RURAL FLOODPLAIN MANAGEMENT PLANS

Background document to the Macquarie Valley Floodplain Management Plan 2021

Water Management Act 2000

September 2021

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Abbreviations and acronyms

Abbreviation/acronym	Description
ABS	Australian Bureau of Statistics
ADS40	airborne digital sensor
AEP	annual exceedance probability
AHIMS	Aboriginal Heritage Information Management System
ASDST	Aboriginal Sites Decision Support Tool
ATWG	Aboriginal Technical Working Group
AWIS	Aboriginal Water Initiative System
Barwon–Darling Valley FMP	*Floodplain Management Plan for the Barwon–Darling Valley Floodplain 2017*
DECC	former NSW Department of Environment and Climate Change
DECCW	former NSW Department of Environment, Climate Change and Water
DEM	Digital Elevation Model
DVP	depth-velocity product
DWE	former NSW Department of Water and Energy
EP&A Act	*Environmental Planning and Assessment Act 1979*
FMP	floodplain management plan
FPWEC	First Peoples' Water Engagement Council
FS	flood study
FRMP	floodplain risk management plan
FRMS	floodplain risk management study
GL	gigalitres
GVAP	gross value of agricultural production
Gwydir Valley FMP 2016	*Floodplain Management Plan for the Gwydir Valley Floodplain 2016*
HHIMS	Historic Heritage Information Management System
IPW	infrastructure protection work
IRP	Interagency Regional Panel
IRSAD	Index of Relative Socio-economic Advantage and Disadvantage
LGA	local government area
LiDAR	Light Detection and Ranging
LLS	Local Land Services
Macquarie Valley FMP 2021	*Floodplain Management Plan for the Macquarie Valley Floodplain 2021*
MDB	Murray–Darling Basin
MDBA	Murray–Darling Basin Authority
ML	megalitres
MZ A	Management Zone A – Major discharge areas, defined floodways
MZ BH	Management Zone BH – Major flood discharge areas in high-level floodways

Abbreviation/acronym	Description
MZ B	Management Zone B – Flood storage and secondary flood discharge areas
MZ C	Management Zone C – Flood fringe and flood protected developed areas
MZ CU	Management Zone CU – Urban areas
MZ D	Management Zone D – Special protection areas
NBAN	Northern Murray–Darling Basin Aboriginal Nations
NOW	NSW Office of Water
NSW	New South Wales
NSW DPI	NSW Department of Primary Industries
OEH	former NSW Office of Environment and Heritage (now part of Environment, Energy and Science within the NSW Department of Planning, Industry and Environment)
PCT	plant community type
RORB	general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs
SEIFA	Socio-economic Indexes for Areas
SKM	Sinclair Knight Merz
TAG	Technical Advisory Group
VIS	NSW Vegetation Information System
Water Act	*Water Act 1912*
WM Act	*Water Management Act 2000*
WRC	Water Resources Commission New South Wales
WSP	water sharing plan

Purpose

The purpose of this document is to inform local landholders and the wider community about how the rural floodplain management planning approach presented in the *Rural Floodplain Management Plans: Technical manual for plans developed under the Water Management Act 2000* (the Technical Manual) has been applied across the Macquarie valley floodplain. This document should be read in conjunction with the Technical Manual and the *Floodplain Management Plan for the Macquarie Valley Floodplain 2021* (Macquarie Valley FMP 2021).

The Macquarie Valley Floodplain

This document relates to the Macquarie valley floodplain, as shown in Figure 1 and Figure 2. The Macquarie catchment is in central-west NSW and constitutes 6% of the Murray–Darling Basin (MDB). The Macquarie River is the main trunk stream of the catchment. It forms at the confluence of the Fish and Campbells rivers and extends in a north-westerly direction for 500 kilometres from the Great Dividing Range near Oberon to the Barwon–Darling River between Walgett and Brewarrina (Sinclair Knight and Partners Pty Ltd 1984a). The Macquarie catchment is bordered by the catchments of the unregulated Bogan and Castlereagh rivers to the west and east, respectively, and covers approximately 7,500,000 hectares (NSW Office of Environment and Heritage (OEH) 2012a).

The main cities and towns in the region include Orange, Bathurst, Mudgee, Wellington, Dubbo, Narromine and Warren. The Macquarie system is a network of tributaries, anabranches and distributary streams (Davies et al. 2012). Principal tributaries of the Macquarie River predominate upstream of Narromine in the relatively steep and undulating landscape of the upper catchment. These include the Cudgegong, Turon, Bell and Talbragar rivers. Below Narromine, a complex system of anabranches and effluent creeks begins on the broad and flat plains connecting the Macquarie, Bogan, Castlereagh and Barwon–Darling river systems.

The Macquarie Marshes wetland system, parts of which are recognised as wetlands of international ecological significance and are listed as a Ramsar site under the Ramsar Convention, is an ecologically and culturally significant feature of the lower reaches of the Macquarie River. It is the largest flood-dependent ecological asset in the catchment (Commonwealth Environmental Water Office 2013).

The Macquarie River is a regulated watercourse between Burrendong Dam – the largest flow-regulating structure in the Macquarie catchment, with a capacity of 1,118 gigalitres (GL) – and the Macquarie Marshes. Burrendong Dam was constructed in 1967 upstream of Wellington, immediately below the confluence of the Cudgegong and Macquarie rivers. Before it was constructed, flood work development was limited to minor works including weirs and regulators built in the late 1800s and early 1900s to divert water from the Macquarie to pastoral properties along the effluent creeks that leave the river between Narromine and the Macquarie Marshes.

After the dam was built, there was a major increase in flood work development. Burrendong Dam was built:

- to supply water for urban, domestic, stock and irrigation purposes
- to provide storage capacity for flood mitigation
- for conservation through the provision of flows for environmental benefit.

Windamere Dam (361 GL), located on the Cudgegong River upstream of Mudgee, is used for rural, urban and industrial supply. Windamere Dam regulates a relatively small percentage of the Macquarie catchment above Narromine. It has a relatively minor impact on flooding at and below Narromine compared to Burrendong Dam (Bewsher Consulting Pty Ltd 1998).

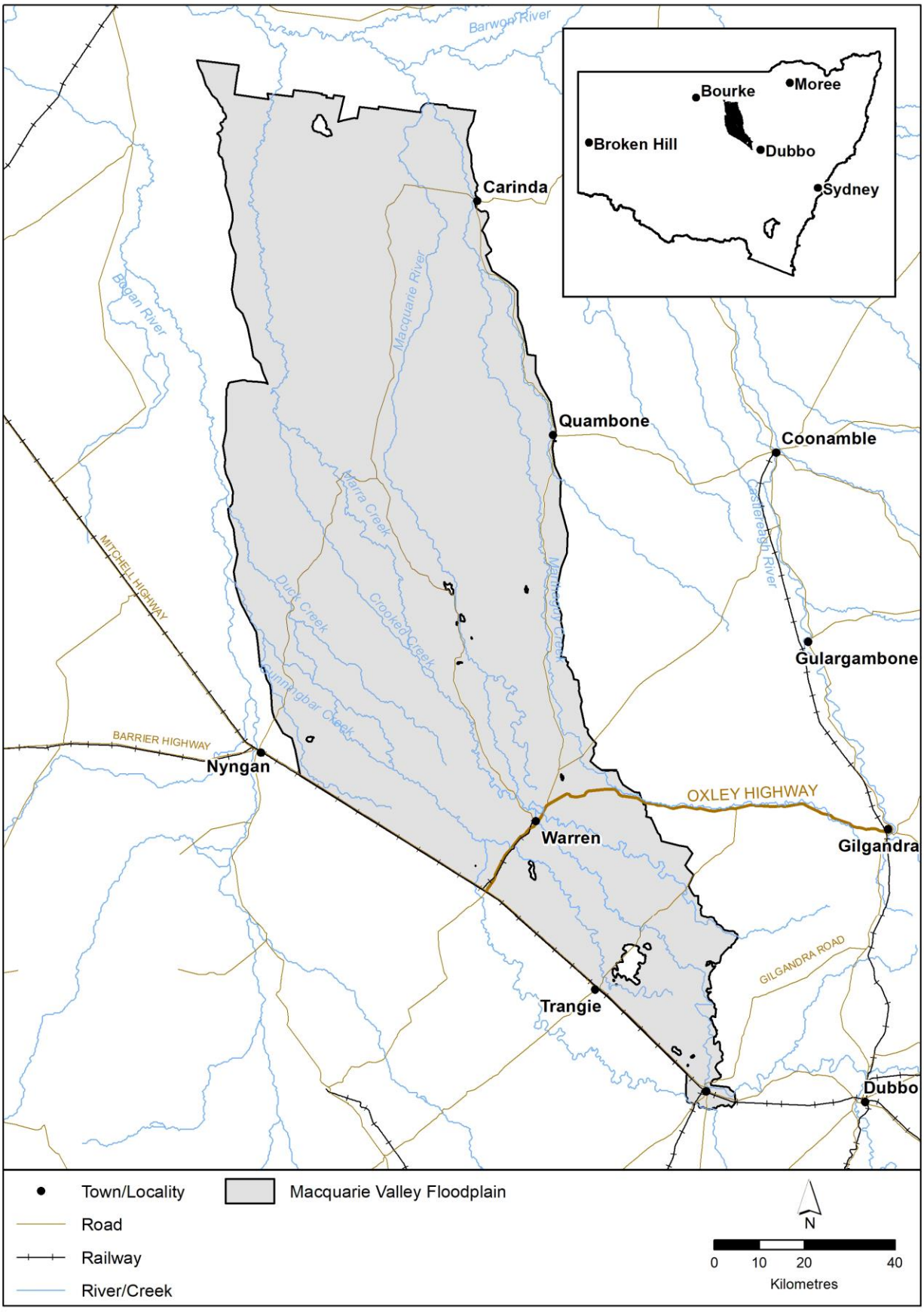

Figure 1: Extent of the Floodplain Management Plan for the Macquarie valley floodplain 2021

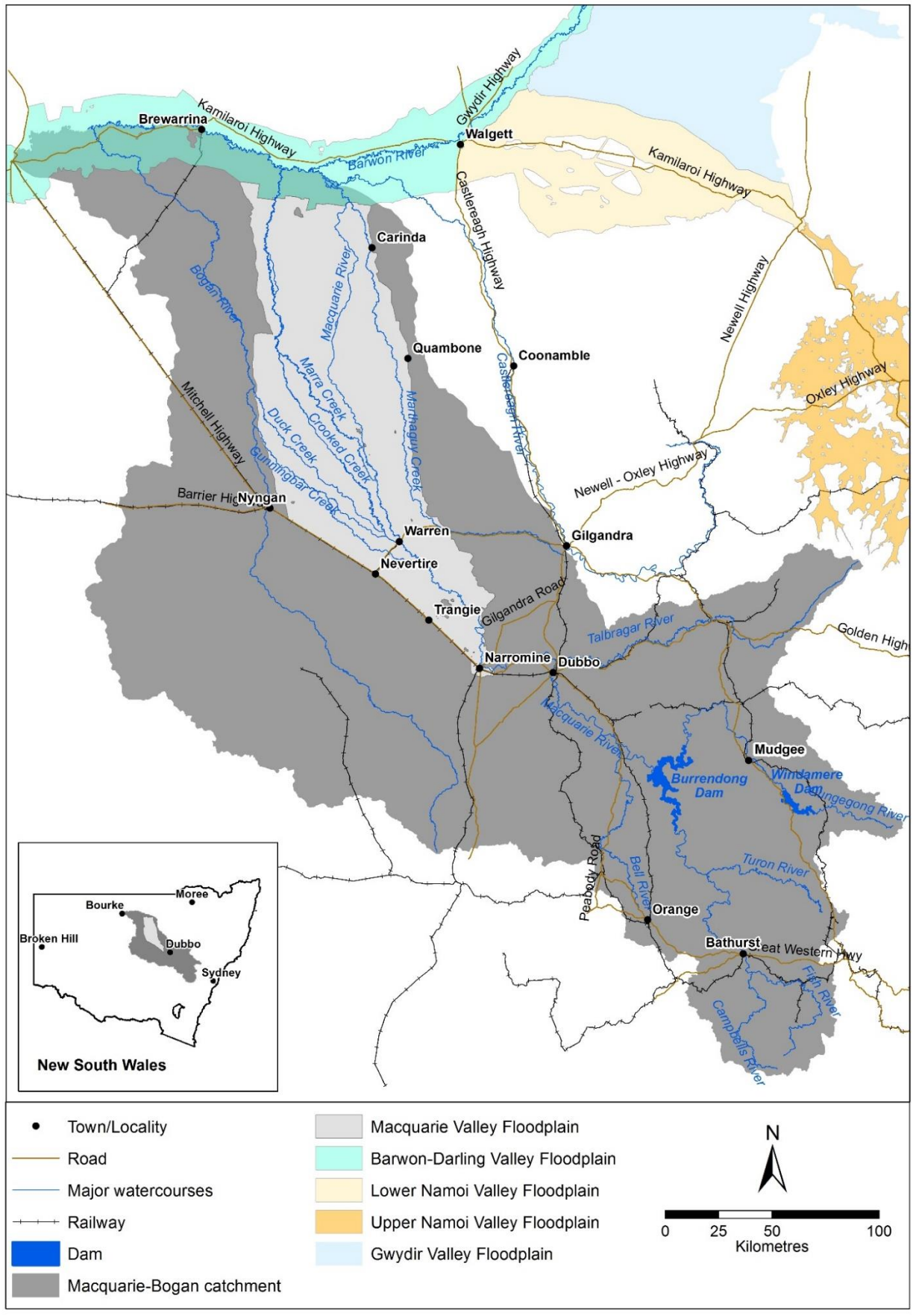

Figure 2: The Macquarie valley floodplain and the Macquarie–Bogan catchment

Other flow-regulating structures in the Macquarie, including weirs and regulators, are used to store and distribute water for irrigation and domestic uses such as town water supply.

The construction of Burrendong Dam led to a major change in land use on the Macquarie valley floodplain from low-intensity grazing to high-intensity irrigation. Channels and levee banks were built on large areas of the floodplain, mainly between Narromine and Oxley Station, to deliver water and protect high-value crops from flood damage. These large-scale earthworks reduced the flood storage volume that was available under natural conditions and caused floods to rise above historical levels (Sinclair Knight Merz (SKM) 2008).

The Macquarie valley floodplain begins at Narromine and includes a system of effluent creeks that flow towards the Bogan River at its western extent, and the Marthaguy Creek at its eastern extent (Figure 1). The northern extent of the floodplain is marked by the confluence of the Macquarie River and Marthaguy Creek. The channel capacity of the Macquarie River decreases progressively downstream of Narromine as it enters the flat alluvial plains near Warren, which are characterised by a complex system of anabranches and effluent creeks connecting the Macquarie, Bogan and Barwon–Darling rivers (Green et al. 2011; NSW Office of Water (NOW) 2012). Major effluent streams in this region on the western part of the Macquarie Valley Floodplain include the Beleringar, Gunningbar, Crooked, Duck and Marra creeks, which carry flows from the Macquarie River to the lower Bogan River and Barwon River.

Downstream of Warren, between Marebone Weir and Carinda, the Macquarie River flows for 120 kilometres through a meandering network of effluent channels and anabranches including the internationally and nationally significant Macquarie Marshes wetlands (Green et al. 2011). The wetlands consist of shallow swamps, lagoons, creeks and floodplains covering more than 200,000 hectares when fully flooded by flows from the Macquarie River and its streams and anabranches (Thomas et al. 2015; Green et al. 2011). The Macquarie River exits the Macquarie Marshes as a single channel and flows for 80 kilometres to the Barwon River, upstream of Brewarrina. In this reach, known as the lower Macquarie, the Macquarie River is joined by Marthaguy Creek, followed by the Castlereagh River.

The floodplain ecosystems are unique and diverse. Many are flood-dependent and require a particular frequency of inundation to remain viable. Floodplain water flows are therefore crucial to maintaining the structure, function and long-term survival of the flood-dependent ecological communities that occur on the Macquarie valley floodplain. The Macquarie Marshes wetlands[1] are among the largest and most important freshwater wetlands in the MDB, and unique in size and diversity (NOW 2012). The ecological significance of the Macquarie Marshes is recognised at local, state and national levels of government and internationally through the Ramsar Convention (Ramsar Convention 1971). When inundated for extended periods, the Marshes are an important breeding and refuge area for a variety of waterbirds, including egrets, ibis, herons, spoonbills and cormorants, in addition to other wetland fauna (Kingsford & Auld 2005; Kingsford & Thomas 1995; Murray–Darling Basin Authority (MDBA) 2013). The Marshes can support more than 500,000 waterbirds in large floods (OEH 2013). Native floodplain vegetation including extensive communities of river red gum, common reed beds and water couch areas are distinctive features of the Marshes. The ecological functions and habitats of the Marshes have been under increased stress in recent years due to the combined effects of river regulation and drought.

[1] The Macquarie Marshes wetlands may be referred to as the Marshes when discussing these wetlands in a general sense in this report.

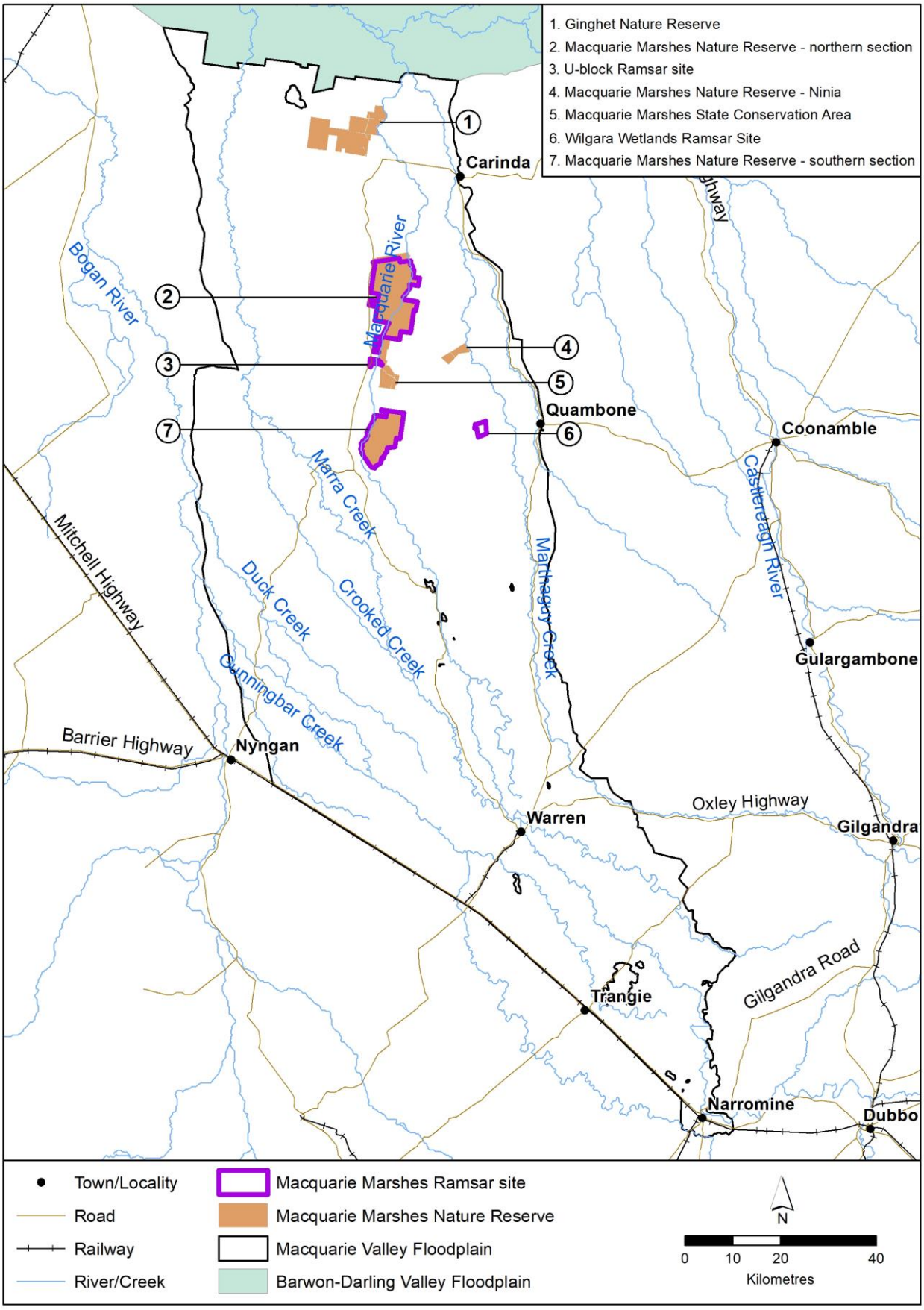

Figure 3: Conservation areas of the Macquarie valley floodplain

The Macquarie valley floodplain is culturally significant due to Aboriginal and European settlement. The Wailwan (also Weilwan) people were the original inhabitants of the floodplain. Aboriginal people traditionally occupied the more frequently watered parts of the landscape where resources were plentiful. The floodplain contains many cultural sites and values that are important to the local Aboriginal community.

The NSW Government has administered floodplain management in this region since the late 1970s in response to the impact of flood works associated with irrigation development on the passage of floodwaters. Planning has focused on areas with intensive irrigation development and where major flood events revealed changes to flooding behaviour caused by flood works.

Floodplain development guidelines were prepared in 1978 and 1982 for the Macquarie River between Narromine and Warren, and Warren and Oxley Station, respectively (Figure 4. These guidelines served as the main reference for landholders undertaking floodplain development, including the construction of flood control works (NSW Water Resources Commission (WRC) 1978; WRC 1982). The *Macquarie River (Narromine to Oxley Station) Floodplain Management Plan* (hereafter referred to as the Macquarie River FMP 2008) gazetted in 2008 under Part 8 of the *Water Act 1912* (Water Act) superseded these guidelines (NSW Department of Water and Energy (DWE) & Department of Environment and Climate Change (DECC) 2008). The Macquarie River FMP 2008 provided a coordinated and integrated network of floodways of adequate hydraulic capacity and continuity to effectively convey floodwaters and support the floodplain environment (Figure 4).

The Lower Macquarie floodplain was designated to capture existing and potential floodplain developments in the Lower Macquarie region. The Lower Macquarie floodplain was designated in 1985 under Part 8 of the Water Act (Figure 4). An FMP has not previously been made for the designated Lower Macquarie floodplain.

To build on the floodplain management planning to date, the Macquarie Valley FMP 2021 has been prepared in accordance with the floodplain planning and environmental protection provisions of the *Water Management Act 2000* (WM Act). The Macquarie Valley FMP 2021 will aim to coordinate flood work development to protect flooding behaviour while minimising risk to life and property from the effects of flooding. The Macquarie Valley FMP 2021 provides management zones and rules to be used when determining flood work development approvals for new flood works, and amendments to existing flood works. Existing floodplain management arrangements that apply to the Macquarie valley floodplain have been reviewed and, where relevant, incorporated into the design of management zones, rules and assessment criteria in the Macquarie Valley FMP 2021.

