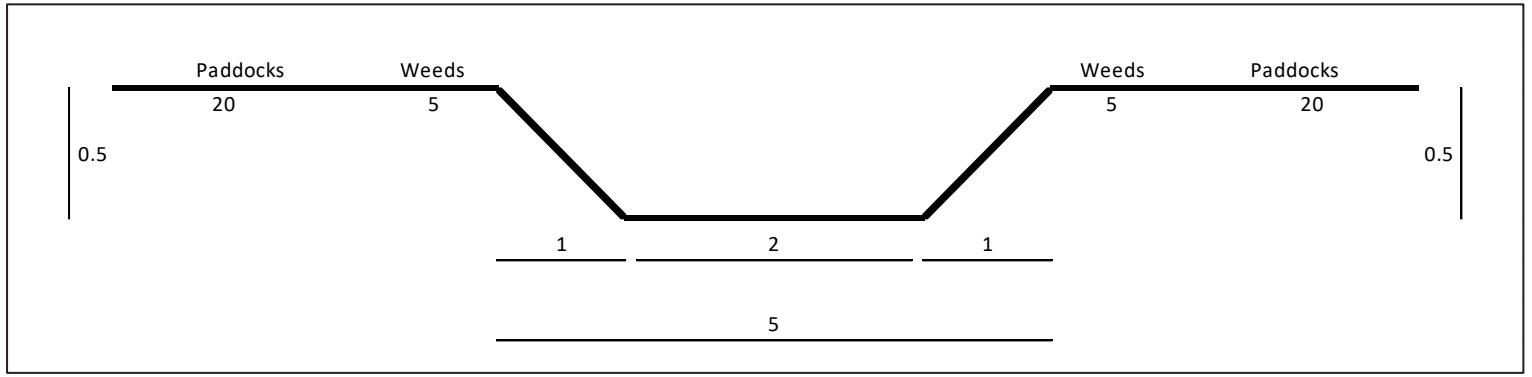
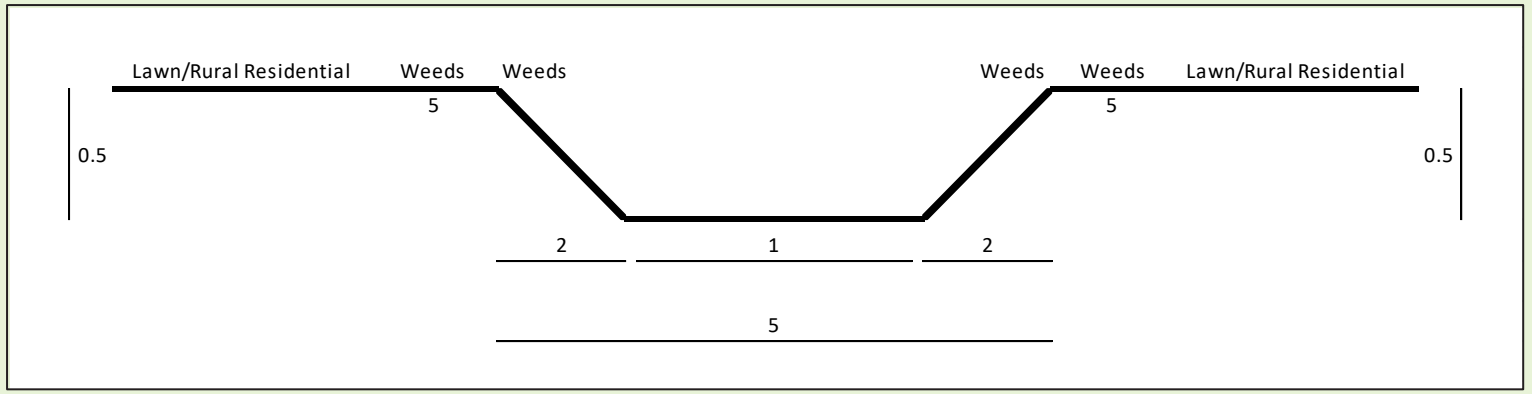
Reach B		
Reach D		