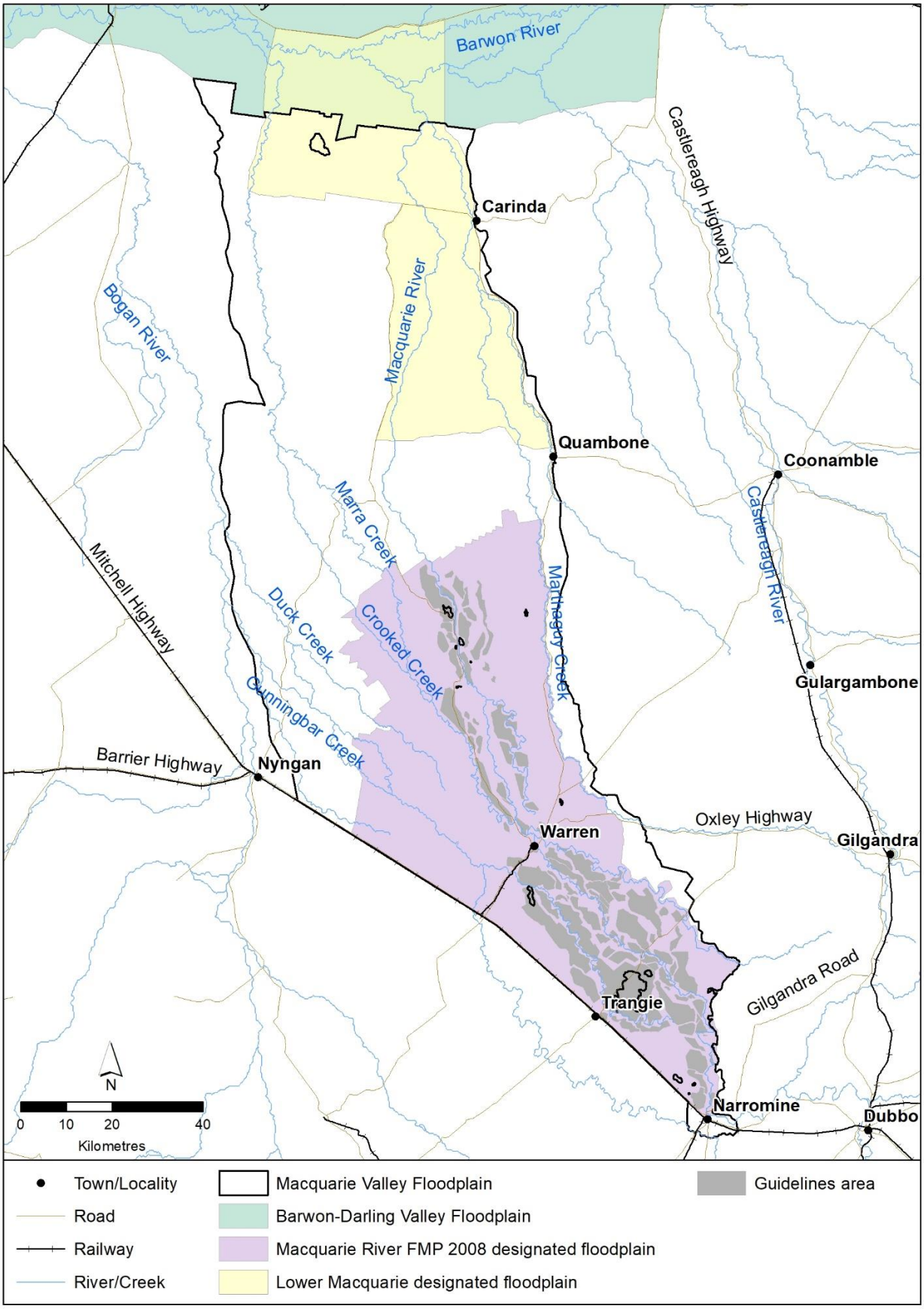

Figure 4: Floodplain development guidelines and floodplains designated under Part 8 of the *Water Act 1912*

Flooding in the Macquarie Valley Floodplain

Flood behaviour in the Macquarie valley floodplain is influenced by a range of factors including catchment characteristics and floodplain topography. Variations in topography, changes to infrastructure development, geomorphology, and vegetation may alter the nature of flooding. These variations influence flood level, water velocity and flow distribution at a local scale, and cumulatively at a broader floodplain scale. In the Macquarie valley floodplain, flood behaviour varies between the upstream and downstream reaches because of:

- the nature of flood work development
- variations in river regulation and land use
- the pattern of anabranching and distributary channels and associated extensive wetlands.

The Macquarie River originates in a high plateau area of the Great Dividing Range and is formed by the junction of the Fish and Campbells rivers upstream of Burrendong Dam. Downstream of the dam to Narromine, flooding is restricted due to the relatively narrow, bedrock-confined Macquarie channel. Three major tributaries, the Talbragar, Bell and Little rivers, join the Macquarie along this reach.

From Narromine, the channel capacity of the river decreases progressively as it enters wide alluvial plains downstream of Warren. With a reduced channel capacity, much of the flow of large flood events is carried overbank through a complex system of effluent creeks and anabranches connecting the Macquarie, Bogan and Barwon–Darling river systems. Flooding in the Macquarie valley floodplain is mostly generated from runoff in the catchment above Narromine. Flood flows from the Ewenmar Creek and Marthaguy Creek catchments also contribute to flooding in the Macquarie valley floodplain downstream of Narromine.

Downstream of Marebone Weir, north of Warren, the Macquarie River breaks down into a series of interconnecting and distributary channels with extensive associated floodouts[2] and floodplain wetlands in the Macquarie Marshes. The Macquarie exits the Marshes as a single channel and is joined by Marthaguy Creek followed by the Castlereagh River before flowing into the Barwon River upstream of Brewarrina. Flooding can be influenced by floodwaters from the Bogan, Castlereagh and Barwon rivers at the fringes of the Macquarie valley floodplain.

Historically, floods in the Macquarie catchment have occurred in the summer or winter months. This is due to heavy daily summer rainfalls when a depression forms to the north, causing moist northerly airstreams west of the Great Dividing Range, or due to high winter monthly rainfalls generated by a series of well-developed troughs associated with southern depressions. Major floods recorded before and after the construction of Burrendong Dam occurred during late summer or early autumn, or during winter. Smaller floods mostly originate from runoff from the upper catchment during winter and spring. The capture of high winter flows in Burrendong Dam and their release during the summer months has altered the seasonality of smaller floods.

Narromine to Marebone

A considerable amount of overbank flooding occurs in the Macquarie River reach between Narromine and Marebone. **Error! Reference source not found.** shows the watercourses referred t o in this section.

During the 1990 flood, approximately 50% of the peak flow recorded at Narromine broke out of the Macquarie River in the reach between Narromine and Gin Gin (SKM 2002). Major breakouts from the left bank in this reach include Bugaboo Point, located 25 kilometres downstream of Narromine

[2] A floodout is a site at the downstream end of a river where channelised flow ceases and floodwaters spill across adjacent, unchannelled, alluvial surfaces (Tooth 2000).

Bridge, and nearby downstream Rocky Point. These were active during the large floods of 1955 and 1990 (SKM 2002).

Bugaboo Point was also active during the 2010 flood. Most of this breakout flow travels along the wide, flat floodplain to Buddah Lake and Trailgang Cowal, eventually entering Beleringar Creek (SKM 2002).

Between Rocky Point and Gin Gin, overbank flows onto the left bank of the Macquarie are more confined due to the elevated nature of the floodplain in this reach (SKM 2002). These flows return to the Macquarie through Gin Gin Creek. On the right bank, overflows occur in a north-westerly direction, mainly downstream of the Crooked Creek offtake onto 'Edithville Station' and 'Weemabung'. This water passes as a wide front over the Trangie-Collie Road before draining into the upper reaches of Greenhide Creek. During major floods, some outflow can also pass into Crooked Creek. These flows join Ewenmar Creek downstream (SKM 2002).

The Macquarie River reach from Gin Gin to Marebone Weir is more prone to overbank flooding than that from Narromine to Gin Gin, with comparatively smaller, medium-sized floods capable of initiating breakouts over both banks (SKM 2002). This reach represents the start of the effluent creek system that transports outflows from the main Macquarie River channel onto the western floodplain (see effluent creek system) (Sinclair Knight and Partners Pty Ltd 1984a). Major breakouts from the right bank of the river along this reach charge Ewenmar Creek and Five Mile Cowal and contribute to substantial flooding on the eastern part of the Macquarie valley floodplain. Flood peaks take approximately 3 days to pass along the Macquarie River between Gin Gin and Marebone.

Immediately downstream of Gin Gin Bridge, large outflows and overbank flows from the right bank of the Macquarie travel across a wide floodplain area into Greenhide Creek. Flows from Greenhide Creek pass into the upper reaches of Birchells Plain Creek, which is joined by extensive outflows from the river at Reddenville Break before passing into Ewenmar Creek. Reddenville Break is a major breakout onto the eastern floodplain that carries outflows through a cutting north-west to Ewenmar Creek via Birchells Plain Creek (SKM 2002). The breakout is controlled by a block dam that starts to overtop when flows reach 12,000 megalitres (ML) per day at Gin Gin (MDBA 2013).

Ewenmar Creek drains a catchment of 190 square kilometres and can carry substantial flows from catchment runoff and flood inflows from the Macquarie River. Flood outflows from the Ewenmar pass over its right bank and move cross-country, flowing parallel to the Macquarie before passing into Five Mile Cowal upstream of the Oxley Highway. Five Mile Cowal is a wide, meandering anabranch that carries flood flows through the eastern floodplain to Marebone, where the Cowal joins the Macquarie.

In minor to moderate floods, the right bank floodwaters downstream of Warren are generally narrowly confined between the Macquarie and Five Mile Cowal, as far as downstream as the Drungalear Break, where water breaks to the north-east. Under major flood conditions, floodwaters from Tiger Bay Cowal (which crosses the floodplain near Warren) and Five Mile Cowal result in more widespread flooding on the eastern bank of the Macquarie River.

Marthaguy Creek, a tributary of the Macquarie that joins the river downstream of Carinda, flows broadly parallel to the Macquarie along the Gin Gin to Marebone reach east of Five Mile Cowal. Marthaguy Creek drains a substantial catchment area (about 650,000 hectares) and carried significant flood flows through the Macquarie valley floodplain during the 2010 flood.

Figure 5: Major rivers and creeks between Narromine and Marebone Break

Effluent creek system

The western floodplain between Gin Gin and Marebone is characterised by a network of distributary offtakes formed from a combination of the lowland slopes and variable rainfall and runoff (WMA Water 2008). These north-west trending distributaries are collectively known as the effluent creek system and include the Beleringar, Gunningbar, Duck, Crooked and Marra creeks. This system disperses flood flows to the northwest and west towards the Bogan and Barwon Rivers (**Error! Reference source not found.**).

Beleringar Creek carries significant volumes of Macquarie flood outflow across the western part of the Macquarie valley floodplain from approximately 6 kilometres upstream of the Oxley Highway to its confluence with Gunningbar Creek, east of Nyngan. Beleringar flood flows are fed from Bugaboo Point via Trangie Cowal and from Macquarie outflows below Gin Gin Bridge and through the Beleringar Creek Regulator. A number of breakouts occur between Gin Gin Bridge and the Beleringar Creek Regulator, which enter Mullah Cowal and Ban Ban Creek and run parallel to the Macquarie between the river and Trangie Cowal. Most of this water flows overland as a wide front and drains into Beleringar Creek before Ban Ban Creek joins the Macquarie (SKM 2002).

Gunningbar Creek leaves the Macquarie from Warren Weir and is a major carrier of Macquarie River floodwaters. Flows into Gunningbar are controlled by a regulator that is kept open during floods. Flow diverted into Gunningbar Creek from the Macquarie is diverted into Duck and Crooked creeks. During large floods, Macquarie flows meet Gunningbar Creek downstream of the Gunningbar regulator. High Macquarie River flows also break out to Gunningbar Creek downstream of Warren Weir and upstream of Warren township (WMA Water 2008). Gunningbar flows eventually drain to the Bogan River about 50 kilometres downstream of Nyngan.

Crooked Creek originates as an offtake of Gunningbar Creek just downstream of Warren township. The creek receives flood inflows from the Macquarie via Burlong Creek and the Mumblebone anabranch (upstream of Marra Break), which operates during times of high flow (WMA Water 2008). Some Macquarie flows can additionally reach the creek after crossing Carinda Road near ‘Raby’. Flows in Crooked Creek eventually drain into Marra Creek.

Duck Creek leaves Crooked Creek approximately 2 kilometres from the Crooked Creek offtake from Gunningbar and eventually drains to the Bogan River about 70 kilometres downstream of Nyngan. During high-volume floods, flows from Gunningbar Creek spread to Duck Creek (as occurred in 1990).

Marra Creek leaves the Macquarie River upstream of Marebone Weir and carries flood flows to its junction with the Barwon River about 40 kilometres upstream of Brewarrina. Flood flows enter Marra Creek from Marra Break, which consists of 2 natural breakouts on ‘Mumblebone’. Low Macquarie flows are delivered to Marra Creek by Marra Creek Cutting, an artificial channel constructed in 1978 downstream of the natural offtake (WMA Water 2008). Marra Creek also receives Westward flood flows passing across the Macquarie River near Mount Harris and inflows from Milmiland and Crooked creeks.

Macquarie Marshes and lower Macquarie River

The nature of flooding in the Marshes and lower Macquarie River is summarised in 4 sections:

- Marebone to Oxley–Gum Cowal
- East Marsh
- South Marsh (Oxley to Pillicawarrina)
- North Marsh to the lower Macquarie River (Figure 6).

The Macquarie Marshes wetlands form downstream of Marebone Weir where the Macquarie divides into a braided river pattern along the main channel and the Gum Cowal–Terrigal Creek.

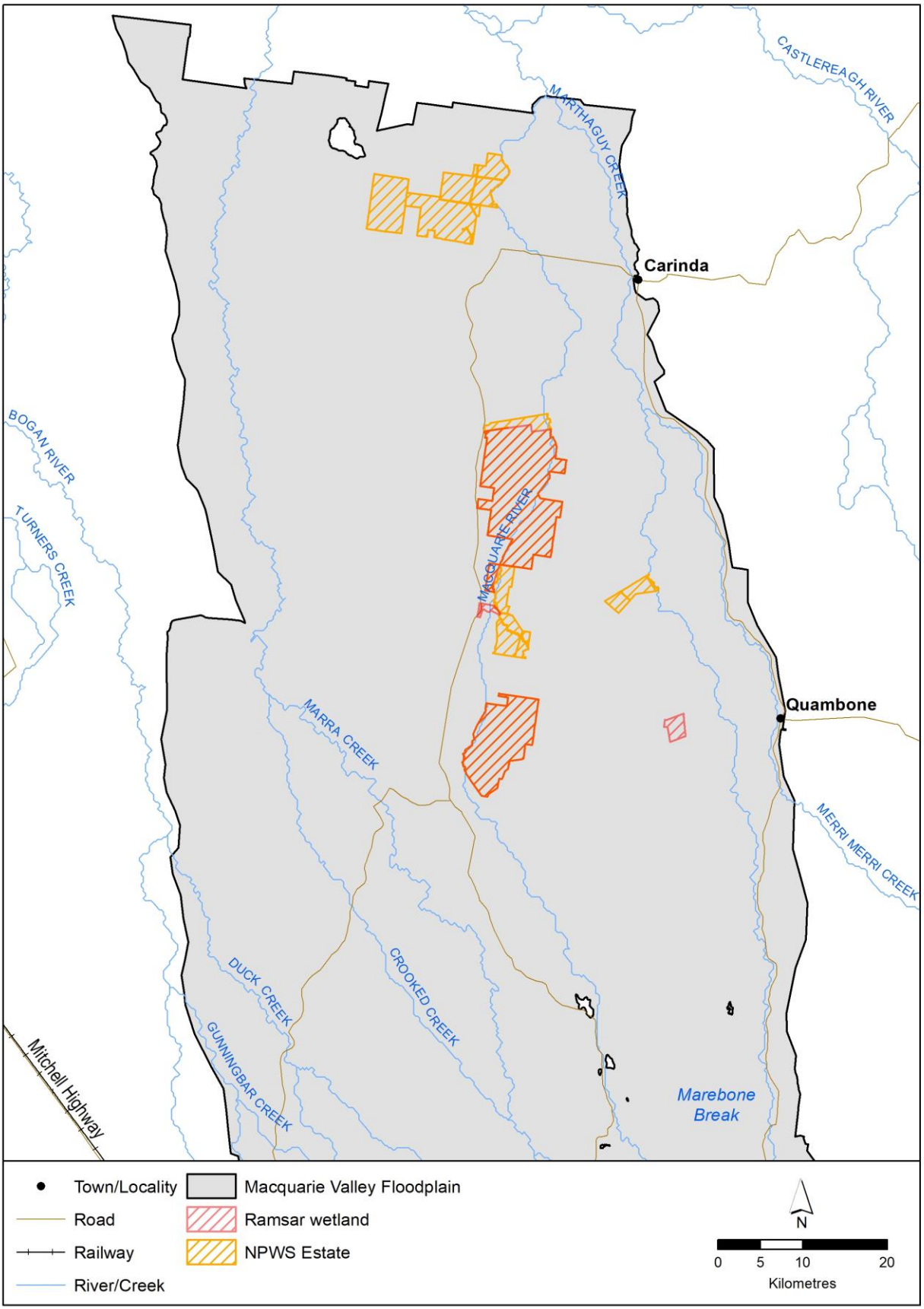

Figure 6: Major rivers and creeks between Marebone Break and the downstream extent of the Macquarie valley floodplain

The wetlands consist of shallow swamps, lagoons, creeks and floodplains that cover more than 200,000 hectares when fully flooded (Thomas et al. 2015; Green et al. 2011). Records of significant floods events in the Macquarie Marshes correspond with relatively long periods of high flow at Marebone Weir (greater than 50 days and 3,000 ML per day). Flows are spatially variable as the nature of flooding is dependent on the arrangement of active anabranches and wetland feeder channels. Downstream of the Macquarie Marshes, the Macquarie River flows as a single channel for 80 kilometres, joining the Barwon River upstream of Brewarrina. The Marthaguy Creek joins the lower Macquarie at the downstream extent of the Macquarie valley floodplain.

Marebone to Oxley–Gum Cowal

The Macquarie separates into 2 channels at Marebone: the Macquarie River and Marebone Break. Regulated flow in these channels is controlled by Marebone Weir and Marebone Regulator, respectively. During large floods, significant flows pass through Marebone Break, inundating a broad area known as The Jungle. At Gradgery Lane, these flows meet Macquarie flows and are conveyed downstream via the Macquarie River, a floodway through irrigated development adjacent to Mt Harris, Bulgeraga Creek and Back Swamp. Historically, substantial flood flows have passed overland from Marebone Break to the east of Back Swamp, eventually draining to Gum Cowal and Terrigal Creek. Overbank flows from the Macquarie River also travel to the west of Mt Harris into Marra Creek (as in the August 1990 flood). The Oxley Break, which formed during large floods in the 1950s, connects the Macquarie River to Bulgeraga Creek (DHI 2008).

Bulgeraga Creek flows northward along the western edge of Back Swamp until its bifurcation with Gum Cowal. Flows from Back Swamp meet Gum Cowal just downstream of the bifurcation and continue on through the Marshes. Near the confluence of Back Swamp floodwaters and Gum Cowal, the channel capacity of each of these effluents progressively diminishes and the width of the floodplain increasingly expands (SKM 2002).

East Marsh: Downstream of Gum Cowal

Watercourses of the East Marsh include Gum Cowal–Terrigal Creek, Long Plain Cowal and Dusty Swamp (Department of Environment, Climate Change and Water (DECCW) 2010). Flood flows in Marthaguy Creek combine with Terrigal Creek flows, continuing northwards along the eastern edge of the East Marsh.

Merri Merri Creek, which drains a catchment originating near the Castlereagh River at Gulargambone, joins the Marthaguy from the south-west upstream of Carinda. Marthaguy Creek meets the Macquarie River at the downstream extent of the Macquarie valley floodplain.

Long Plain Cowal is a shallow flood-runner with limited channel capacity that transports flows from Oxley northward towards the North Marsh, between the Gum Cowal–Terrigal Creek and Marthaguy Creek system, and Bulgeraga Creek. Overland flooding from Gum Cowal occurs mainly around Oxley, and links with Long Plain Cowal during periods of high flooding (DHI 2008). Long Plain Cowal and Dusty Creek to the east are inundated only in medium to large floods (DECCW 2010). Overland flooding through the Long Plain Cowal area contributed to flooding along the lower reaches of Terrigal Creek and Marthaguy Creek in the August 1990 flood.

South Marsh: Old Oxley to Pillicawarrina

The South Marsh between ‘Old Oxley’ (downstream of Oxley Break) and ‘Pillicawarrina’ is a complex set of channels and wetlands that include Mole Marsh, Willancorah Swamp, Monkey Swamp, the Southern Macquarie Marshes Nature Reserve and Buckiinguy Swamp (DECCW 2010).

Monkeygar Creek is the main flow channel through the South Marsh, breaking away from the Macquarie River (named the Old Macquarie River downstream of the offtake), just downstream of ‘Old Buckiinguy’. Since the 1970s, the Monkeygar Creek channel has been eroded and incised, limiting overbank flooding (Ralph et al. 2016). Flow breaks out from the Monkeygar at high flow

levels into 2 effluents: The Breakaway, which leaves the Monkeygar to the west and enters the Old Macquarie River channel upstream of the Gibson Way crossing, and Little Monkeygar Creek. Downstream of the confluence of The Breakaway and the Old Macquarie River channel – which here is again known as the Macquarie River – the channel is ill-defined and subject to overbank flooding (DHI 2008).

Upstream of the Monkeygar Creek offtake, several effluent creeks exit the Macquarie River. These include Milmiland and Buckiinguy creeks on the left bank, and Monkey Creek and a series of high-level effluent creeks on the right bank. During floods, flows from the high-level effluents join with those of Monkey Creek further downstream (Rankine and Hill Pty Ltd 1979). Flows in Buckiinguy Creek provide water to Milmiland Creek and the significant wetlands in Buckiinguy Swamp and Buckiinguy Lagoon to the west of the creek, and then return to the Macquarie. During high flows, water leaves the Buckiinguy and floods the region between the Macquarie and the Warren-Carinda Road (Rankine and Hill Pty Ltd 1979). Flows are only conveyed to the Old Macquarie River from Buckiinguy Swamp at times of high flow (DHI 2008).

During floods, Monkey Creek flows inundate Monkey Swamp and pass into the Monkeygar Creek to the west and Bulgeraga Creek to the east. The Bulgeraga Creek floodplain passing through the South Marsh downstream of Oxley is a major flood flow path during large floods. The Macquarie River rejoins Monkeygar Creek downstream of the Monkeygar Creek confluence with Bulgeraga Creek. At this point, a single channel called the Macquarie River is formed, which flows past Pillicawarrina to the North Marsh (DHI 2008).

North Marsh and lower Macquarie River

The main watercourses and waterbodies in the North Marsh include the Bora Channel, the Ginghet Creek, the River Paddock, Pillicawarrina, the Zoo Paddock, Loudens Lagoon, Hunt's Woodland, the confluence of Monkeygar and Bulgeraga creeks, and the Macquarie Channel (DECCW 2010).The Macquarie River through the North Marsh is characterised by a shallow channel with relatively low flow capacity. This results in significant overland flooding, predominantly in the southern areas of the North Marsh (DHI 2008).

On entry to the Northern Macquarie Marshes Nature Reserve, flow splits between the Macquarie River and the Little Bora, then the Bora Channel near the entrance to the Northern Bypass Channel. The Bora Channel is relatively wide at its offtake. However, both the channel and the river quickly break down into a series of small braided channels and wetlands within the North Marsh, where only part of the flow is conveyed within the primary channel. The Bora Channel eventually rejoins the Macquarie. However, a significant portion of flow from the Bora passes into the Ginghet Creek and Blue Light Lagoon systems. Flood flows passing along Ginghet Creek inundate Ginghet Swamp and traverse the floodplain in a north-westerly direction, eventually draining to Marra Creek upstream of its confluence with the Barwon River.

The Northern Bypass Channel offtake from the Macquarie, located approximately 2 kilometres downstream of the Bora Channel offtake, generally travels north along the eastern side of the North Marsh. The Northern Bypass was constructed in 1972 to direct water around the Northern Marshes to provide supply downstream, mainly for stock and domestic uses (Barma Water Resources 2010). Despite the series of siphons beneath the channel, the Northern Bypass can act as a levee during large floods due to its raised bank levels which were constructed to limit overbank flows and the eastern extent of inundation, including that caused by floodwaters from Long Plain Cowal within the North Marsh (DHI 2008). The Northern Bypass rejoins the Macquarie River within the marsh area, before the Macquarie again meets the Bora Channel.

Downstream of its convergence with the Bora Channel and other flow lines north of Duck Swamp, the Macquarie River channel extends along the eastern edge of the North Marsh, with numerous marsh inflows draining into the river from the wetland area to the west of the channel. Wetland inundation in this area is broad and limited simply by the flow available to spread across the floodplain.

In marked contrast to the channel characteristics of the river upstream of the Marshes, the Macquarie River channel becomes larger and more defined as it passes through and downstream of the North Marsh. Downstream of 'Yanda' the floodplain narrows to only 1 to 2 kilometres and is confined by small topographic rises to a broad terrace (Torrible et al. 2010). The floodplain continues to narrow downstream towards the confluence of the Macquarie River with Marthaguy Creek. This junction marks the downstream extent of the Macquarie valley floodplain.

Key changes to the natural flooding regime

The natural flooding regime of the Macquarie River has been altered over the years by the construction of dams (particularly Burrendong Dam), weirs, flood works, town levees and major roads and railways, as well as from vegetation clearing for farming and irrigation works. These changes have altered the nature, frequency, extent and duration of flooding in the Macquarie valley floodplain.

Early changes to the flow regime took place in the late 1800s and early 1900s when a series of weirs and regulators were built to divert water from the Macquarie River to pastoral properties along the effluent creek system. The natural flooding regime was substantially modified following construction of Burrendong Dam in 1967. The dam has had a significant impact on floods in the lower Macquarie River due to the large proportion of the catchment area it controls (1,390,000 hectares), its large flood mitigation capacity, and controlled flood releases by operation of the spillway (SKM 2002; Torrible et al. 2010).

An analysis of natural daily flows for the Macquarie River at Dubbo showed that flood flows above 4,600 ML per day (or flows that occur or are exceeded for 15% of the time) are reduced significantly due to the mitigation impacts of Burrendong Dam. However, moderate to low flows (below 4,600 ML per day) are significantly increased due to river regulation and irrigation releases from the dam. The duration of flood events on the Macquarie valley floodplain can be extended due to controlled releases from the dam for flood mitigation purposes. This occurred during the 2010 flood.

Additional findings from studies that have analysed measured and modelled flows confirm the significant alteration of the Macquarie River flow regime due to river regulation and extraction, including:

- significant reduction in moderate to high flows in the Macquarie River and 'end-of-system' flows (particularly Marthaguy Creek) (CSIRO 2008)
- alteration of seasonality of streamflow, with high winter flows reduced by upstream dams capturing water and summer flows increasing due to the release of water for downstream users (CSIRO 2008)
- an increase in the average period between large flows in winter and spring at the Oxley gauge and a reduction in the average volume of these events (CSIRO 2008)
- a reduction in the number of small flows greater than 1,000 ML per day likely to cause flooding passing the Oxley gauge (Jenkins et al. 2006, in DECCW 2010)
- permanent low flows in previously intermittent streams (Grimes 2001)
- a significant reduction in the frequency of floods in the Macquarie Marshes and the area inundated, specifically less frequent spring inundation, which is a major component of the inundation regime of the Marshes and an important driver for vegetation distribution (Thomas et al. 2010; Thomas et al. 2011).

Evidence shows that the natural flow regime of the effluent creek system has undergone substantial change with alterations to commence-to-flow levels, channel capacities, and the distribution, seasonality, variability and frequency of high and low flows as a result of floodplain development (WMA Water 2008).

The advent of river regulation with the construction of Burrendong Dam led to a major change in land use on the Macquarie valley floodplain from low-intensity grazing to high-intensity irrigation.

Channels and levee banks were built on large areas of the floodplain, mainly between Narromine and Oxley Station, to deliver water and protect high-value crops from flood damage. These large-scale earthworks reduced the flood storage volume that was available under natural conditions, causing floods to rise above historical levels (SKM 2008). Flood works have redistributed flows and increased flow velocities on the Macquarie valley floodplain during historic flood events, in some cases resulting in bank failure and substantial flood damage.

Changes to vegetation cover including dense regrowth can affect the hydraulic roughness of floodplains and increase the hydraulic resistance of flood flows, leading to localised increases in flood levels and increased flow duration. Conversely, vegetation clearing can cause channel erosion and scour, and can decrease flow duration with a decreased level of hydraulic resistance.

While erosion and sedimentation are natural occurrences on floodplains, key anthropogenic changes include increased sediment loads from catchment disturbance and additional erosion and scouring due to river regulation and the impacts of flood works. In its assessment of the geomorphic condition of the Macquarie catchment, the Murray–Darling Basin Authority (MDBA) found that in the lowland zone, which includes the Macquarie valley floodplain, floodplain sediment deposition had generally increased, and channel morphology had been modified across about half of the area since European settlement. These changes can influence flooding regimes, and both sediment accumulation and channel erosion have had a major impact on natural flooding regimes in the Marshes. This has adverse implications for flood-dependent vegetation that is not having its inundation requirements met due to changes in the overland flooding regime.

Developing the plan

The Macquarie Valley FMP 2021 was developed by Department of Planning, Industry and Environment's (the department) Water Group with technical support from the department's Energy, Environment and Science Group. The department employed a 10-step process as outlined in the Technical Manual and in the following sections (see **Error! Reference source not found.**). The p rocess involved collecting best available data and analysis of current floodplain management arrangements to inform hydraulic, ecological, cultural and socio-economic assessments. During data collection and technical assessments, the Macquarie Technical Advisory Group (TAG) and Aboriginal Technical Working Group (ATWG) were engaged in consensus-based decision-making. The outputs from the assessments ensure that the steps used to determine the floodplain boundary, management zones and rules are supported by good science.

Consultation on the Macquarie Valley FMP 2021 occurred in 2 stages: targeted consultation and public exhibition. The consultation stages align with the department's internal policy, originally developed for the making and review of water sharing plans (WSPs) under the WM Act. During targeted consultation and public exhibition, we invite community feedback on the boundaries, management zones, rules and assessment criteria in the FMP.

Targeted community consultation with stakeholders, including members of the Aboriginal community, occurred at Warren, the Macquarie Marshes and Dubbo in May 2017. Public exhibition of the Macquarie Valley FMP 2021 occurred over 60 days from 16 July 2018 to 13 September 2018. Outcomes from targeted consultation and public exhibition are provided in this document in 'Consultation and review of the plan'.

An Interagency Regional Panel (IRP) was responsible for the formal review and whole-of-government endorsement of the Macquarie Valley FMP 2021. Facilitated by the department, the IRP reviewed the draft plan before targeted consultation and public exhibition. The IRP also reviewed all submissions received during public exhibition and was responsible for the endorsement of the final boundary, management zones, rules and assessment criteria before commencement. More details on the IRP review process are outlined in 'Consultation and review of the plan'.

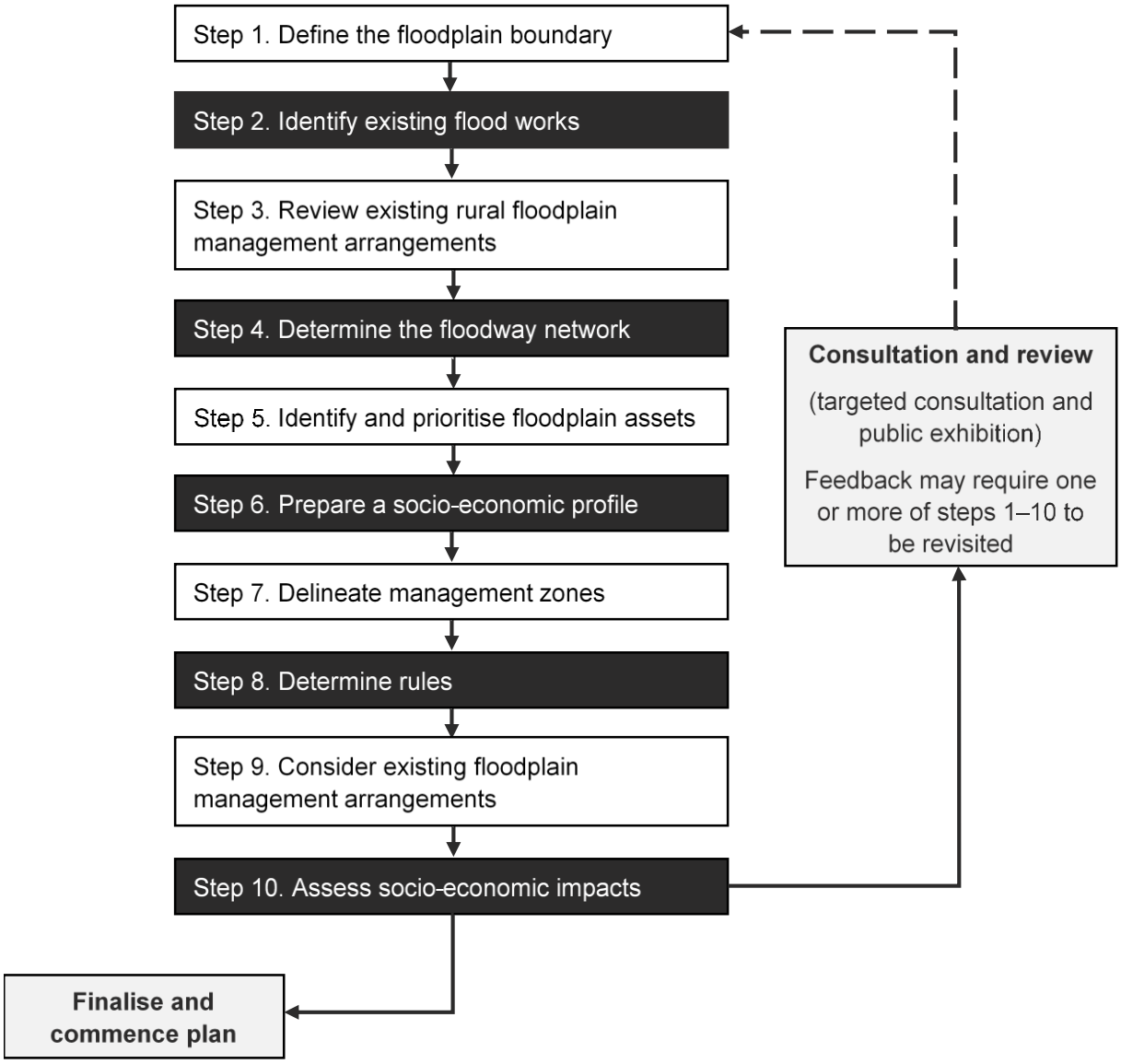

Figure 7: Ten steps used to develop rural floodplain management plans under the WM Act

Appendix 1 contains a detailed table of the ten steps, including the input/process and output/outcome related to each step.

Step 1: Define the floodplain boundary

The Macquarie Valley FMP 2021 applies to the area defined as the Macquarie valley floodplain, which covers 1.24 million hectares. This floodplain was defined to capture the floodplain areas inundated during flooding of major rivers, and to include any flood works that may affect flooding. When compared to the existing Water Act Part 8 designated floodplains, the overall extent of boundary change is significant, with the addition of approximately 474,000 hectares (Figure 4).

The Macquarie valley floodplain boundary was delineated based on the consideration of the following:

- **Designated floodplains**
    - Existing and potential floodplain developments in the Macquarie valley floodplain were identified from the following existing floodplain areas designated under Part 8 of the *Water Act 1912*:
        - *Lower Macquarie floodplain*, designated in 1985
        - *Macquarie River floodplain*, designated in 2008 as part of the Macquarie River FMP 2008
- **The hydrology of the Macquarie River**
    - Floodplain areas influenced primarily by the hydrology of the Macquarie River were included within the Macquarie Valley FMP 2021 floodplain boundary and were determined by examining the following information:
        - flood imagery of the 1990 and 2010 floods
        - the *Macquarie Valley Floodplain Atlas* (Sinclair Knight and Partners Pty Ltd 1984b)
        - OEH inundation mapping (Fisher et al. 2016; Thomas et al. 2015; Thomas et al. 2010)
        - 2008, 2014 and 2015 light detection and ranging (LiDAR) Digital Elevation Models (DEMs)
        - hydrodynamic modelling of the Macquarie River and Marthaguy Creek flows.
    - The floodplain was extended from the Macquarie River floodplain for the Macquarie River FMP 2008 to include the Macquarie Marshes and the effluent creek system. Part of the floodplain of Marthaguy Creek, a tributary of the Macquarie River, was also included because of significant flooding during the December 2010 flood and the contribution of substantial inflows to the Macquarie River. Areas considered not to be predominantly influenced by the hydrology of the Macquarie River, including the lower Bogan and Castlereagh floodplain, were not included in the Macquarie valley floodplain.
    - Areas of high ground considered to be above the level of flood-liable land were determined from LiDAR-derived DEMs and contour mapping. These areas were also checked against available flood imagery and flood-dependent vegetation mapping. High ground areas including Mt Foster, Mt Harris and other hills were extracted from the floodplain.
- **Hydraulic effects of development**
    - The floodplain area was extended to include flood works outside existing designated floodplain areas, to meet the objectives of the Macquarie Valley FMP 2021 and to assist with the coordination of all flood works across the extent of major flooding.
- **Cadastral features**

  - Where appropriate, the floodplain was aligned with significant cadastral features (for example, property, parish, county and local government area – LGA) to simplify administration and provide clarity to water users.

- **Planning legacy (unregulated water sharing plans – WSPs)**
  - The Macquarie valley floodplain is entirely within the water management area of the *Water Sharing Plan for the Macquarie Bogan Unregulated and Alluvial Water Source* (2012a). However, alignment of the floodplain boundary with the water management areas of the WSP was not considered important by the Macquarie TAG, as these areas are not delineated according to flooding characteristics.
- **Floodplain harvesting**
  - The floodplain boundary included areas identified in the Floodplain Harvesting Project's expression of interest process for floodplain harvesting licences and potential floodplain harvesting structures. This will ensure consistency with the NSW Floodplain Harvesting Policy (NSW DPI 2013), which only applies to floodplain harvesting activities on properties where all or part of a property lies within the designated floodplain.
- **Other valley FMP floodplain boundaries**
  - The Macquarie valley floodplain was aligned with the boundary for the Barwon–Darling Valley FMP 2017 (NOW 2017) to provide consistency with other boundaries for water management plans under the WM Act.
- **Public infrastructure features**
  - Where appropriate, the boundary aligns with public infrastructure such as railways and state and council roads to simplify administration.
- **Floodplain management arrangements**
  - Where appropriate, the boundary aligns with existing floodplain management arrangements in urban areas, such as a flood study (FS), floodplain risk management study (FRMS) and floodplain risk management plans (FRMP). Amendments to the boundary were made based on information from councils regarding the extent of flood risk management planning arrangements in urban areas.

The overall extent of boundary change when compared to the existing designated floodplains was the addition of approximately 559,000 hectares in some areas and the subtraction of approximately 85,000 hectares in other areas (Figure 4). Table 1, Figure 8 and Figure 9 highlight changes to the existing floodplains to delineate the Macquarie valley floodplain.

Table 1: Method for development of the Macquarie Valley Floodplain boundary

No	Map points	Description of change	Alignment	Rationale/Evidence
1	A–B	Northern boundary contracted to adjoin the Barwon–Darling Valley FMP 2017 boundary	Cadastral features; aligns with other FMP boundary	NSW Cadastre; Barwon–Darling Valley FMP 2017
2	B–C	Expanded to align with Bogewong Rd; includes 1990 flood extent	Public infrastructure; hydrology of Macquarie River	2014 LiDAR-derived DEM; August 1990 Landsat imagery
3	C–D	Aligns with 1990 and 2010 flood extent	Hydrology of Macquarie River	August 1990 Landsat imagery; December 2010 flood
4	D–E	Expanded to align with Macquarie flood atlas extent	Hydrology of Macquarie River	Macquarie Valley Floodplain Atlas 1984
5	E–F	Expanded to align with 2010 flood extent	Hydrology of Macquarie River	December 2010 Landsat imagery
6	F–G	Expanded to align with Quambone flood study area	Floodplain management arrangements	Quambone flood study 2014 (Jacobs Group 2014)
7	G–H	Expanded to align with 2010 flood extent Marthaguy Creek	Hydrology of Macquarie River	December 2010 Landsat imagery
8	H–I	Expanded to align with 2010 flood extent; floodplain wetlands	Hydrology of Macquarie River	December 2010 Landsat imagery
9	I–J	Expanded to align with 2010 flood extent; modelled on Marthaguy Creek flood extent	Hydrology of Macquarie River	December 2010 Landsat imagery; MIKE Flood modelling outputs
10	J–K	Expanded to align with flood works; modelled on 1990 flood extent	Hydrology of Macquarie River	2014 LiDAR-derived DEM; MIKE Flood modelling outputs
11	K–L	Expanded to align with modelled flood extent Marthaguy Creek	Hydrology of Macquarie River	MIKE Flood modelling outputs
12	L–M	Expanded to align with modelled flood extent Marthaguy Creek	Hydrology of Macquarie River	MIKE Flood modelling outputs
13	M–N	Expanded to align with existing flood works	Hydraulic effects of development	2014 LiDAR-derived DEM
14	N–O	Expanded to align with existing flood works; floodplain harvesting registration of interest	Hydraulic effects of development; floodplain harvesting	Licensing data Tenandra channel
15	O–P	Expanded to align with 1990 modelled extent; existing flood works	Hydrology of Macquarie River; hydraulic effects of development	MIKE Flood modelling outputs; 2014 LiDAR-derived DEM
16	P–Q	Expanded to align with 1990 modelled extent; existing flood works	Hydrology of Macquarie River; hydraulic effects of development	MIKE Flood modelling outputs; 2014 LiDAR-derived DEM
17	Q–R	Aligns with Macquarie River FMP 2008 floodplain (no change)	Designated floodplain	Macquarie River FMP 2008

No	Map points	Description of change	Alignment	Rationale/Evidence
18	R–S	Aligns with Merrinong Rd; Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR-derived DEM (improved accuracy in determining road alignment)
19	S–T	Expanded to align with modelled 1990 flood extent	Hydrology of Macquarie River	MIKE Flood modelling outputs
20	T–U	Aligns with Pineview Rd, Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR (improved accuracy in determining road alignment)
21	U–V	Contracted to extract high ground	Hydrology of Macquarie River	2014 LiDAR-derived DEM
22	V–W	Aligns with Pineview Rd, Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR-derived DEM (improved accuracy in determining road alignment)
23	W–X	Contracted to extract high ground	Hydrology of Macquarie River	2014 LiDAR-derived DEM
24	X–Y	Aligns with Burroway Rd, Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR-derived DEM (improved accuracy in determining road alignment)
25	Y–Z	Contracted to extract high ground	Hydrology of Macquarie River	2014 LiDAR-derived DEM
26	Z–AA	Aligns with Burroway Rd, Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR-derived DEM (improved accuracy in determining road alignment)
27	AA–AB	Contracted to extract high ground	Hydrology of Macquarie River	2014 LiDAR-derived DEM
28	AB–AC	Expanded to align with 2010 flood extent	Hydrology of Macquarie River	ADS40 photography, December 2010 flood
29	AC–AD	Aligns with Burroway Rd, Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR (improved accuracy in determining road alignment)
30	AD–AE	Expanded to align with 2010 flood extent	Hydrology of Macquarie River	ADS40 photography, December 2010 flood; MIKE Flood modelling outputs
31	AE–AF	Expanded to align with Narromine flood study with high ground extracted	Hydrology of Macquarie River; floodplain management arrangements	2014 LiDAR-derived DEM; Narromine Levee Feasibility Report 2012 (Lyall and Associates 2012)
32	AF–AG	Expanded to align with Narromine flood study area	Floodplain management arrangements	Narromine Levee Feasibility Report 2012 (Lyall and Associates 2012)
33	AG–AH	Aligns with Mitchell Hwy, Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR (improved accuracy in determining road alignment)
34	AH–AI	Aligns with Mitchell Hwy, Macquarie River FMP 2008 floodplain (no change)	Public infrastructure; designated floodplain	2014 LiDAR (improved accuracy in determining road alignment)

No	Map points	Description of change	Alignment	Rationale/Evidence
35	AI–AJ	Expanded to align with Mitchell Hwy	Public infrastructure; hydrology of Macquarie River	2014 LiDAR; August 1990 Landsat imagery
36	AJ–AK	Expanded to align with delineation of Macquarie–Bogan influence	Hydrology of Macquarie River	2014 LiDAR-derived DEM; August 1990 Landsat imagery
37	AK–AL	Expanded to align with Monkey Bridge Road	Public infrastructure	2014 LiDAR-derived DEM
38	AL–A	Expanded to align with delineation Macquarie–Bogan influence	Hydrology of Macquarie River	2014 LiDAR-derived DEM; August 1990 Landsat imagery
39	HA1	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
40	HA2	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
41	HA3	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
42	HA4	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
43	HA5	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	About 5 m above 2010 flood level
44	HA6	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	About 5 m above 2010 flood level
45	HA7	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	About 5 m above 2010 flood level
46	HA8	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
47	HA9	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
48	HA10	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
49	HA11	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
50	HA12	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-

No	Map points	Description of change	Alignment	Rationale/Evidence
51	HA13	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	Little Mount
52	HA14	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	Mt Harris
53	HA15	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	Mt Foster
54	HA16	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	-
55	HA17	Contracted to extract high ground extracted (from analysis of 2014 and 2015 LiDAR-derived DEM)	Hydrology of Macquarie River	About 2.5 m above 1990 flood level

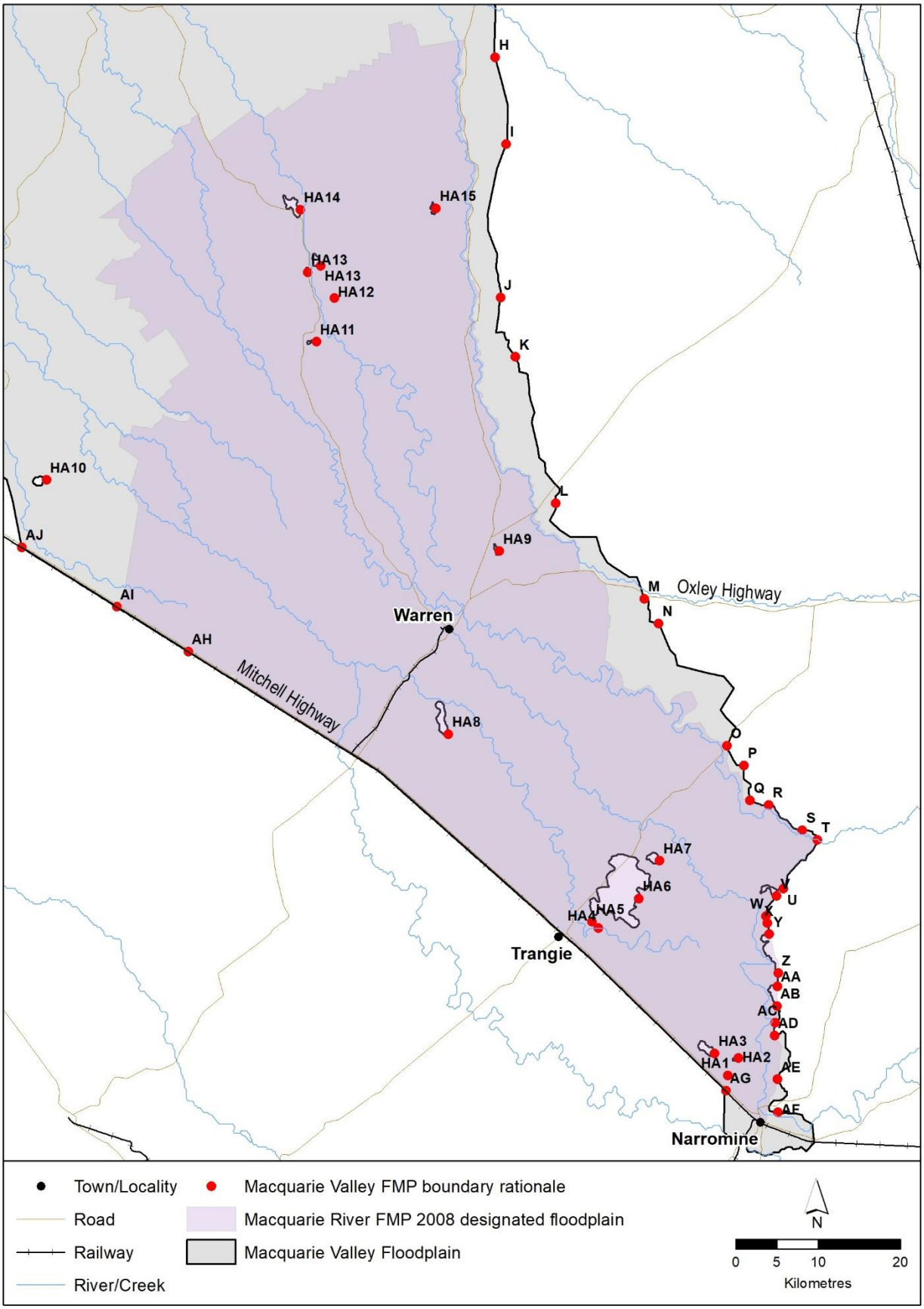

Figure 8: Macquarie Valley Floodplain boundary (1 of 2)

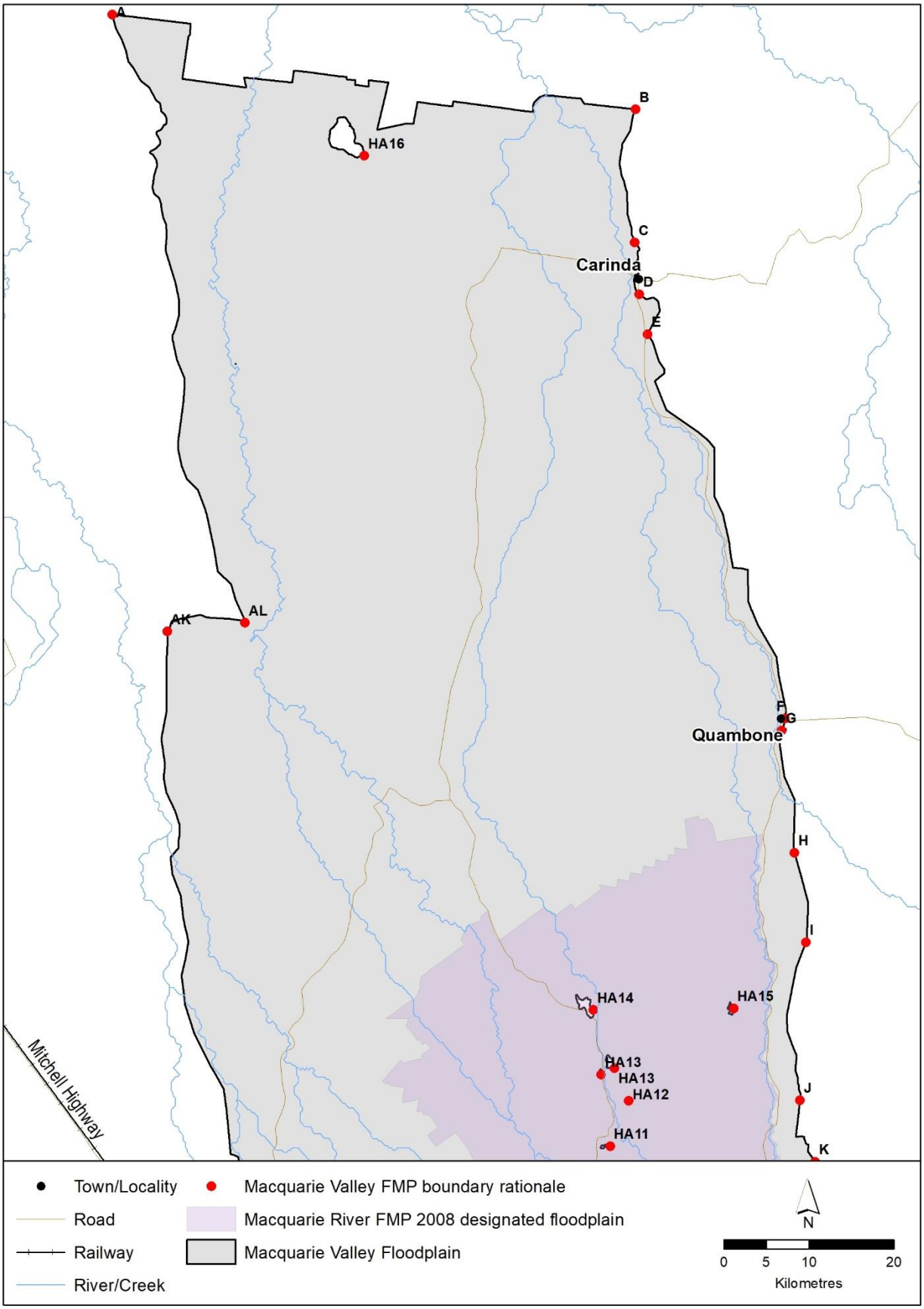

Figure 9: Macquarie Valley Floodplain boundary (2 of 2)

Step 2: Identify existing flood works

As of May 2020, approximately 32,600 hectares (3% of the floodplain) is enclosed by approved flood works in the Macquarie valley floodplain (Figure 10).