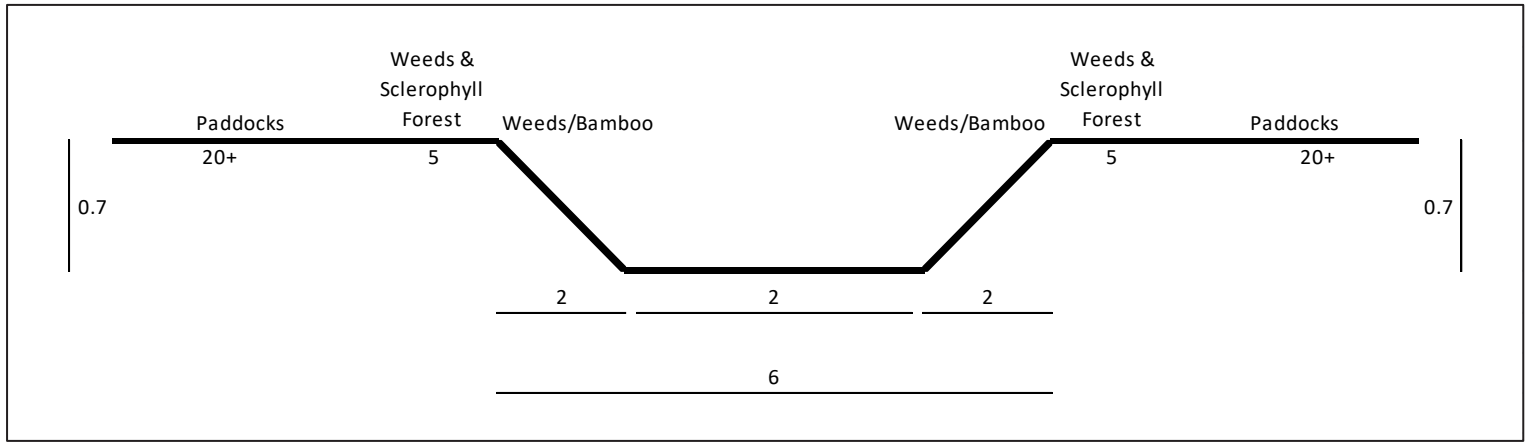
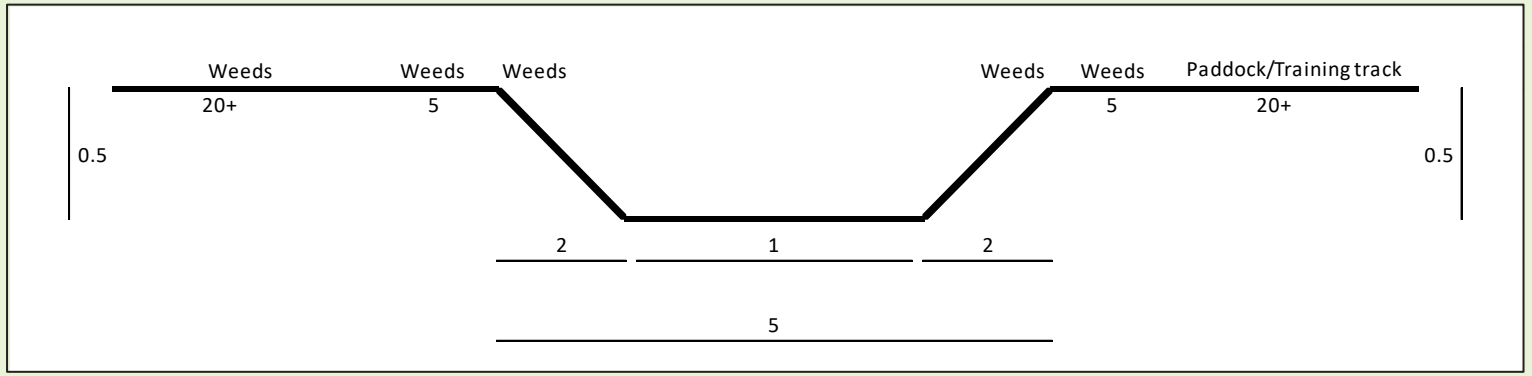
Reach E		
Reach F		