Individual works (linear features) and works not visible at a scale of 1:20,000 have not been mapped in the footprint area shown in Figure 10.

Mapped footprint areas may include:

- below-ground and above-ground supply channels
- infrastructure protection works
- levees
- private access roads
- storages
- stock refuge works
- other earthworks and embankments such as earthen banks for waterponding to remediate scalded claypans and halt soil erosion

Limited height works were also included in the existing work footprint areas. Instream works are not identified as flood works but are generally identified as controlled activities under the WM Act. Supply channels and storages may be identified as water supply works and flood works.

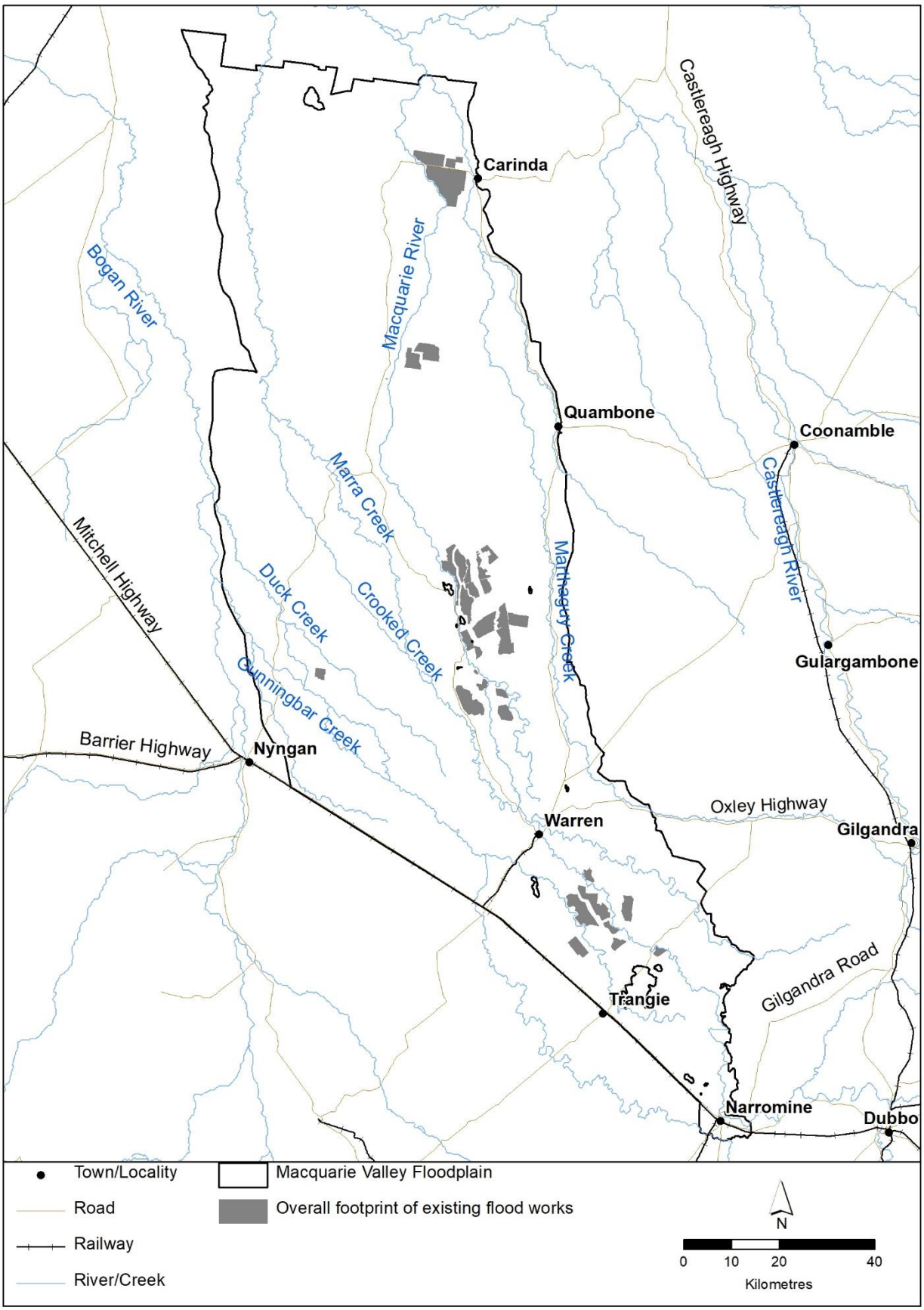

Figure 10: Overall footprint of constructed flood works

Step 3: Review existing rural floodplain management arrangements

Existing rural floodplain management arrangements in the Macquarie valley floodplain include:

- two first-generation rural floodplain development guidelines that are non-statutory
- one second-generation statutory rural FMP
- one rural floodplain risk management study (Figure 4).

When the Macquarie Valley FMP 2021 is enacted, it will supersede all current plans and guidelines in the Macquarie valley floodplain.

As mentioned previously, while the Lower Macquarie floodplain was designated in 1985 under Part 8 of the Water Act (Figure 4), an FMP was not made for the designated Lower Macquarie floodplain.

Existing rural floodplain management arrangements in the Macquarie valley floodplain include:

- **First-generation rural floodplain development guidelines (non-statutory)**
  - *Guidelines for Flood Plain Development Macquarie River Narromine to Warren* (1978) NSW WRC
  - *Guidelines for Flood Plain Development Macquarie River Warren to Oxley Station* (1982) NSW WRC
- **Second-generation statutory rural floodplain management plans**
  - *Macquarie River FMP 2008* NSW DWE and DECC (adopted under Water Act August 2008)
- **Outcomes from flood studies**
  - *Macquarie River (Narromine to Oxley Station) Floodplain Management Study – Floodplain Risk Management Study* (SKM 2008).

A detailed history of floodplain management in the Macquarie valley floodplain is outlined in Appendix 2.

Existing rural floodplain management arrangements in the Macquarie valley floodplain were reviewed to determine their respective:

- floodplain management principles
- ecological and cultural heritage considerations
- floodway networks
- hydraulic models
- design flood events
- types of works considered for approval
- advertising requirements for applications
- assessment process for flood work applications, including any assessment criteria used.

Step 4: Determine the floodway network

Step 4 involved selecting floods of different magnitudes (design floods) and constructing hydrologic and hydraulic models to simulate their movement of those floods through the river channels and floodplain. Data from this modelling as well as additional data, such as flood imagery, was used to map the floodway network.

The Macquarie floodway network (Figure 11 and Figure 12) comprises 3 hydraulic categories:

- floodways (190,900 hectares or 15% of the floodplain), which are areas where a significant discharge of floodwater occurs during the 2000 large design flood upstream of Warren and the Oxley Highway, and the 1990 large design flood downstream of Warren and the Oxley Highway
- high-level floodways (17,300 hectares or 1% of the floodplain), which are areas upstream of Warren and the Oxley Highway that are important for conveying and temporary storage of floodwaters, and where a significant discharge of floodwater occurs during the 1990 large design flood and larger events
- inundation extent (392,100 hectares or 32% of the floodplain), including areas of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.

Approximately 648,100 hectares, or about 52% of the Macquarie valley floodplain, is outside the inundation extent of the small and large design floods and/or an urban area where there is a FS, FRMS, FRMP, or the area is protected by a flood mitigation work, such as a town levee. These floodplain areas are not part of the floodway network.

The floodway network is the hydraulic basis for the management zones, rules and assessment criteria of the Macquarie Valley FMP 2021. Further information on design floods and hydraulic criteria is provided below.

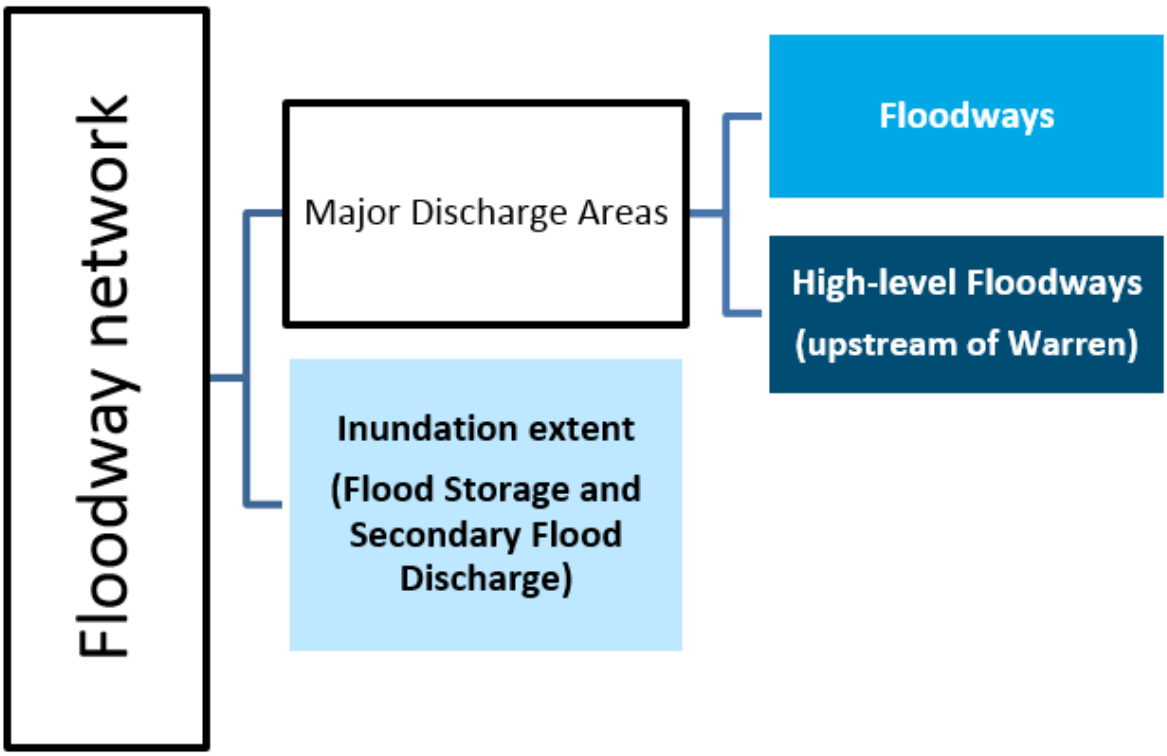

Figure 11: Finger diagram of hydraulic categories comprising the floodway network

Design floods

A design flood is a flood of known magnitude or annual exceedance probability (AEP) that can be modelled. Design floods form the basis of the floodway network and this information is used as the hydraulic basis when developing the management zones. Selection of a design flood is based on an understanding of flood behaviour and associated flood risk. Multiple design floods may be selected to account for the social, economic and ecological consequences associated with floods of different magnitudes.

Three design floods were selected for the Macquarie Valley FMP 2021:

- 1990 large design flood – August 1990 (3% AEP at the Macquarie River at Narromine gauging station (GS 421006))
- 2000 large design flood – November 2000 (8% AEP at the Macquarie River at Narromine gauging station (GS 421006))
- small design flood – March 2012 (33% AEP at the Macquarie River at Narromine gauging station (GS 421006))

Modelling of the 1990 large design flood used the peak flood discharge inflow for the 1990 flood in the Macquarie River and the peak flood discharge inflows for the December 2010 flood in the Ewenmar, Marthaguy and Merri Merri Creeks (the eastern tributaries). This combination was used because the 2010 flood has a similar probability of occurrence in the eastern tributaries as the 1990 flood has for the Macquarie River, thereby maintaining a similar probability of occurrence across the floodplain for the 1990 large design flood. Using design rainfalls (Pilgrim, D. H & Institution of Engineers, Australia 1987), the December 2010 flood has been estimated to be between a 2% and 5% AEP flood for the eastern tributaries. Note that even though the 1990 large design flood is made up of peak flood discharge inflows from the 1990 and 2010 floods, it is referred to throughout this document as the 1990 large design flood.

A flood frequency analysis was undertaken to assist with the selection of the design floods (

Table 2 for large floods and Table 3 for small floods). The flood frequency analysis was used to determine the relationship between peak flood discharge at a location of interest and the likelihood that a flood event of that size or greater would occur (see Appendix 3 for more details on design floods and how the flood frequency analysis results were obtained). Note that the records for the retired Narromine gauge (No 421006) were combined with flows at the Baroona gauge (No 421127), located 12 kilometres upstream, and are referred to as ‘Narromine’.

Table 2: Annual exceedance probability (AEP) for large historic flood events at selected locations in the Macquarie Valley Floodplain

Location (gauging station number)	1955 Flood event AEP	1990 Flood event AEP	1998 Flood event AEP	2000 Flood event AEP	2010 Flood event AEP	2016 Flood event AEP
Macquarie River at Narromine (GS 421006)	0.7%*	2.9%	10%	8%	2.5%	13%
Macquarie River at Baroona (GS 421127)	0.7%*	2.9%	10%	8%	2.5%	13%
Macquarie River at Gin Gin (GS 421031)	n/a	4.5%	7.7%	6.3%	3.3%	10%
Gunningbar Creek at d/s Weir (GS 421017)	n/a	7.1%	9.1%	8.3%	7.7%	11%
Marra Creek at Carinda Road (GS 421097)	n/a	9.1%	17%	33%	4%	13%
Marthaguy Creek at Carinda (GS 421011)	n/a	4.4%	10%	14%	2.3%	14%
Macquarie River at Carinda (GS 421012)	n/a	2.6%	4.2%	14%	2.5%	5%

* based on pre-Burrendong Dam dataset

Table 3: Annual exceedance probability (AEP) for small historic flood events at selected locations in the Macquarie Valley Floodplain

Location (gauging station number)	1992 Flood event AEP	1996 Flood event AEP	2012 Flood event AEP
Macquarie River at Narromine (GS 421006)	25%	25%	33%
Macquarie River at Baroona (GS 421127)	25%	25%	33%
Macquarie River at Gin Gin (GS 421031)	25%	33%	33%
Gunningbar Creek at d/s Weir (GS 421017)	50%	1% EY#	13%
Marra Creek at Carinda Road (GS 421097)	33%	50%	20%
Marthaguy Creek at Carinda (GS 421011)	50%	50%	33%
Macquarie River at Carinda (GS 421012)	50%	50%	33%

Exceedance per year

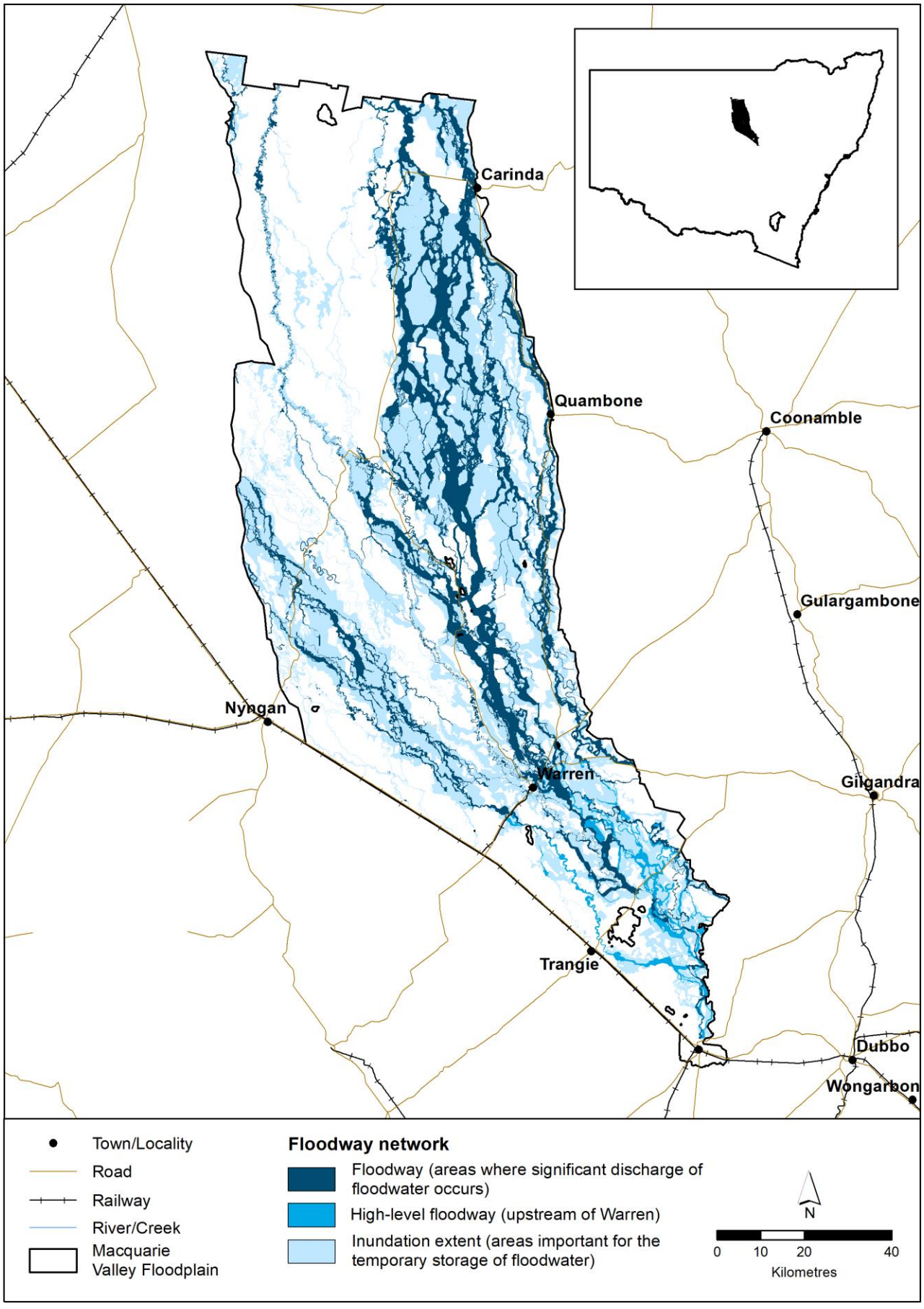

Figure 12: The Macquarie floodway network

The large design floods were used to delineate floodways with significant discharge. The 1990 large design flood was used to determine the extent of floodways downstream of Warren, and the extent of high-level floodways upstream of Warren. The 1990 large design flood was selected for these areas because:

- it is a recent large flood and therefore likely to be in the collective memory of floodplain users
- it was a large flood for most areas of the Macquarie valley floodplain
- there is a significant amount of information about the event
- it matches the 'blue zone' adopted in the Macquarie Marshes Water Management Plan 1996 (National Parks and Wildlife Service & Department of Land and Water Conservation 1996)
- it aligns with the design flood for the Macquarie River FMP 2008 for areas upstream of Warren.

The peak discharge of the December 2010 flood was used to estimate inflows from the Ewenmar, Marthaguy and Merri Merri creeks to the Macquarie valley floodplain as the 1990 flood was relatively small in these catchments.

The 2000 large design flood was used to determine the extent of floodways upstream of Warren. It was selected for this area because:

- it is a recent large flood and therefore likely to be in the collective memory of floodplain users
- there is a significant amount of information about the event
- modelling showed that because of the extent of development between Narromine and Warren, floodways could not be designed to convey the 1990 flood in this area without significant socio-economic impact. Therefore, the smaller 2000 flood was adopted as the design standard for floodways in this region.

The 2012 small design flood was selected to ensure that critical flow paths to ecological and cultural assets that are dependent on flooding are considered in the configuration of the management zones and during the technical assessment of a flood work application.

The 2012 flood was selected as the small design flood because:

- its magnitude was within the range recommended by the MDBA as important for supporting ecosystem functions within the floodplain environment (MDBA 2012)
- it is likely to be a larger event than an environmental flow release and thus would encapsulate the smaller-magnitude flows recommended by the Australian Government and OEH for supporting ecosystem functions within the Macquarie valley floodplain
- it is a recent flood event
- there is a significant amount of data available for the event
- a flood of this magnitude inundates a sizeable portion of the flood-dependent vegetation in the Macquarie Marshes (Thomas et al. 2012)
- it is a good example of the smallest dam spill from Burrendong Dam
- it will contribute to the protection of the passage of water actively managed by environmental water deliveries to ecological assets in the Macquarie region that require environmental watering.

Although not a design flood per se, the 1955 flood (0.7% AEP at the Macquarie River at Narromine gauging station (GS 421006) pre-Burrendong Dam) was also modelled to provide additional hydraulic information. This modelling was used to indicate flooding behaviour for floods larger than the 1990 large design flood, including the extent of flood-liable land. Similarly, for the tributary systems (Marthaguy, Ewenmar and Merri Merri creeks), the 1% AEP flood was used to provide additional hydraulic information for areas beyond the extent of the 2010 design flood. The 1% AEP

design flood was based on rainfalls calculated in Pilgrim, D. H & Institution of Engineers, Australia 1987 rather than a historical flood.

Hydrologic models

Hydrologic models simulate rainfall runoff on a catchment by converting storm rainfall to flow hydrographs. This is done using a procedure known as runoff routing, which subtracts losses, such as from soil infiltration, from the total rainfall. The rainfall excess is then routed through the catchment storage to produce flow hydrographs at specified locations (Laurenson et al. 2010).

The majority of floodwater within the Macquarie valley floodplain is generated from the Macquarie River upstream of Narromine and at a number of locations along the length of the river. However, there are several ungauged tributaries that can contribute significant volumes of water to floods within the Macquarie. These tributaries flow into the Macquarie valley floodplain from its eastern boundary, generally flow in a north-westerly direction and have several links and interactions with flow from the Macquarie River. Notable ungauged tributaries are the Marthaguy, Merri Merri and Ewenmar creeks. Flow from these tributary systems can interact with floodplain flows from the Macquarie and is therefore important to consider in the design of the Macquarie Valley FMP 2021 floodway network.

For the Macquarie Valley FMP 2021, a RORB (RORBWin Version 6.15, 2010) hydrologic model was used to simulate the rate of runoff from the ungauged tributary catchments and estimate peak flood discharges and hydrographs. The model is set up using a series of parameters that describe the catchment area topography and soils. To ensure that the correct values are used for each parameter, the hydrological models are usually calibrated against gauged flows. Because the Macquarie tributaries are ungauged, an alternate approach was taken. Hydrological modelling was undertaken for the nearby gauged Coolbaggie Creek to estimate the 4 parameters of RORB to be used in the ungauged catchments (seeTable 4 for a description of RORB parameters) and these parameters were then applied to the ungauged systems.

The Coolbaggie Creek gauged model was calibrated based on 3 floods over the period of record, in:

- July 1998
- November 2010
- March 2012.

These floods were selected because they represent both large floods as well as a range of hydrograph types, with compound peaks occurring in the 2010 and 1998 floods.

When calibrating the Coolbaggie Creek RORB model, the values for k_c were based on the default equation in the RORB manual and catchment area (Laurenson et al. 2010) and m was maintained at the recommended value of 0.8 (See Table 4).

The calibration aimed to achieve a consistent k_c, but continuing loss and initial loss was varied for individual storms based on antecedent catchment conditions.

The average values for m, initial loss and continuing loss from the calibrated Coolbaggie Creek RORB were used to simulate the flows for the 1998, 2010 and 2012 floods in the ungauged catchments. The parameter k_c was adjusted for the area of each model's sub-catchment. The average parameter values from the Coolbaggie Creek model are summarised in Table 4.

The simulated flows from the 3 RORB models for the ungauged catchments were used as inputs to the hydraulic models (see Appendix 4 for more detail).

Table 4: Coolbaggie Creek RORB calibrated parameter values

Parameter	Description	1998 Flood event	2010 Flood event	2012 Flood event	Adopted for ungauged
k_c	Dimensional coefficient related to the time delay of flood routing	26.5	26.5	26.5	26.5
m	Dimensionless exponent defines the non-linearity of the catchment	0.8	0.8	0.8	0.8
Initial loss (mm)	Used to determine the rainfall excess of the storm	0	20	48	30
Continuing loss (mm/hr)	Used to determine the rainfall excess of the storm	1.2	1.2	1.2	1.2

The hydraulic models were run for the 2010 flood as an additional calibration procedure and the extent of flooding in the tributary systems was compared to available satellite imagery. It was found that the models tended to over-predict the extent of flooding in 2010 and the inflows were scaled down to match the flood patterns of the 2010 flood. These scaling factors were then used for all tributary inflows. The likely reason for this over-estimation is that Coolbaggie Creek (the basis for the calibration) has a higher average slope than the ungauged tributaries and is likely to generate a higher runoff for a given rainfall.

Hydraulic models

The Macquarie valley floodplain was divided into 4 reaches for hydraulic modelling purposes (Figure 13). The MIKE FLOOD software modelling package was used for each of the 4 reaches. This included a one-dimensional channel model (MIKE 11) that can represent channel cross-sections and processes in great detail, and a two-dimensional model (MIKE 21) that uses a 40-metre resolution grid to represent overland flow.

The hydraulic models used to develop the Macquarie Valley FMP 2021 floodway network are outlined in Table 5. For information on hydraulic model networks, boundaries, structures, hydraulic parameters and model calibration, see Appendix 4.

Table 5: Hydraulic models in each floodplain reach

Floodplain model	Area	Model description
Reach 1 – Upstream	603,500 ha	A MIKE FLOOD model was built from Narromine to Canonba Road in the north-west and Oxley Station to the north. The major tributary inflows within this reach include Marthaguy and Ewenmar creeks and Boggy Cowal.
Reach 2 – Downstream Macquarie	451,500 ha	A MIKE FLOOD model was built from just south of Marebone to the junction of Marthaguy Creek and the Macquarie River. The major tributary inflows include Merri Merri, Crooked and Marthaguy creeks and Five Mile Cowal.
Reach 3 – Downstream effluents (1D)	311,700 ha	A MIKE 11 model was built from just west of where Bena Billa Creek joins Duck Creek to Yarrawin. The major inflows include the Marra and Crooked creeks.
Reach 4 – Downstream effluents (2D)	72,700 ha	A MIKE FLOOD model was built from north of Carlton to Old Warren Road. The major inflows for this reach include the Duck and Gunningbar creeks and Rigleys Cowal.

Hydraulic model outputs used to develop the Macquarie Valley FMP 2021 floodway network were:

- a depth-velocity product map from the 1990 large design flood (Figure 14) and the 2000 large design flood (Figure 15)
- inundation extents of the small design flood (Figure 15) and the 1990 and 2000 large design floods (Figure 17).

These outputs were used to determine whether an area of flooding was a floodway and determine the appropriate width of identified floodways.

The overall footprint of constructed works was identified in Step 2. For the purposes of hydraulic modelling, the floodplain areas enclosed by existing flood works that are not limited-height works (downstream of Warren) were assumed to not be overtopped by floodwater and were represented accordingly in the existing works model's computational grid. Areas protected by works with limited-height conditions, such as upstream of Warren (as indicated by licence files), were assumed to be overtopped by floodwater. These were represented in the models at their existing height and allowed for overtopping.

Model calibration

Hydraulic models were calibrated using selected historic flood events that are around the design flood magnitude and that activate all likely flow paths. The models were calibrated against a range of data sources, which are listed in the Technical Manual.

See Appendix 4 for more information on:

- model software
- extents
- mesh
- boundary conditions
- initial conditions
- roughness maps
- setup parameters
- calibration.

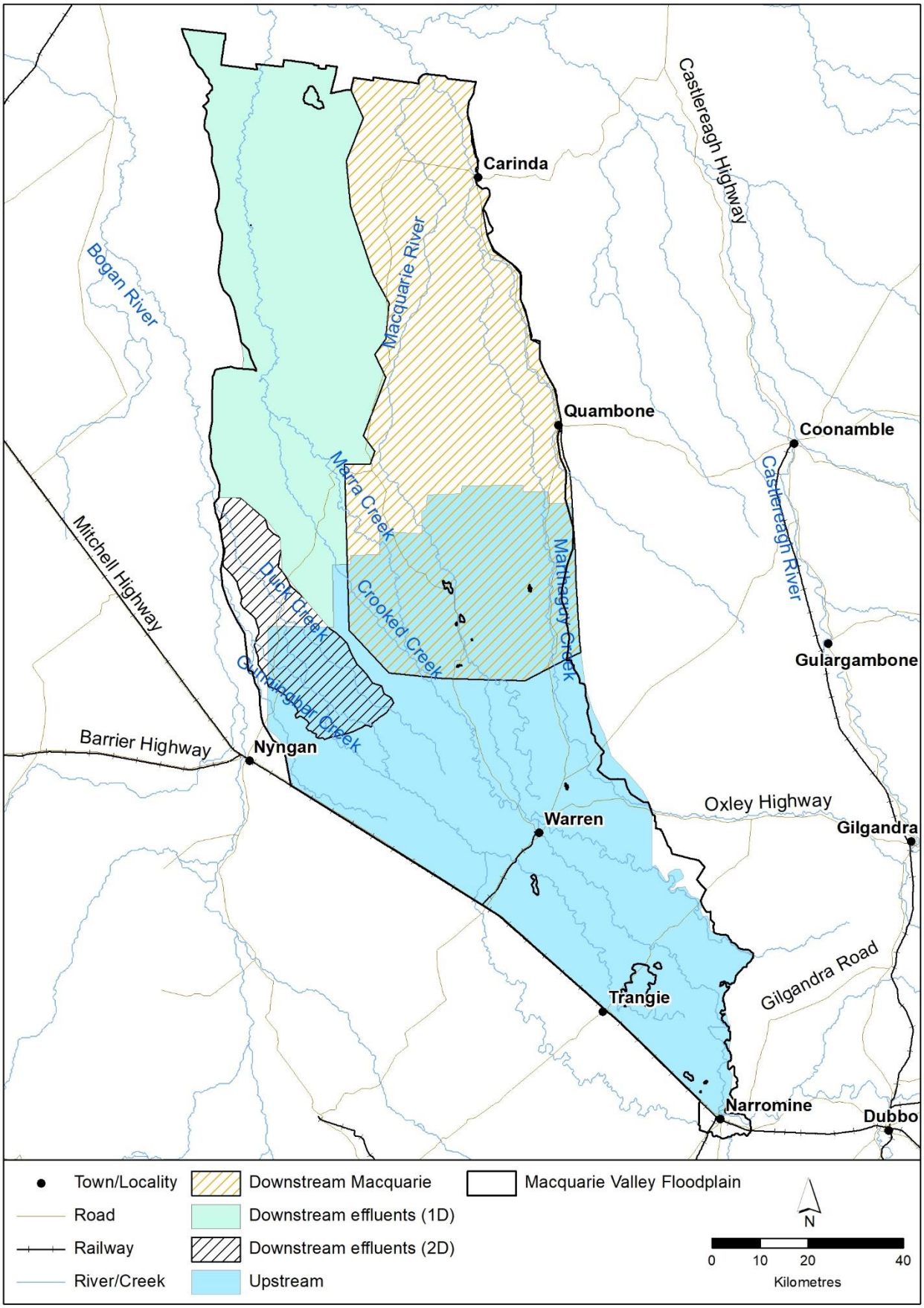

Figure 13: The 4 reaches of the Macquarie valley floodplain

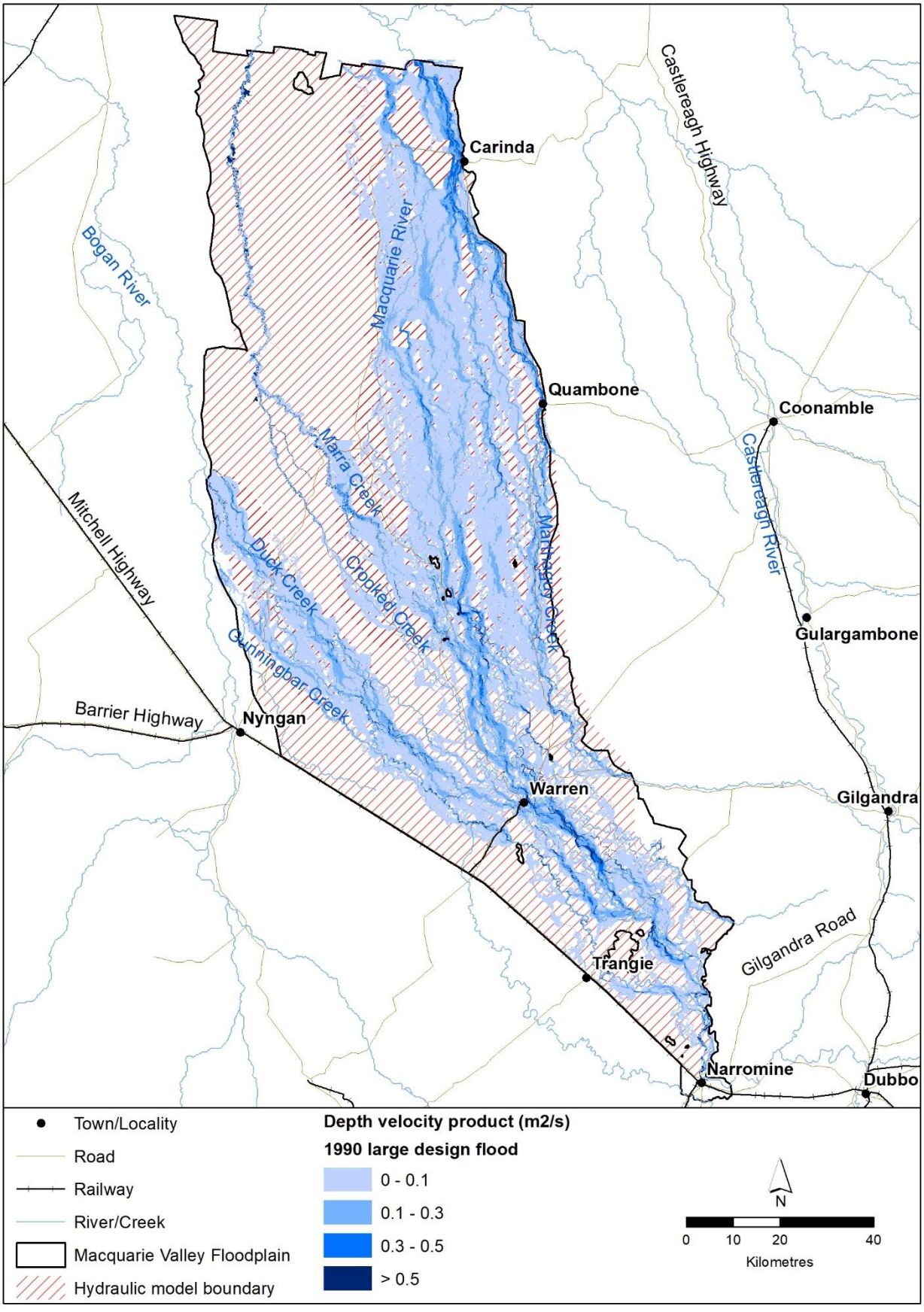

Figure 14: Depth velocity threshold map for 1990 large design flood

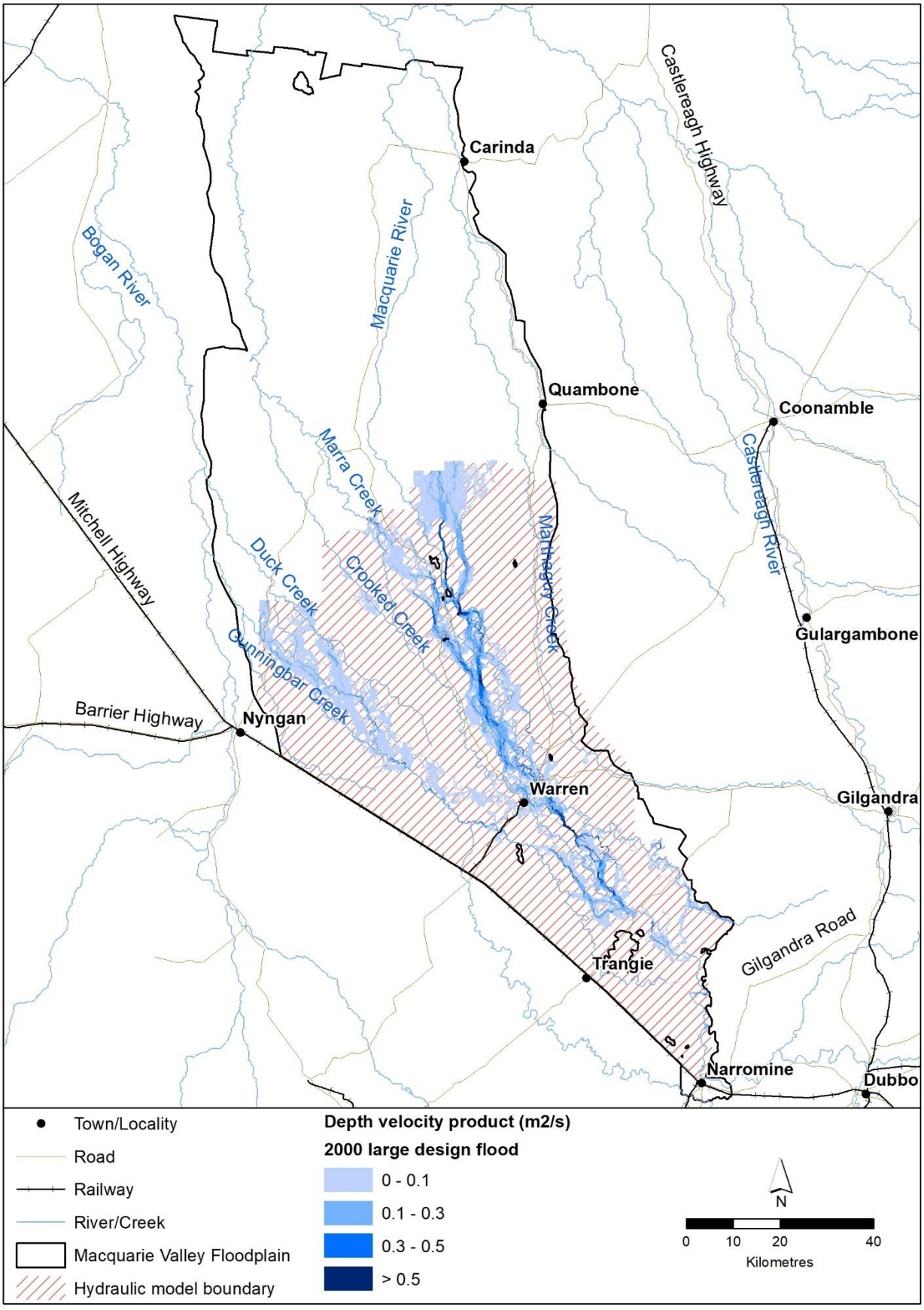

Figure 15: Depth velocity threshold map for 2000 large design flood

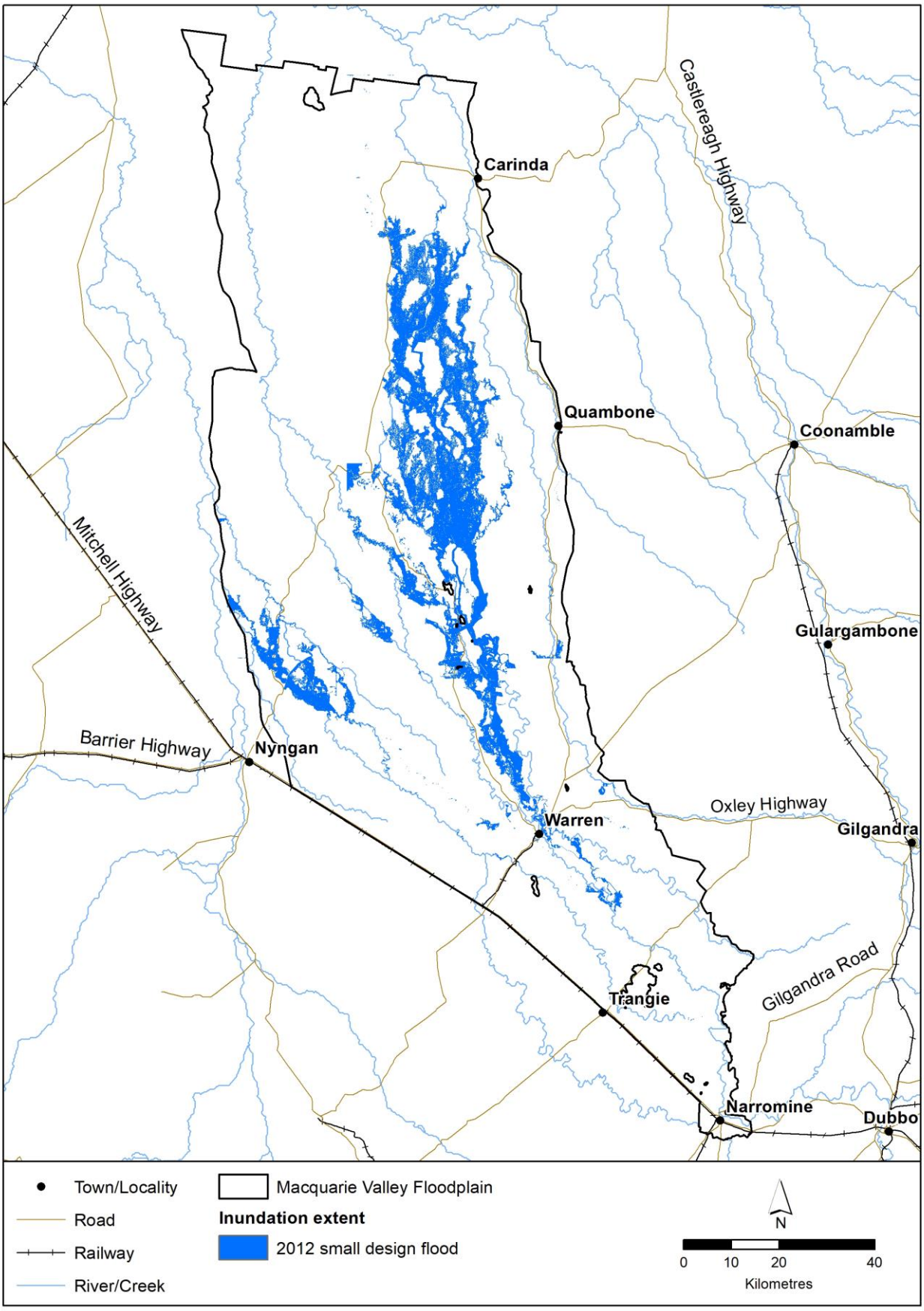

Figure 16: Inundation extent of the 2012 small design flood

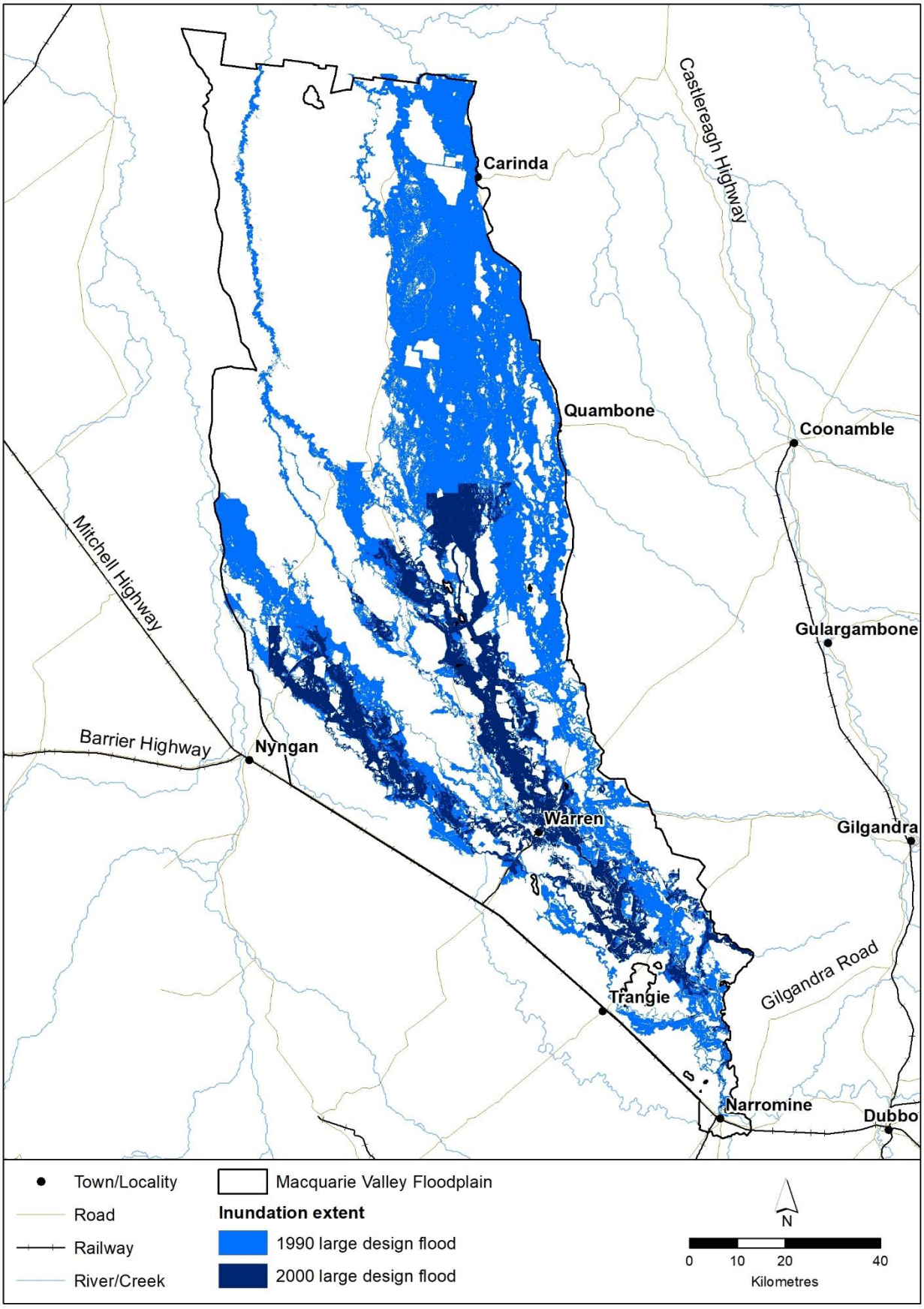

Figure 17: Inundation extents of the 1990 and 2000 large design floods

Hydraulic criteria for the floodway network

There are no industry-specific procedures for identifying floodways or defining their extent; however, advances in tools used to simulate flooding (such as two-dimensional hydrodynamic models) and improved topographic data (such as LiDAR) allow practitioners to more rigorously interrogate flood characteristics (Thomas & Golaszewski 2012). Improvements to models and input data has enabled quantitative approaches for delineating floodways, such as depth-velocity product (DVP) thresholds and extents of design floods. Nevertheless, there is no definitive flood modelling procedure that can be applied to automate the process of generating floodway extents. Additionally, the methodology should involve iterative assessments (Thomas & Golaszewski 2012).