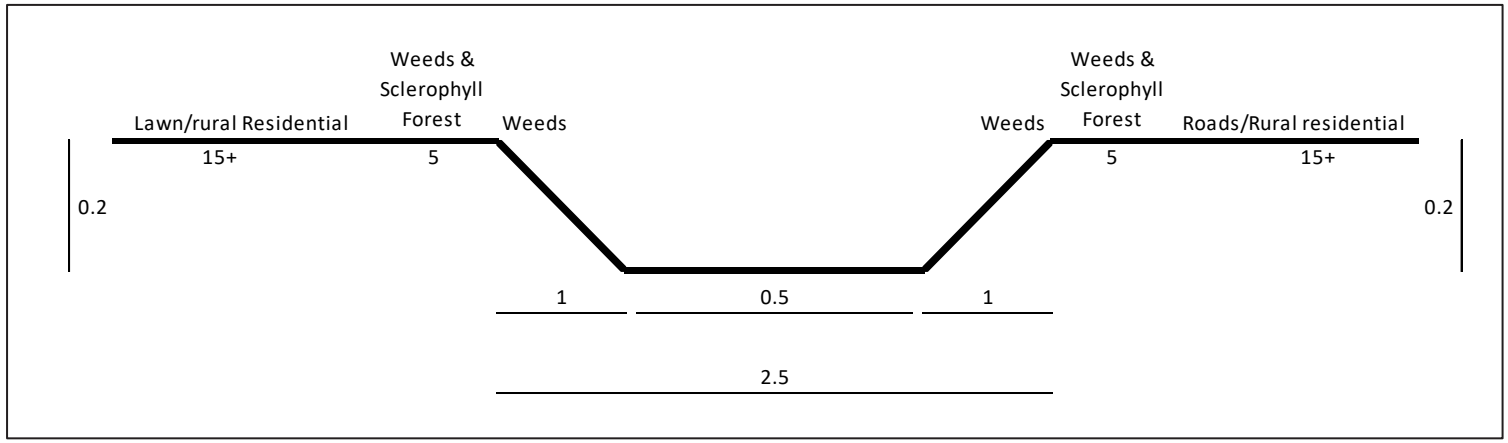
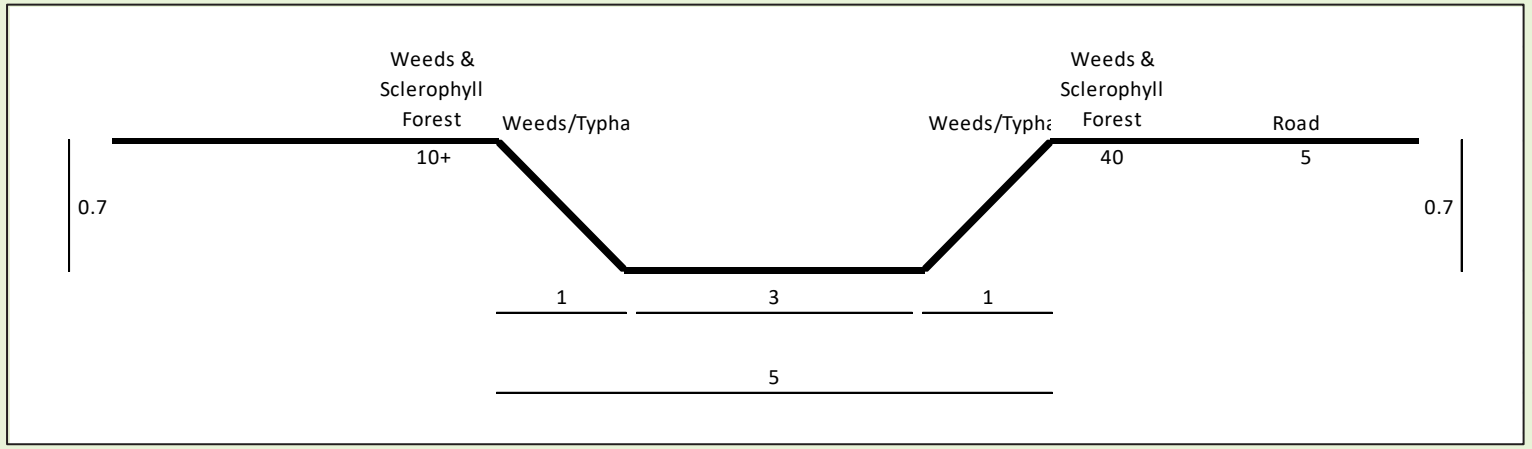
Reach C

Appendix B Riparian Corridor Cross Sections

Note: Schematic representations only. Measurements are in metres.

Creek	Reach	
Mullet Creek	Reach E	
Mullet Creek	Reach F	

Creek	Reach	
Mullet Creek	Reach D	
Mullet Creek	Reach A	

Creek	Reach	
Mullet Creek	Reach B	
Mullet Creek	Reach C	

eco logical AUSTRALIA
A TETRA TECH COMPANY

1300 646 131
www.ecoaus.com.au