Through consultation with the TAG and local stakeholders, criteria to interpret two-dimensional flood modelling outputs were determined, including deciding on appropriate DVP thresholds and the use of the small design flood extent. From this consultation, several hydraulic criteria options were developed. Each option proposed a target depth-velocity threshold that would be used to delineate floodways. An impact analysis of each option was also undertaken. The IRP used this information to justify the option that was adopted to provide the greatest hydraulic flood connectivity balanced with socio-economic considerations. The hydraulic criteria endorsed by the IRP and used to delineate the floodway network are described in Table 6 and the outcomes are described in detail below.

Once the thresholds were selected, applying the criteria in the spatial context remained a complex and iterative process requiring specialist input from practitioners with skills in interpreting flood data and floodplain geomorphology, and in understanding the importance of hydraulic controls and conveyance (NSW Government 2005).

Table 6: Summary of criteria used to delineate the hydraulic categories in the floodway network

Hydraulic category	Criteria
Floodways	Areas that have a DVP of greater than 0.1 m^2/s for the 2000 large design flood upstream of Warren Areas that have a DVP of greater than 0.1 m^2/s for the 1990 large design flood downstream of Warren Parts of the 2012 small design flood extent that ensure continuity of floodways
High-level floodways (upstream of Warren)	Areas that have a DVP of greater than 0.1 m^2/s for the 1990 large design flood upstream of Warren, and are outside the floodway extent (MZ A)
Inundation extent	Areas not already defined as floodways, or high-level floodways that are within the extent of the 1990 large design flood
Areas outside floodway network	Flood fringe area outside the 1990 large design flood extent Floodplain areas enclosed by existing flood works that were assumed to not be overtopped by floodwater

Floodways

Hydraulic criteria were determined for floodways and high-level floodways through consideration of existing floodplain management arrangements, hydraulic model outputs, feedback from targeted consultation, potential socio-economic impacts, and discussions with the TAG. The criteria are described in detail below.

The location and size of floodways in the floodway network is strongly reflected in the design of the management zones. Therefore, the socio-economic impacts were also considered when determining the DVP threshold used to derive floodways. This is discussed further below and in Step 10.

Floodways were derived using DVP information from hydraulic modelling of the floodplain to identify areas of high velocity and depth. A DVP threshold of greater than 0.1 square metres per second for the 1990 large design flood was initially adopted to define floodways across the Macquarie valley floodplain (Figure 14). However, it became apparent that upstream of Warren, floodways passed through large areas of existing development, meaning that they could not be designed to convey the 1990 large design flood without significant socio-economic impact. As a result, floodways upstream of Warren were derived using a DVP threshold of greater than 0.1 square metres per second for the smaller 2000 large design flood (Figure 15).

Floodways derived from the DVP thresholds were compared with the inundation extent of the small design flood. This comparison was undertaken to ensure that areas of the floodplain activated during small floods were identified as floodways regardless of whether they reached the DVP thresholds. Such areas are also likely to be the first floodways activated during large flood events. For instance, Figure 18 shows that although the large design flood would activate both floodway A and floodway B, only floodway B would be identified as a floodway using the DVP threshold. By considering the inundation extent of the small design flood, floodway A would be picked up in the floodway network as a floodway. Such floodways may be important for connecting flood-dependent ecological and cultural assets to floodwater during smaller floods.

To ensure that the floodways represent on-ground conditions, additional data was also used to guide the location of the floodways, including:

- flood aerial photography and satellite imagery from design floods (see Appendix 5)
- spatial watercourse layers, topographical mapping, ADS40 DEM and LiDAR
- previous floodplain management arrangements
- local knowledge obtained from floodplain communities and floodplain/environmental managers.

High-level floodways

High-level floodways were defined as areas upstream of Warren with a DVP of greater than 0.1 square metres per second for the 1990 large design flood, which were located beyond the extent of floodways derived from the 2000 large design flood.

These areas are important for the conveyance and temporary pondage of floodwaters and the discharge of significant flows during large events such as the 1990 large design flood (Figure 14).

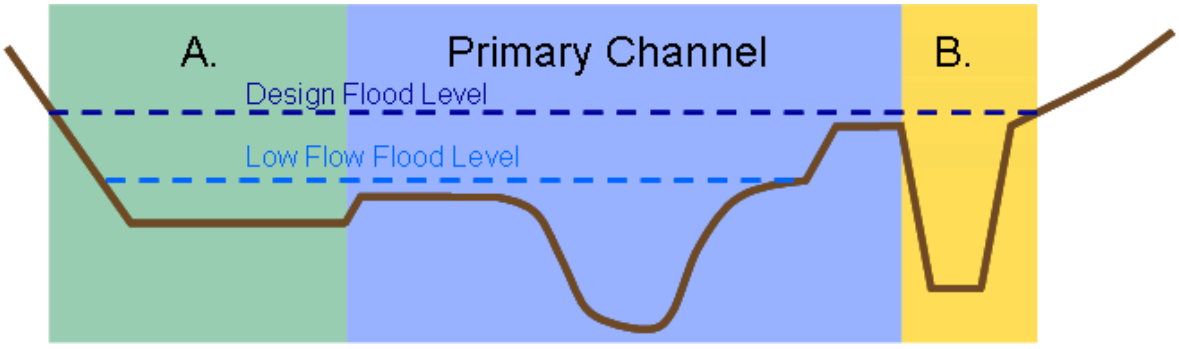

Figure 18: Identification of floodways using the depth-velocity threshold map versus inundation extent

Inundation extent

Hydraulic modelling produced the inundation extent of the 1990 large design flood across the floodplain. Where the flood extent was reliable, its outer limits were used to determine the inundation extent. Where topographic data was insufficient to accurately map the extent of the flood, the limits to the inundation extent were determined by using aerial and satellite flood imagery of the design event.

Areas within the extent of the design event are considered important for providing temporary pondage during large floods. Areas beyond the extent of the 1990 large design flood may also be flood-prone but would only become inundated during larger floods including extreme events and would generally have low conveyance or pondage capacity.

Step 5: Identify and prioritise floodplain assets

Step 5 was undertaken to identify and prioritise the many unique and diverse ecological and cultural floodplain assets found on the Macquarie valley floodplain and to inform the design of the management zones, rules and assessment criteria in later steps.

Ecological assets

During Step 5, ecological assets were:

- identified using best-available spatial data
- grouped using information on their optimum watering requirements
- prioritised to select the assets that best represent biodiversity on the floodplain.

Identifying ecological assets

The Macquarie Valley FMP considered 3 types of ecological asset: wetlands, other floodplain ecosystems, and areas of groundwater recharge (Figure 19). However, areas of groundwater recharge are not mapped, due to data limitations.

Recent regional-scale mapping of plant community types (PCTs) was predominantly used to identify wetlands and other floodplain ecosystems. In addition to recent regional-scale mapping of PCTs, several historic regional-scale vegetation maps were used to identify semi-permanent wetlands on the Macquarie valley floodplain.

Each of the flood-dependent vegetation communities identified were collated into hydro-ecological functional groups according to the surface water requirements of the dominant or canopy species in the floodplain vegetation community to maintain their ecological character, including semi-permanent wetlands, floodplain wetlands (flood-dependent shrubland wetlands) and other floodplain ecosystems. The latter category included flood-dependent forest/woodland (wetlands) and flood-dependent woodlands.

The following regional-scale vegetation maps sourced from the NSW Vegetation Information System (VIS) were used to create a composite vegetation map for the Macquarie valley floodplain:

- State Vegetation Type Map: Central West/Lachlan Regional Native Vegetation PCT Map Version 1.4. VIS ID 4468 (OEH 2015; OEH 2017a; OEH 2017b)
- 2013 Vegetation Map of the Macquarie Marshes. VIS ID 4892 (Bowen & Fontaine 2014, Bowen et al. 2019)
- Existing Vegetation Mapping of Brewarrina Shire, Northern Floodplains, Far Western NSW (Department of Infrastructure, Planning and Natural Resources (DIPNR) 1998).

The following older regional-scale vegetation maps and vegetation components sourced from the VIS were also used to identify semi-permanent wetlands in the Macquarie valley floodplain:

- Lower Macquarie Floodplain Vegetation. VIS ID 1032 (Steenbeeke 1995) – including Wetland, Water Couch, Open Water, Mixed Marsh, Cumbungi
- Lower Macquarie Castlereagh Region – Existing Vegetation. VIS ID 816 (Kerr, Jowett, & Robson 2003) – including Wetlands on grey clay floodplain depressions and watercourses
- Witts (1995) Carinda–Barwon mapping of the lower Macquarie Marshes. Vegetation mapping and interpretation by Greg Steenbeeke (unpublished map, NSW Department of Land and Water Conservation, Dubbo) – including Common Reed, Mixed Marsh, and other Ephemeral
- DLWC Existing Vegetation Map of Eastern Walgett Regional Vegetation Community (Walgett Shire east of the Barwon River). VIS ID 804 (Peasley & Walsh 1999) – including Swamps – Lagoons – Wetlands (NW VEG H02).

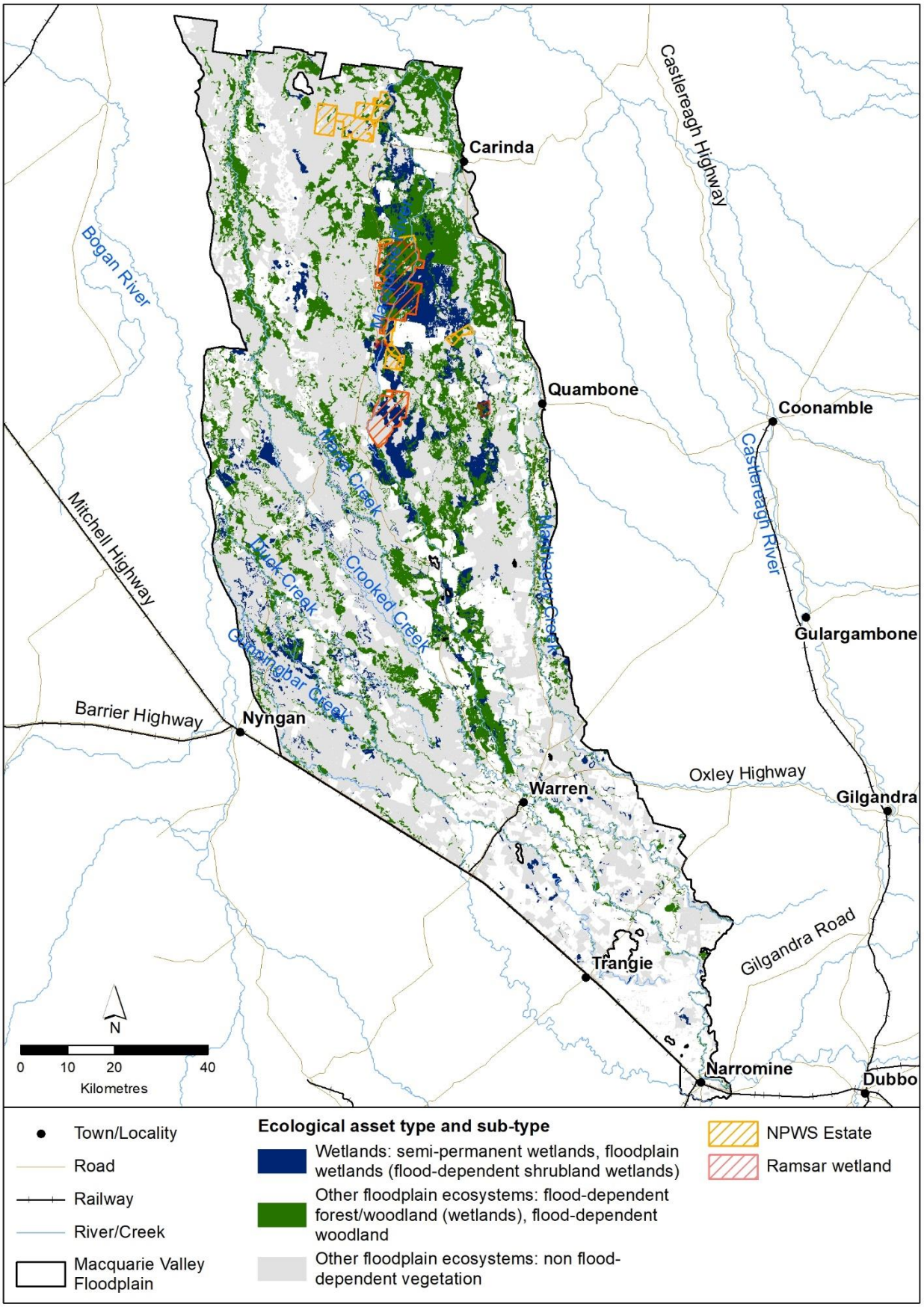

Figure 19: Ecological assets identified in the Macquarie valley floodplain

In areas where existing vegetation mapping overlapped, the separate datasets were examined to select the coverage with superior representation of native vegetation patterns. Vegetation maps were ranked on reliability assessed using the following considerations:

- More recent studies were considered more reliable than older studies.
- Fine-scale nature reserve studies were regarded as more reliable than coarse-scale studies.
- Studies with more intensive field sampling were regarded as more reliable than those that were based on sparse field sampling.

Maps with the highest assembly rank took precedence over those with lower ranks. Table 7 lists the existing regional vegetation maps and studies and the assembly rank used for compiling a seamless, composite vegetation map for the Macquarie valley floodplain.

In addition to native vegetation mapping, NSW Land use data (OEH 2011) was used to identify additional wetland features across the floodplain, including floodplain swamp–billabong (Marsh/wetland) and swamp (Marsh/wetland).

Table 7: Regional vegetation maps and studies, and the assembly rules used for the compilation of a seamless, composite vegetation map for the Macquarie valley floodplain

Vegetation mapping dataset name (reference)	NSW Vegetation Information System Number[a]	Rank[b]	Proportion of FMP area	Area
2013 Vegetation Map of the Macquarie Marshes (Bowen & Fontaine 2014, Bowen et al. 2019)	VIS ID 4892	1	20%	245,320 ha
State Vegetation Type Map: Central West/Lachlan Regional Native Vegetation PCT Map Version 1.4. (OEH 2015; OEH 2017a; OEH 2017b)	VIS ID 4468	2	78%	963,903 ha
Preclearing and Existing Vegetation Mapping of Brewarrina Shire, Northern Floodplains, Far Western NSW (DIPNR 1998)	VIS ID 1658	3	2%	31,246 ha

[a] The NSW Vegetation Information System (VIS) provides the NSW Government, its clients and the community with a central authoritative repository for native vegetation data.

[b] Maps with the highest assembly rank took precedence over those with lower ranks.

More information about the NSW Vegetation Information System is available on OEH's website at www.environment.nsw.gov.au/research/VegetationInformationSystem.htm .

Ecological asset type – wetlands

The ecological asset, *wetlands*, comprises semi-permanent (non-woody) wetlands and floodplain (flood-dependent shrubland) wetlands (Figure 20) (*wetlands* are defined in the glossary).

Semi-permanent (non-woody) wetlands (covering 47,000 hectares) require annual or more frequent inundation to maintain their structural integrity and community condition. Semi-permanent wetlands contain the following PCTs:

- shallow freshwater wetland sedgeland in depressions on floodplains, on inland alluvial plains and floodplains (PCT 53)
- common reed – bushy groundsel aquatic tall reedland grassland wetland of inland river systems (PCT 181)
- cumbungi rushland wetland of shallow semi-permanent water bodies and inland watercourses (PCT 182)
- water couch marsh grassland wetland of frequently flooded inland watercourses (PCT 204)
- permanent and semi-permanent freshwater lakes wetland of the inland slopes and plains (PCT 238)

- rat's-tail couch sod grassland wetland of inland floodplains (PCT 242).

Floodplain wetland (flood-dependent shrubland) wetlands (covering 24,800 hectares) requires flooding at intervals of one to 5 years to maintain their structural integrity and community condition (Roberts & Marston 2011; Rogers & Ralph 2011). Floodplain wetland contains the following PCTs:

- cane grass swamp tall grassland wetland of drainage depressions, lakes and pans of the inland plains (PCT 24)
- nitre goosefoot shrubland wetland on clays of the inland floodplains (PCT 160)
- river cooba swamp wetland on the floodplains of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 241)
- lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247).

Wetlands can provide habitat for a variety of flood-dependent fauna such as nesting waterbirds, fish, amphibians and turtles.

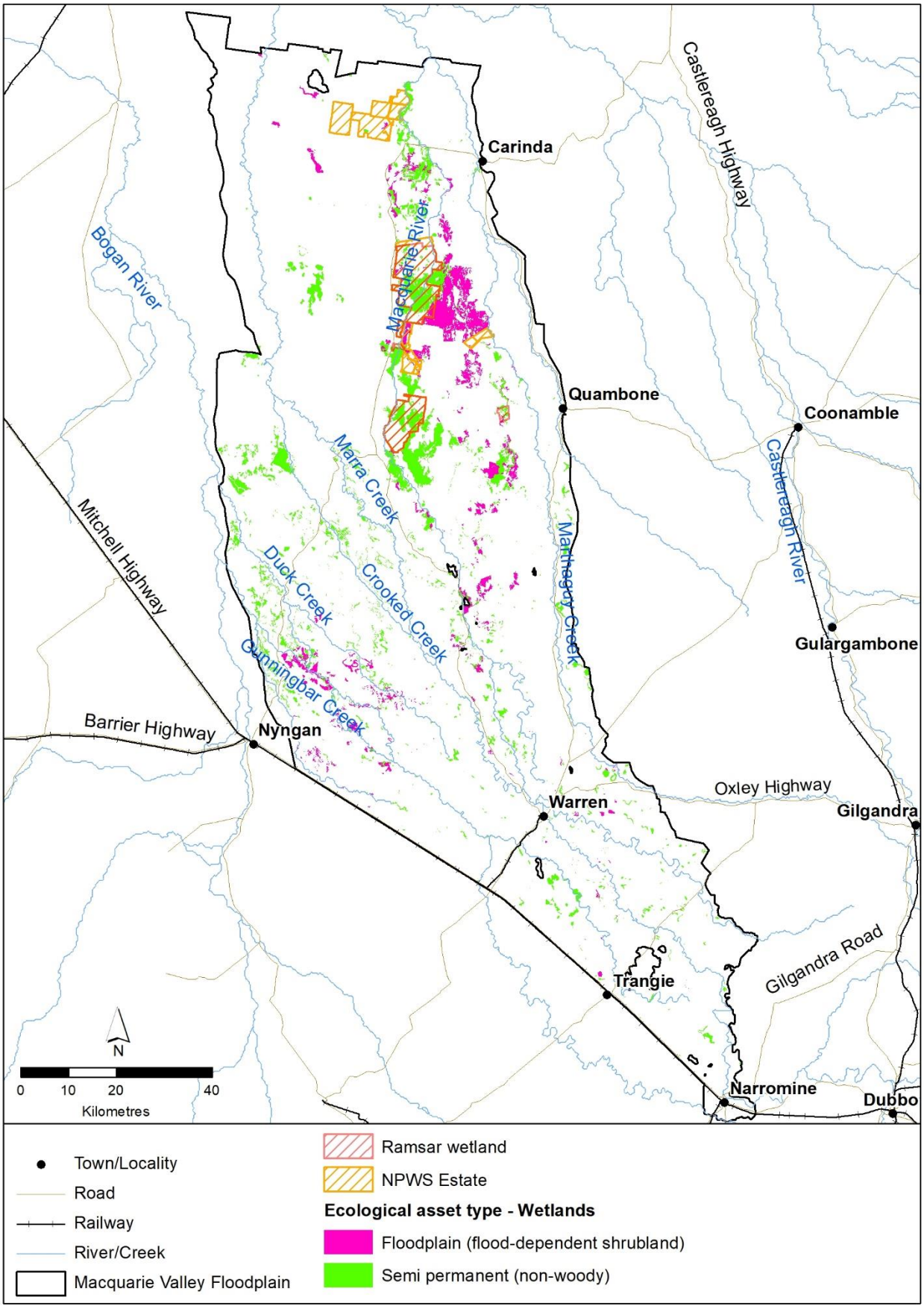

Figure 20: Location and type of wetlands identified as ecological assets

Ecological asset type – other floodplain ecosystems

The ecological asset, *other floodplain ecosystems*, comprises flood-dependent forest/woodland (wetlands), flood-dependent woodlands (Figure 21).

Flood-dependent forest/woodland (wetlands) (covering 78,400 hectares) requires flooding at intervals of between one and 3 years for forests or up to 2 to 4 years for woodlands (Roberts & Marston 2011). Flood-dependent forest/woodland (wetland) contains the following PCTs:

- river red gum tall to very tall open forest or woodland wetland on rivers on floodplains, mainly in the Darling Riverine Plains Bioregion (PCT 36)
- yellow box – river red gum tall grassy riverine woodland of the NSW South Western Slopes Bioregion and Riverina Bioregion (PCT 74)
- river red gum riparian tall woodland or open forest wetland in the Nandewar Bioregion and Brigalow Belt South Bioregion (PCT 78)
- river red gum swampy woodland wetland on cowals (lakes) and associated flood channels in central NSW (PCT 249)
- river red gum grassy chenopod open tall woodland (wetland) on floodplain clay soil of the Darling Riverine Plains bioregion and western Brigalow Belt South bioregion (PCT 454).

Flood-dependent woodland (covering 146,500 hectares) requires flooding at least once every 10 years (Roberts & Marston 2011). Flood-dependent woodland contains the following PCTs:

- black box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37)
- coolibah– river cooba – lignum woodland wetland of frequently flooded floodplains, mainly in the Darling Riverine Plains Bioregion (PCT 39)
- coolibah open woodland wetland with chenopod or grassy ground cover, on grey and brown clay floodplains (PCT 40)
- poplar box – coolibah floodplain woodland on light clay soil, mainly in the Darling Riverine Plains Bioregion (PCT 87).

The flood-dependent forests and woodland may provide habitat for flood-dependent fauna including waterbirds and frogs.

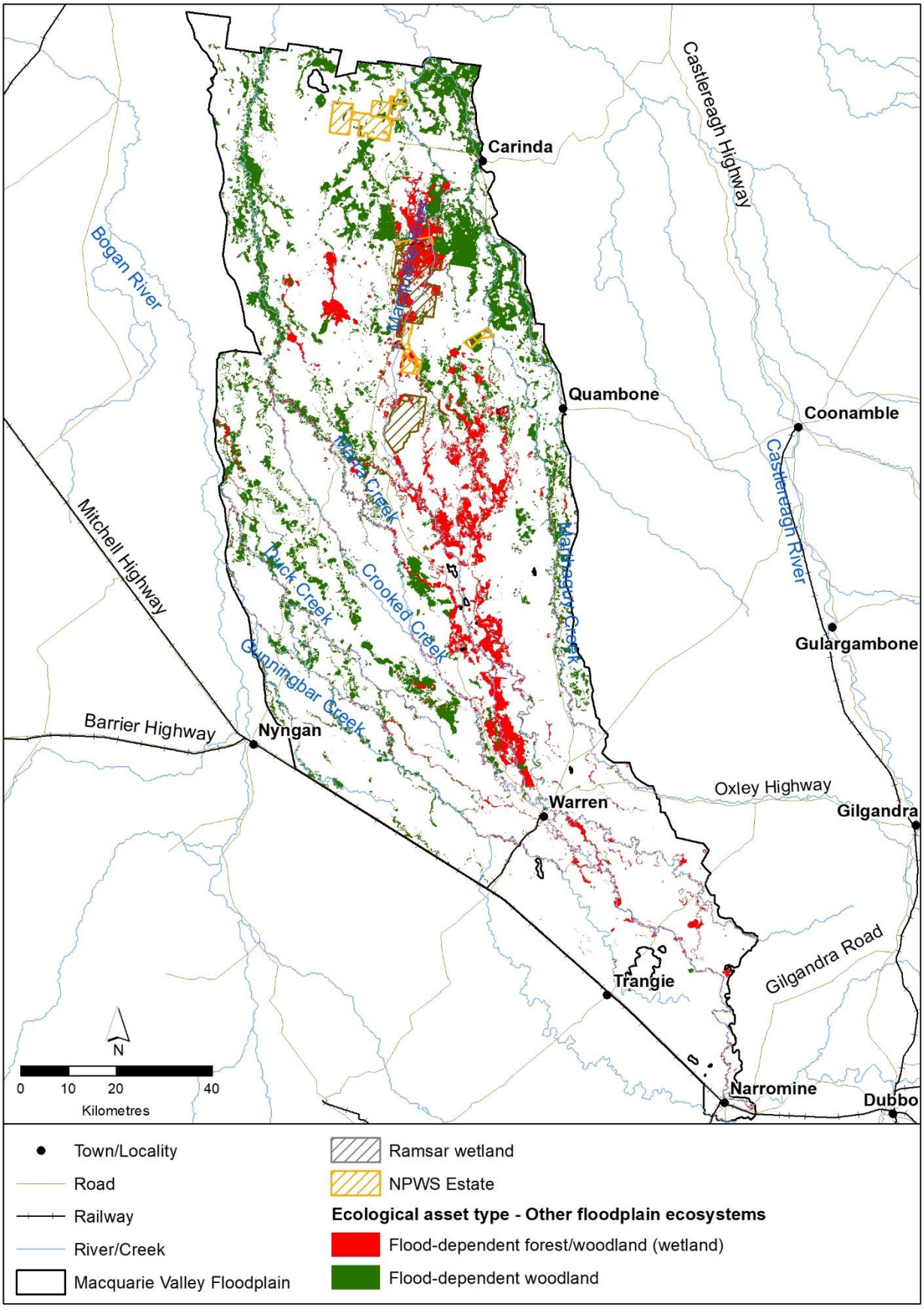

Figure 21: Location and type of other floodplain ecosystems identified as ecological assets

Ecological asset type – groundwater recharge

Groundwater recharge areas are sites where water from a flood event leaks through the soil profile into underlying aquifers. In general, flooding is an important source of groundwater recharge on floodplains, and changes to flood connectivity may impact on groundwater storage.

There is limited available spatial information related to the distribution of groundwater recharge areas in the Macquarie valley floodplain. However, several previous groundwater studies document groundwater recharge areas in the Macquarie valley floodplain.

The Macquarie channel bed is considered to be a primary recharge area on the floodplain. Most groundwater recharge in the floodplain occurs through the bed of the Macquarie River during high inbank flows, with recharge on the floodplain confined to paleochannels (floodplain watercourses). This recharge is a relatively slow process (DWE & DECC 2008).

Groundwater recharge is also thought to occur within the bedrock-confined alluvial valley upstream of Narromine and in the channel for a short distance downstream (Ralph & Hesse 2010). As described by Ralph and Hesse (2010), within the Macquarie Marshes, near-surface shallow groundwater is recharged from floodwaters and rainfall on the floodplain, but this remains isolated and distinct from the main, and typically deep, groundwater aquifers (Hollins et al. 2009). The work of Hollins et al. (2009) in relation to surface water interaction and groundwater recharge in the Northern Macquarie Marshes Nature Reserve suggests that the groundwater system is recharged by piston flow mechanisms whereby older water within the soil profile is forced downwards into the soil profile consequential to larger rainfall events or overbank flows.

Observations of groundwater levels in parts of the northern Macquarie Marshes show a clear link between surface water flooding and major recharge events to the groundwater system in the lower Macquarie River (CSIRO 2008). The watertable in the Macquarie Marshes rises and falls with floods and droughts (Brereton 1993). As described by OEH (2012b), following the floods of 1999–2000, groundwater levels in parts of the North Marsh were observed to be within one to 2 metres of the surface. In 2006, following 5 years without significant floods in the marsh, the groundwater level in the same areas was observed to be between 6 metres to 8 metres below the surface (OEH 2012b).

The study of Bureau of Rural Sciences (Macaulay & Kellett 2009) also identified several locations of groundwater recharge on the floodplain, including:

- leakage from the Macquarie River (during high flows) to recharge the shallow alluvial aquifers between Buddah and Warren
- leakage from Ewenmar Creek to the alluvium
- bed underflow leakage and aquifer recharge from the Macquarie River corridor between Narromine Weir and Timbrebongie.

The Macquarie Valley FMP will assist in maintaining flood-sourced groundwater recharge by protecting as natural a flood-flow distribution as practicable and maintaining core floodplain inundation. This will improve the likelihood and duration of natural groundwater recharge areas being subjected to natural flood inundation.

If more information on flood-sourced groundwater recharge areas becomes available, the Macquarie Valley FMP 2021 may need to be reviewed to ensure that they are adequately considered in the future design of the management zones and rules.

Flood dependency of wetlands and other floodplain ecosystems

The distribution of vegetation across a floodplain may reflect the water regime (Casanova & Brock 2000). Floodplain vegetation communities of the Macquarie valley floodplain have varying degrees of flood dependence. The time scales of flooding and the spatial extent of wet/dry ecotone may influence the types of plants that can germinate, grow and reproduce (Brock & Casonova 1997; Capon & Brock 2006). Previous studies in the Macquarie Marshes have related the distribution of

vegetation across the floodplain to inundation gradients at different time scales: in the short term (months), driven by individual flood events; and in the long term (decades), driven by historical inundation frequency (Driver & Knight 2007; Thomas et al. 2010; Thomas et al. 2011). In the absence of flooding, the understorey of flood-dependent vegetation communities such as river red gum occurring on the floodplain may switch to more terrestrial species (Thomas et al. 2010).

The flood dependency of ecological assets in the Macquarie valley floodplain was a key consideration informing FMP management zone delineation, which aims to protect the passage of floodwaters to ecological assets dependent on flooding, to maintain their long-term persistence, structural integrity and community condition.

Wetlands and other floodplain ecosystems were categorised into hydro-ecological functional groups according to the surface watering requirements of the dominant or canopy species in a vegetation community. This was to maintain their ecological character using information sourced from the reviews of Roberts and Marston (2011) and Rogers and Ralph (2011), which provide a synthesis of the best available knowledge of surface water requirements of common floodplain plants (Table 8). This information is consistent with DECCW (2010) and OEH (2012b), which document known water requirements for the maintenance of wetland and floodplain plants in the Macquarie Marshes Nature Reserves (Table 8).

Table 8: Hydro-ecological functional groups that comprise wetlands and other floodplain ecosystems in the Macquarie valley floodplain, and their flooding frequency requirements

(Source: Optimum watering requirements adapted from Roberts and Marston 2011 and Rogers and Ralph 2011)

Ecological asset	HEF* group	Vegetation community common name	Ideal watering frequency
Wetlands*	Semi-permanent (non-woody) wetland	Shallow freshwater wetland sedgeland in depressions on floodplains, on inland alluvial plains and floodplains (PCT 53). Common Reed – Bushy Groundsel aquatic tall reedland grassland wetland of inland river systems (PCT 181). Cumbungi rushland wetland of shallow semi-permanent water bodies and inland watercourses (PCT 182). Water couch marsh grassland wetland of frequently flooded inland watercourses (PCT 204). Permanent and semi-permanent freshwater lakes wetland of the inland slopes and plains (PCT 238). Rat's-tail couch sod grassland wetland of inland floodplains (PCT 242).^	Annual or near annual
Wetlands	Floodplain (flood-dependent shrubland) wetland	Cane grass swamp tall grassland wetland of drainage depressions, lakes and pans of the inland plains (PCT 24). Nitre goosefoot shrubland wetland on clays of the inland floodplains (PCT 160). River cooba swamp wetland on the floodplains of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 241). Lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South Bioregion and Darling Riverine Plains Bioregion (PCT 247).	Every year to once every 5 years

Ecological asset	HEF* group	Vegetation community common name	Ideal watering frequency
Other floodplain ecosystems	Flood-dependent forest and woodland wetland	River red gum tall to very tall open forest or woodland wetland on rivers on floodplains, mainly in the Darling Riverine Plains Bioregion (PCT 36). River red gum riparian tall woodland or open forest wetland in the Nandewar Bioregion and Brigalow Belt South Bioregion (PCT 78). River red gum swampy woodland wetland on cowals (lakes) and associated flood channels in central NSW (PCT 249). River red gum grassy chenopod open tall woodland (wetland) on floodplain clay soil of the Darling Riverine Plains Bioregion and western Brigalow Belt South Bioregion (PCT 454). Yellow box – river red gum tall grassy riverine woodland of NSW South Western Slopes Bioregion and Riverina Bioregion (PCT 74).	Once every 3 to 5 years
Other floodplain ecosystems	Flood-dependent woodland	Black box woodland wetland on NSW central and northern floodplains including the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion (PCT 37). Coolibah – River cooba – lignum woodland wetland of frequently flooded floodplains, mainly in the Darling Riverine Plains Bioregion (PCT 39). Coolibah open woodland wetland with chenopod or grassy ground cover, on grey and brown clay floodplains (PCT 40). Poplar box – coolibah floodplain woodland on light clay soil, mainly in the Darling Riverine Plains Bioregion (PCT 87).	1 in <10 years

* Examples of wetlands include lakes, lagoons, rivers, floodplains, swamps, billabongs and marshes

* HEF = hydro-ecological functional

^ Rat's-tail couch, *Sporobolus mitchellii* grows on clayey soils of floodplains, muddy flats, water-logged areas or depressions subject to submersion, and may also naturally occur as patches in the black box/coolibah box zone. No specific watering requirements are documented for rat's-tail couch in Rogers and Ralph (2011) or Roberts and Marston (2011).

Prioritisation of ecological assets

Ecological assets were prioritised to select the assets that best represent biodiversity in the Macquarie valley floodplain. High-priority assets were then considered in the design of the management zones to protect their flood connectivity. Ecological assets were predominantly prioritised by the Macquarie TAG during workshops in September and November 2014.

As outlined in the technical manual, the targets determined by the TAG were used to drive the selection of priority assets using the conservation planning decision software, Marxan. This decision support tool is used to assist the determination of areas of high conservation significance where floodplain connectivity should be secured (Ball & Possingham 2000; Possingham, Ball & Andelman 2000; Ball, Possingham & Watts 2009). Conservation targets are prescribed in Marxan to determine the amount of each feature the program is instructed to select. In conservation planning, variable targets are often prescribed for ecological surrogates based on ecological objectives, to determine relative conservation priority (higher and lesser priority areas).

The formulation of targets focused on the medium- to long-term goal of using 1991 as a contemporary baseline for spatial distribution of flood-dependent vegetation communities defined by the Wilson 1992 communities of the lower Macquarie wetlands.

In the Macquarie valley floodplain, the TAG endorsed conservation targets of 100% for most asset types to ensure their future persistence. For 2 PCTs within the wetland asset type – water couch marsh grassland wetland of frequently flooded inland watercourses (PCT 204) and lignum shrubland wetland on regularly flooded alluvial depressions in the Brigalow Belt South bioregion and Darling Riverine Plains bioregion (PCT 247) – the TAG endorsed targets to restore the extent and condition of these communities to 80% of their 1991 spatial extents. As a result, the Marxan analysis determined that all ecological assets were a high priority. Nevertheless, the prioritisation method was undertaken in full, for completeness and to provide information on the relative conservation significance of animal species and flood-dependent PCTs identified in studies as determined by targets set by the TAG.

The prioritisation method involved:

- partitioning the floodplain into planning units (see Appendix 6)
- using local and expert knowledge to set targets for ecological surrogates (see Appendix 7)
- developing a spatial layer (constraint surface) that represents the ability to physically connect floodwaters to ecological assets, to constrain the selection of priority planning units (see Appendix 8)
- running Marxan to identify priority ecological assets and selection frequency scores.

Marxan analyses key ecological surrogates to represent biodiversity patterns, and identifies floodplain areas that complement each other, producing an efficient, well-connected system that aims to ensure the future persistence of flood-dependent ecological assets. Ecological surrogates are spatially definable components of biodiversity patterns and may include mapped information such as vegetation, waterbird habitat and fish biodiversity hotspots.

Priority ecological assets

For the Macquarie valley floodplain, the decision support software was run using the targets prescribed by the TAG with one million iterations across 100 runs using a simulated annealing optimisation method (Ball & Possingham 2000). The best solution from the 100 runs was chosen to identify the high-priority planning units because it has the minimum amount of planning units that achieved the conservation targets at the least cost (Figure 22).

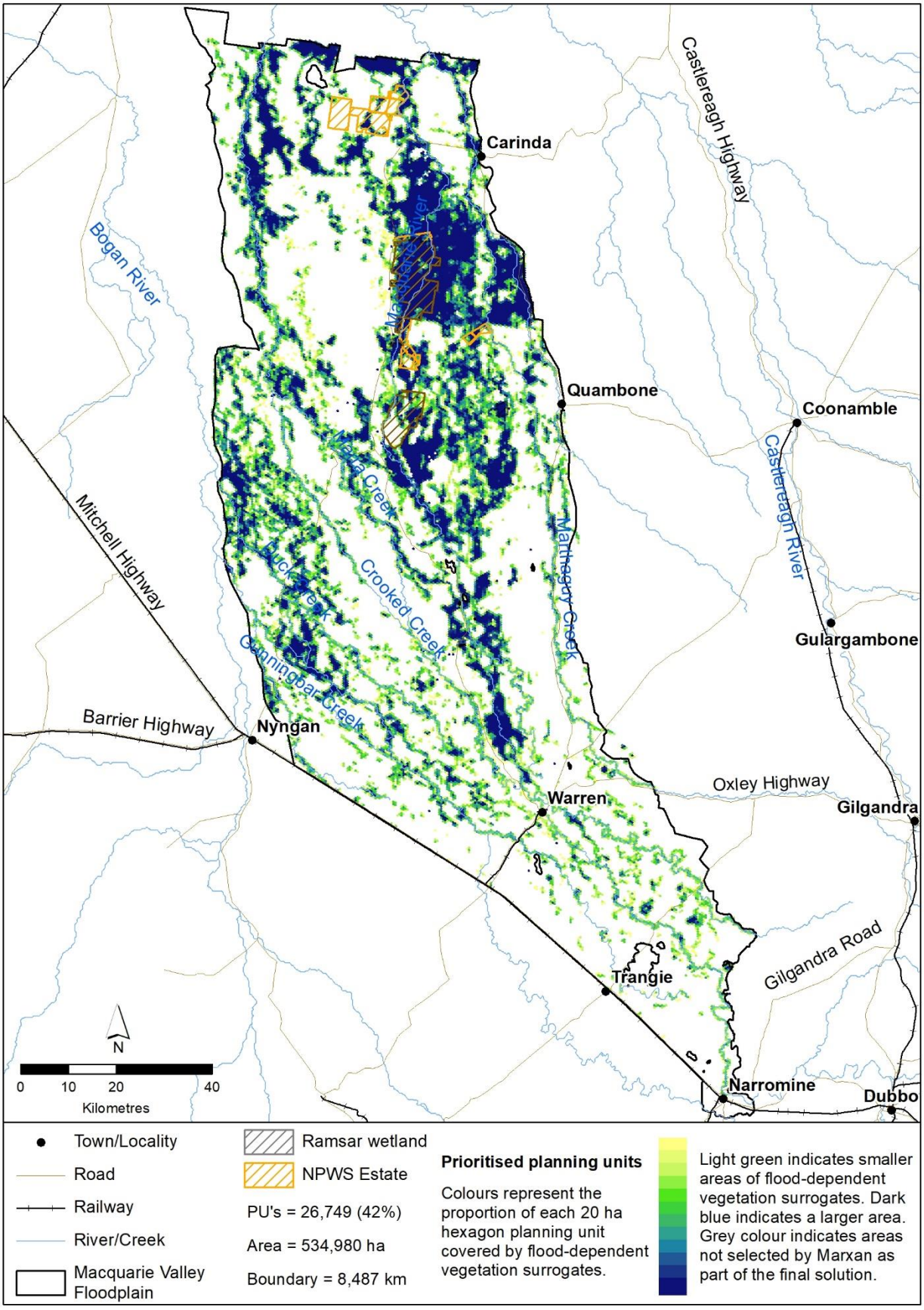

Figure 22: High-priority planning units selected in Marxan

Selection frequency score

Another output of running the Marxan software is the selection frequency score (Figure 23). The number of times a planning unit was selected in each of the 100 runs was counted to measure the relative importance of planning units. The selection frequency score provides feedback on how likely it is a specific area will be included in an efficient solution. When a planning unit is never selected it is attributed a frequency score of 0, while those that are always selected will have a selection frequency equal to the maximum number of runs of the Marxan software (that is, the highest possible frequency score for a planning unit is 100 if there are 100 runs). Areas with a high frequency score are consistently important in the solutions. They are highly irreplaceable and have fewer substitutes if conservation objectives are to be achieved efficiently.

The optimal set of planning units mapped from Marxan identified parts of the Macquarie valley floodplain that are important for achieving a range of conservation targets. This included parts of the floodplain that are essential for maintaining connected riparian ecosystems and protecting flood-dependent species and habitats. These focal areas of the floodplain were identified systematically at the landscape scale using a variety of spatial ecological data that represent biodiversity patterns.

Additional information, including the distribution of mapped, flood-dependent vegetation boundaries that represent the current distribution of native vegetation species at discrete sites, hydraulic assessments and cultural heritage assets were also considered to guide demarcation of final floodplain management zones. Combined with the optimal set of planning units, these components formed part of the larger decision framework for determining the floodplain management zones in the Macquarie valley floodplain.

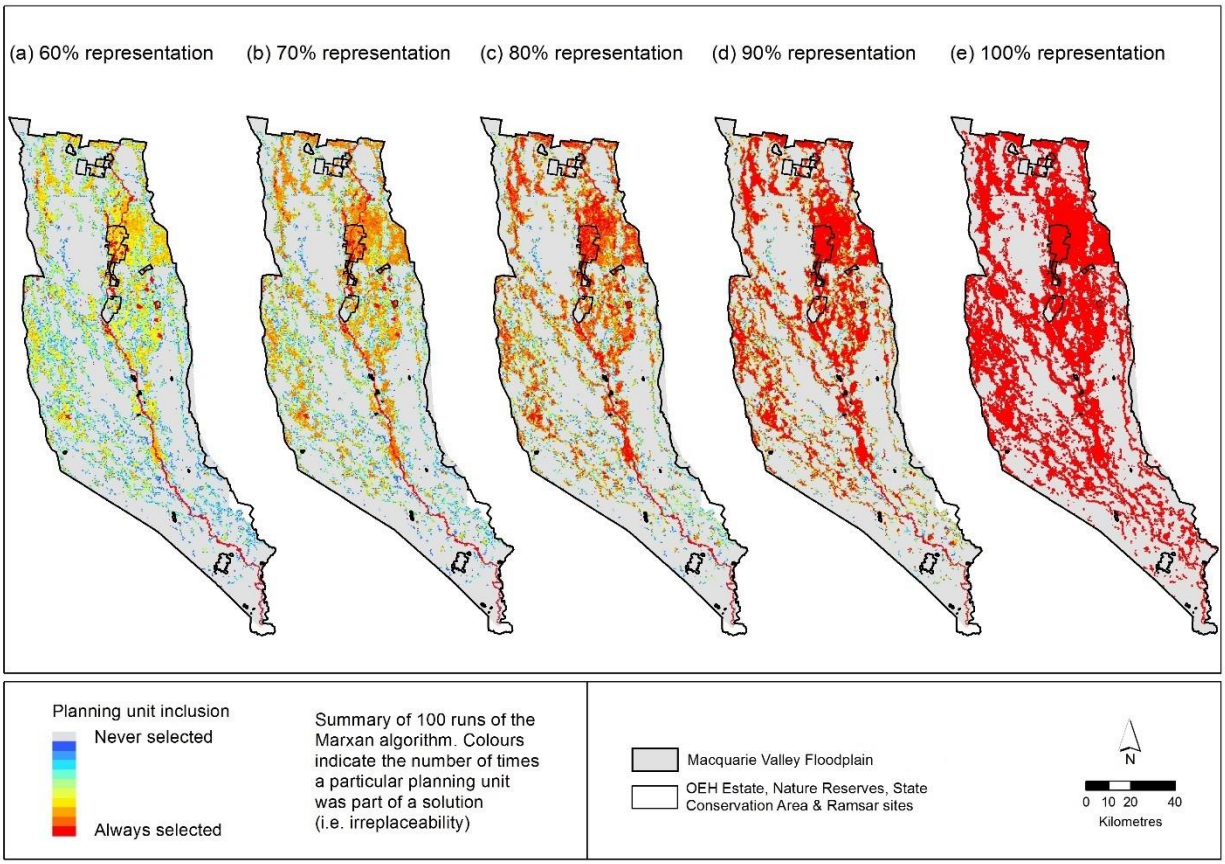

Figure 23: Relative priority (selection frequency as an index of irreplaceability) of planning units based on the Marxan analysis, achieving a range of different representation targets for flood-dependent vegetation assets for the Macquarie valley floodplain

Cultural assets

The Macquarie valley floodplain contains assets that have Aboriginal and cultural heritage value (cultural assets). The Macquarie Valley FMP 2021 identified and prioritised 2 types of cultural assets:

- **Aboriginal cultural values** – including sites, objects, landscapes, resources and beliefs that are important to Aboriginal people as part of their continuing culture. Aboriginal cultural values also include functions, services and features that benefit Aboriginal people that are listed in federal, state and local government databases.
- **Heritage sites** cultural heritage objects and places as listed on federal, state and local government heritage registers.

In some cases, information about sensitive cultural assets is held by elders and may not be listed in a federal, state or local database or register. To accommodate this information, flexibility has been integrated into the Macquarie River Valley FMP to accept Aboriginal values and heritage sites that are derived from any other source deemed relevant by the Minister for Water, Property and Housing.

Cultural asset type – Aboriginal cultural values

The Wailwan and Ngemba Nations are recognised as the traditional owners of the majority of the Macquarie valley floodplain. The Wailwan and Ngemba lived on land inclusive of the region north of Brewarrina to south of the Warrumbungle Range, with the area bounded by the Barwon River to the north, the Bogan River to the west and the Castlereagh River to the east (Torrible & Wettin 2009). The Wailwan and Ngemba had connections with the surrounding Wiradjuri, Youalaroi, Wongiapaan, Gowanbrea and Kamilaroi groups (Thompson 1978; Beck 1989).

Findings from Cuddie Springs – an important archaeological and paleontological site located within the Macquarie valley floodplain 30 kilometres northwest of the Macquarie Marshes – indicates that there has been a continual presence of Aboriginal people in the area and use of resources for at least 30,000 years, with grinding stones found in the 30,000 year soil horizon (Torrible & Wettin 2009; Fillios et al. 2010). The Wailwan and Ngemba people used the numerous rivers, creeks and floodplains for a multitude of purposes including fishing, hunting, gathering plants, transport, recreation, ceremonies and campsites (Torrible & Wettin 2009). Burial sites and scarred trees – the bark of which was used to make canoes, campsites, and medical and ceremonial adornments – are located on the Macquarie valley floodplain (Torrible & Wettin 2009). Due to the highly variable rainfall that characterises the Macquarie catchment, the Wailwan and Ngemba lived by the rivers, creeks and waterholes in drought periods, and moved onto the grassy plains during wet and flooding times (Torrible & Wettin 2009).

The Aboriginal community maintains a strong presence in the Macquarie valley floodplain and has a strong cultural connection to the area (Torrible & Wettin 2009).

The Macquarie valley floodplain contains many cultural sites and values that are important to the local Aboriginal community. Due to the sensitive nature of the data, specific Aboriginal values cannot be listed or mapped in published documents; however, Aboriginal values were generally found to include:

- a network of places with spiritual significance that link water connectivity across the landscape, and which are important for understanding the cultural significance of the connection between all elements of the biophysical system
- sites with scarred trees, where bark was removed to make tools and utensils, or ceremonial markings
- Cuddie Springs, a complex of Aboriginal and palaeontology sites with international scientific significance
- locations of ceremonial and gathering sites

- Aboriginal burial sites
- shell midden sites
- earth mound (in-ground ovens) sites including those associated with the Macquarie Marshes
- wetlands and river channels, including the Macquarie Marshes, which were an important focus of settlement, and are also places of spiritual significance
- core semi-permanent wetlands with iconic plants and animals (including cumbungi, nardoo and cod fish)
- riverine forests, woodland and grassland areas with iconic plants and animals, such as River cooba, river red gum, coolibah, Mitchell grass, native millet and water rats
- stone artefacts (including pebble adze stone artefacts), stone arrangements and quarries
- long-lasting waterholes of swamps in wetland areas that may have been a focus of settlement
- semi-permanent waterholes and channels on the floodplain that may have been a focus of settlement
- places within the floodplain that have Dreaming and/or spiritual significance (including Cuddie Springs)
- places of contemporary cultural connection, which may also be heritage sites.

For the Macquarie Valley FMP 2021, Aboriginal values were identified at a regional scale by:

- reviewing previous studies that have investigated cultural values in the floodplain
- consulting with various NSW Government agencies involved in landscape management within the valley, including Central West Local Land Services (LLS), National Parks and Wildlife Service, NOW and OEH)
- targeted consultation with members of the Aboriginal community who have knowledge of values connected with the floodplain
- consultation with the Macquarie ATWG, that comprises Aboriginal people with cultural connection to the floodplain
- context setting, using existing spatial information about the potential distribution of unidentified values according to the Aboriginal Sites Decision Support Tool (ASDST) (Appendix 9).

Aboriginal values were also identified by reviewing the values recorded within the floodplain in the following databases:

- NSW Aboriginal Heritage Information Management System (AHIMS), which includes information on Aboriginal objects, Aboriginal places and archaeological reports
- NSW Aboriginal Water Initiative System (AWIS)
- MDBA Aboriginal Submissions Database
- NSW State Heritage Register, which includes:
    - Aboriginal places
    - State Heritage Register
    - Interim Heritage Orders
    - State Agency Heritage Registers
    - heritage items in local environmental plans
- Australian Heritage Database, which includes places on the:
    - World Heritage List
    - National Heritage List
    - Commonwealth Heritage List
    - Register of the National Estate.

Cultural flows

Aboriginal people view themselves as an inherent part of the river system. A holistic understanding of how water is connected to the land and rivers, and the connection that Aboriginal people feel to river systems, feeds a strong feeling of responsibility for the health of rivers and floodplains. The Murray Lower Darling Rivers Indigenous Nations (MILDRIN) and Northern Murray–Darling Basin Aboriginal Nations (NBAN) define cultural flows as:

> *… water entitlements that are legally and beneficially owned by the Indigenous Nations and are of a sufficient and adequate quantity and quality to improve the spiritual, cultural, environmental, social and economic conditions of those Indigenous Nations. This is our inherent right.*

Cultural flows are being integrated into water planning and management.

Work is currently being undertaken by the National Cultural Flows Planning and Research Committee to improve our knowledge of cultural flows, including Aboriginal water values and uses, and volumes of water that provide for those values and uses. Cultural flows may improve the health and wellbeing of Aboriginal people and empower Aboriginal communities to care for their country and undertake cultural activities.

This body of work was instigated by NBAN. NBAN is a confederation of 24 member Nations that advises and advocates on behalf of Ancestral Owners for the past 2 years. Its sister organisation, MILDRIN, has produced a document called the *Echuca Declaration* from which the adoption of the term Cultural Flows came. Both organisations ratified the above in 2011, providing the aforementioned consistent definition right across the whole MDB.

The Macquarie Valley FMP 2021 does not address cultural water; however, cultural water will likely be a component of the WSPs that the Department of Planning, Industry and Environment is developing, which will incorporate the Aboriginal cultural values identified in this study.

Aboriginal Water Initiative

The First Peoples' Water Engagement Council (FPWEC) was established to provide advice to the National Water Commission on national Aboriginal water issues. The May 2012 advice set the overarching policy framework, including that there must be an Aboriginal water allocation in all water plans; that Aboriginal people are engaged in decision making, planning and management; and that Aboriginal access to water for cultural and economic purposes is mandatory. The FPWEC also sought to establish and implement a National Aboriginal Water Strategy through the Council of Australian Governments. The FPWEC ended its tenure in 2012 and an Indigenous Water Advisory Council was formed to carry on with the initial work of the FPWEC at a national level.

An Aboriginal Water Initiative was established in June 2012 to better involve and represent Aboriginal people in water planning and management in NSW. The initiative allowed the department to start monitoring the success of water sharing plans in meeting their statutory requirements for performance indicators specific to Aboriginal people, including providing water for Native Title rights.

The Aboriginal Water Initiative established a database of water-dependent cultural features. All cultural values and features identified in this study will be included in AWIS, to allow for follow-up investigations of their water requirements and the production of condition report cards. The AWIS must be consulted as part of the flood work assessment process.

Cultural asset type – heritage sites

Heritage sites are cultural heritage objects and places listed on federal, state and local government heritage registers. Some Aboriginal values may also be heritage sites. For the purposes of the

Macquarie Valley FMP 2021, heritage sites were divided into historic heritage sites and Aboriginal heritage sites.

Federal, state and local government heritage databases include:

- Australian Heritage Database
- Historic Heritage Information Management System (HHIMS)
- MDBA Aboriginal Submissions Database
- NSW State Heritage Inventory
- NSW AHIMS
- NSW AWIS.

Flood dependency of Aboriginal values and heritage sites

During the development of the Macquarie Valley FMP 2021, the flood dependency of cultural assets was determined so that consideration could be given to how changes to the flooding regime may affect assets across the floodplain.

Flood dependency – Aboriginal values

Flood dependency of the Aboriginal values nominated by the Aboriginal community was initially identified through discussion with knowledge holders about the nature of each value, and how it is connected with floodwater. Identified Aboriginal values were then reviewed for their flood dependency. Most of the places nominated as having significant Aboriginal values were found to have a strong connection or dependency on flooding, although some sites, including Cuddie Springs, were determined to not have a strong connection to flooding.

Flood-dependent Aboriginal values included sites that are not necessarily flood-dependent, but where the purpose or location of the site is flood-dependent. Examples include ceremonial locations connected with intact flood-dependent vegetation; campsites near wetlands that may persist regardless of flooding but may not be used until the landscape is flooded; and resources only abundant during flood events. Wherever possible, the nature of these cultural relationships was considered in the design of the management zones.

Flood dependency – historic heritage sites

Flood dependency was assessed by reviewing the heritage listing records, to establish the nature of the heritage theme and value of the site, and to determine if it was dependent on or connected with floodwater.

The following historical assets were not identified as being flood-dependent but were considered in relation to potential flood impacts during the design of management zones in the Macquarie Valley FMP 2021:

- **Beleringar Creek Regulator** was constructed in 1902 as a regulatory device to control high water flows from the Macquarie River to the Beleringar Creek. The regulator consists of a vertical steel lift gate in a single concrete bay. The gate has been removed and the regulator is not currently in use. The item is over 100 years old and afforded protection under the auspices of the *NSW Heritage Act 1977.*
- **Buckiinguy Break Return** is a contemporary structure with a memorial dedicated to Sarah Maryanne Thornton, the deceased daughter of the local landowner. The item is not afforded automatic protection under the *Heritage Act 1977*, but it has been assessed as having a high level of contemporary social value.
- **Crooked Creek Weir** is a fixed-crest reinforced concrete weir constructed in 1903. It is an integral component of the water management system in place along Crooked Creek, and contributes to the regulation of essential domestic, stock and irrigation water supply in this region. The item is over 100 years old and therefore afforded automatic protection under the auspices of the *Heritage Act 1977.*

- **Duck Creek Channel No.1** is a simple cutting that regulates water flow down Duck Creek. It is an integral component of the water management system in place along Duck Creek to provide essential domestic, stock and irrigation water supply in this region. The item is 99 years old and therefore afforded automatic protection under the auspices of the *Heritage Act 1977*.
- **Duck Creek Channel No.2** is a simple cutting that regulates water flow down Duck Creek. It is an integral component of the water management system in place along Duck Creek to provide essential domestic, stock and irrigation water supply in this region. The item is 99 years old and therefore afforded automatic protection under the auspices of the *Heritage Act 1977*.
- **Gin Gin Weir** is a mass concrete wall with a fixed-crest gravity weir constructed between 1897 and 1902. The completion of the weir was delayed due to floods, but during the later stages of the construction, work took place on a 24-hour schedule. The weir was designed as storage for the Macquarie River and today is in operation, providing a pumping pool for 2 large irrigation schemes: the Trangie-Nevertire and Tenandra schemes. The scale and setting of the structure contribute to its aesthetic appeal. The weir is 100 years old and is afforded protection under the auspices of the *Heritage Act 1977.*
- **Gunningbar Creek Offtake** is a simple steel mesh and post structure designed to control the water level of the pool at Warren Weir and divert it to the Gunningbar Creek. The structure derives its significance from its association with the Warren Weir and Gunningbar Regulator and plays an important role in the water management complex that is part of the Warren Weir. The structure was rebuilt in 1911 after being washed out as a result of floods. The offtake is 91 years old and still in use.
- **Gunningbar Creek Regulator** is a reinforced concrete bay with a manually operated chain and pulley regulatory gate. Historical research indicates a discrepancy in the date of construction: it was originally constructed in 1911 when substantial works were carried out on the Gunningbar Creek system, or it was reconstructed in 1940. The structure is regarded as an important component of the Macquarie River diversion scheme and provides essential water to the towns of Nyngan and Cobar.
- **Gunningbar Creek Weir** is a fixed-sill concrete crest with 4 bays accommodating timber drop boards. The structure is afforded automatic protection under the *Heritage Act 1977*. The structure is assessed to be of Moderate Local significance as it meets the requirements of the Historic criteria. The structure is regarded as an important component of the Macquarie River diversion scheme and provides essential water to the towns of Nyngan and Cobar.
- **Marebone Weir** meets the requirements of the Social and Representative criteria and has been assessed to be of Low Local significance. This significance is derived from its economic contribution to the development and wellbeing of the local region, by managing and providing essential water to local agricultural and pastoral industries. The Marebone Weir is more than 40 years old and not afforded automatic protection under the *Heritage Act 1977*. Its broader value is acknowledged, as is the collective value of its associated structures.
- **Marra Channel** is 26 years old and not afforded automatic protection under the *Heritage Act 1977*. The Marra Channel and associated works, although not constructed until 1976, were detailed on 1937 plan signed by Chief Engineer Frank Brewster. As such, the Marra Channel and water management system have historic value for their association with Chief Engineer Brewster.
- **Marra Channel Regulator** was constructed in 1977 but appears to have replaced an earlier structure that was in place at least by 1939. Although the current structure is not afforded automatic protection under the *Heritage Act 1977*, it has historic value for its association with Chief Engineer Brewster and indicative historic value for its association with the previous structure.

- **Warren Weir** is an item of high state significance. It fulfils the criteria of Historic, Aesthetic, Social, Rare and Representative value. The weir is more than 120 years old and is a good example of a fixed-crest concrete weir with timber cribwork constructed in the late 19th century in rural NSW. Aesthetically, the simplicity and honesty of the design and fabric used – as well as its natural setting – contribute to the structure's aesthetic appeal. It is both rare and representative of historic public works structures in rural and remote areas of NSW. Warren Weir is afforded automatic protection under the *Heritage Act 1977*.

Flood dependency – Aboriginal heritage sites

The following Aboriginal site types occurring within the region were identified as having flood-dependent values:

- cultural modifications (such as coolamon scars) on living trees that are flood-dependent species
- ceremony and Dreaming sites located within or surrounded by floodplain vegetation
- Aboriginal resource-gathering sites.

Prioritisation of Aboriginal heritage sites

The flood dependence of Aboriginal heritage sites was assessed by reviewing the heritage listing records to establish the nature of the heritage theme and value of the site and determine if this was dependent on or connected with floodwater. The type of Aboriginal heritage site – including the process for identifying these high-priority cultural assets – is outlined below.

Scarred trees

Scarred trees were investigated using AHIMS records and by inspecting the original site cards. Those scarred trees where it was clear that the tree was dead at the time of the recording, were excluded from the prioritisation. As some recordings were more than 30 years old, the location of each tree was also compared to recent airborne digital sensor (ADS) imagery to confirm a reasonable likelihood that the tree still existed. As a result of the comparison with recent ADS imagery, some recordings were found to have locations logged that were inconsistent with information in the original site card. These were corrected.

Ceremonial sites

A search of the AHIMS database identified 9 ceremony sites recorded within the floodplain, some recorded in detail by Etheridge (1918) in the early 20th century.

Resource gathering sites

The AHIMS data also identified 3 Aboriginal resource gathering sites that were known to have been used during historic times. Each of these sites involved flood-dependent plant or animal resources.

Aboriginal burials

There are 10 Aboriginal burials recorded within the floodplain, 6 of which occur adjacent to main channels in the floodplain.

Aboriginal shell middens

There is a single occurrence of an Aboriginal shell midden in the floodplain. These resources were used during flood periods and are associated with lagoons filled during floods.

Earth-mound sites

A key feature of the Macquarie valley floodplain is the occurrence of earth mounds (in-ground ovens) associated with the Macquarie Marshes. Twenty-seven of these sites – which are closely associated with harvesting resources during flood periods – have been recorded.

Prioritisation of Aboriginal values

Targeted consultation was undertaken with members of the Aboriginal community throughout the region who have knowledge about flood-dependent Aboriginal values. Given available time frames, this was not an exhaustive consultation process, and the incorporation of Aboriginal values into the plan should be considered an ongoing process.

Discussions were held in person with community members with printed maps that they could annotate. The maps were left with the community members to give them an opportunity to consider the requirements of the plans, and follow-up discussions were held in the months following.

The consultation process identified a number of areas where the significance of Aboriginal values warranted special protection. In some cases, this was because of the significance and sensitivity of important sites. In other cases, it concerned areas of relatively intact land that were rich with sites associated with living in the floodplain or where contemporary cultural activities are undertaken.

The areas were digitised and used to inform the design of the plan's management zones. The areas identified and their associated values will be stored in a database of flood-dependent Aboriginal values being established by the department. The database will be used during the assessment of flood works applications.

Step 6: Prepare a socio-economic profile

To develop options for future floodplain management, we must understand the floodplain area and respect the community's ability to adapt to change. A socio-economic profile of the Macquarie valley floodplain was determined in this step to effectively consider the social and economic impact of development controls in the floodplain, and the flood risk to life and property from the effects of flooding. The socio-economic profile is detailed in Appendix 10 and a summary is provided below.

The profile is an assembly of existing key socio-economic data that provide a general picture of the catchment in terms of its socio-demographic and economic structures. Key socio-economic data that informs the baseline profile include:

- geographies that are relevant to the socio-economic discussion of the floodplain
- demographic profiles
- employment by industry
- income statistics
- economic wellbeing indicators
- production statistics.

Information from this assessment is used in the socio-economic impact analysis of the proposed plan, which is outlined in Step 10. The socio-economic impact analysis is undertaken in coordination with the development of management zones and rules for a valley, and informs steps 7, 8 and 9 of this process.

Study area geography

Several geographies are relevant to the socio-economic discussion of floodplain management within the Macquarie valley floodplain. The 3 areas examined are:

- the Macquarie floodplain economy
- the Macquarie rural floodplain
- the Macquarie urban floodplain

The Macquarie floodplain economy area (Figure 24) includes the Macquarie rural and Macquarie urban floodplains, as well as the adjacent areas in the Barwon River and Bogan River catchments that engage with the economy of the region. This area (3,698,800 hectares) is located between the regional centres of Dubbo and Brewarrina. Most goods and services consumed in the Macquarie floodplain economy area are sourced from the regional centres of Dubbo, Narromine, Warren, Nyngan and Trangie, or the small townships in the area.

The Macquarie rural floodplain is the rural floodplain area downstream of Narromine, along the Macquarie River to the floodplain junction with the floodplain of the Barwon River. The Macquarie rural floodplain is bounded by the Bogan River floodplain in the west and the Castlereagh catchment in the east. This Macquarie Rural floodplain area (1,245,600 hectares) will be directly impacted by the Macquarie Valley FMP 2021 (Figure 25). The community residents who live and work in this area are predominantly engaged in agriculture, but the community does include people who live in small rural towns. Community services and infrastructure are limited in this area; most of the required farm inputs and human services are provided from local towns and the regional centre of Dubbo.

The Macquarie urban floodplain incorporates the townships of Narromine, Warren, Nyngan and Trangie. Although this area is situated on or adjacent to the floodplain and may be affected by the Macquarie Valley FMP 2021 floodwater, floodwater management in urban areas of NSW is provided under the *Local Government Act 1993*. The communities that live in these towns rely on the surrounding rural floodplain areas both as a source of employment and as a consumer of services.

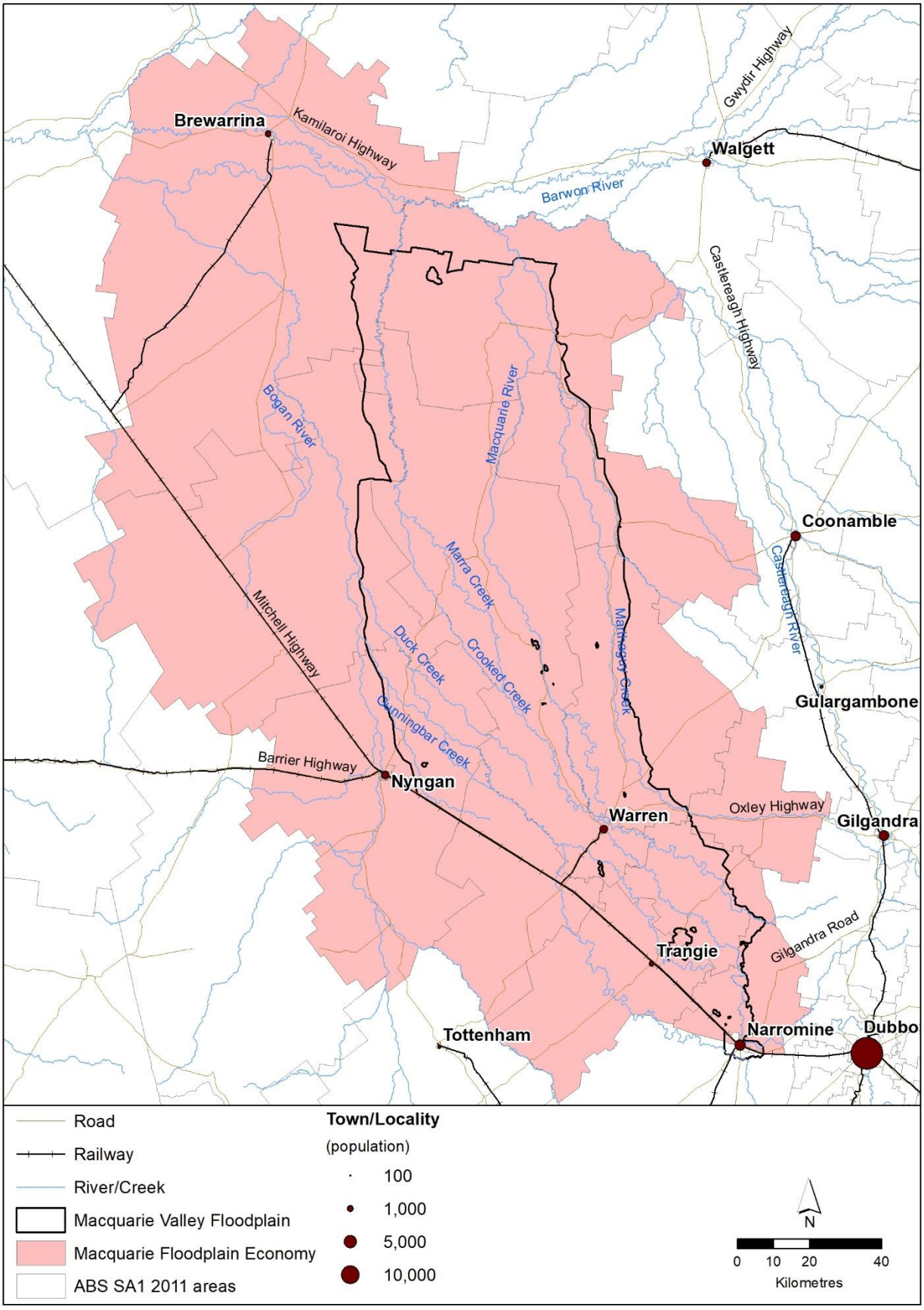

Figure 24: Macquarie valley floodplain and Macquarie valley floodplain area

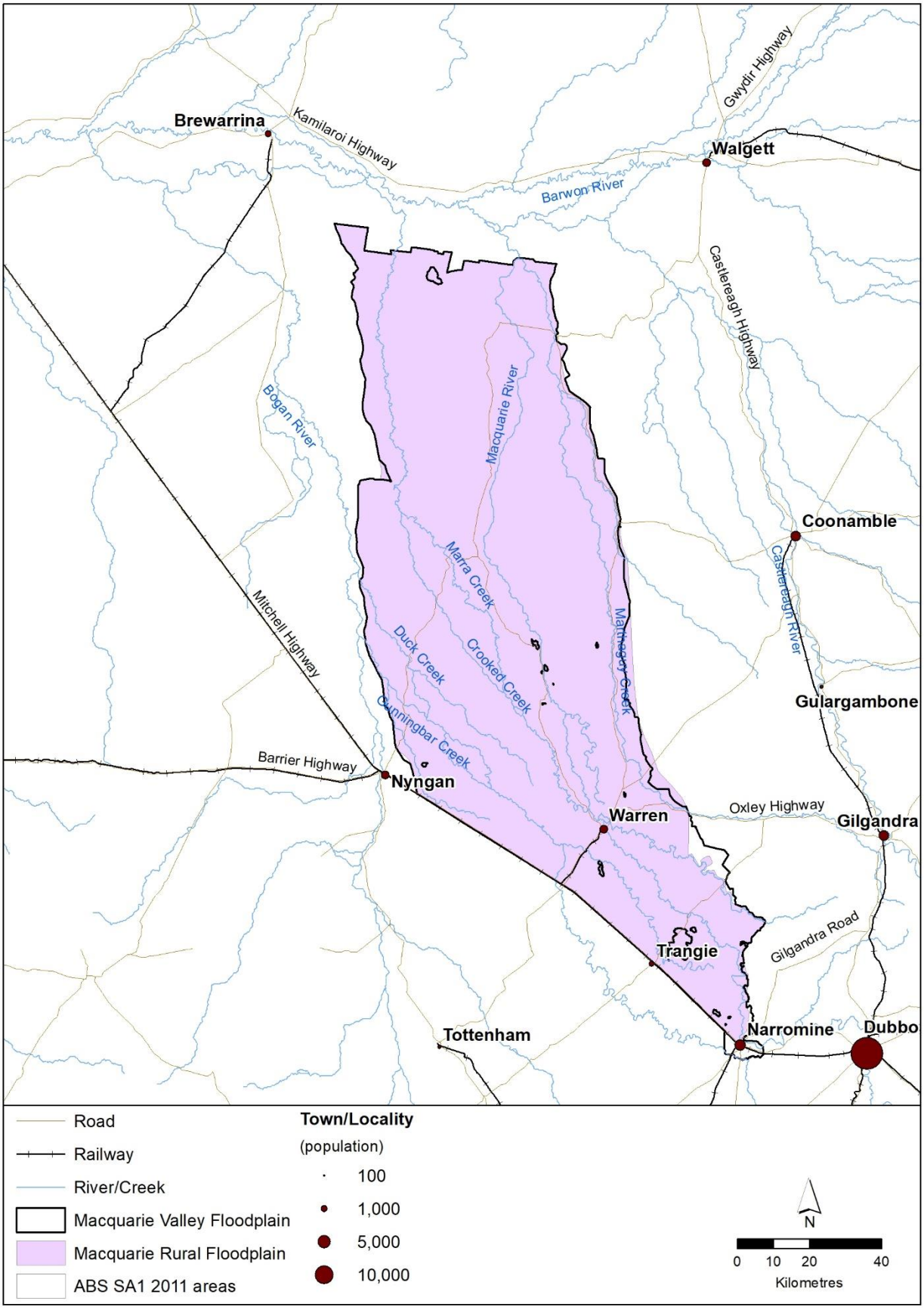

Figure 25: Macquarie valley floodplain and Macquarie Rural floodplain area

Data sources

Demographic data for the Macquarie floodplain economy, Macquarie rural floodplain and Macquarie urban floodplain – on population including the Indigenous community; on sex and age ratios; on household weekly incomes; and on labour participation rates and employment by industry sector – is drawn from the Australian Bureau of Statistics (ABS) Census of Population and Housing 2011 Statistical Area level 1 (SA1) data (ABS 2011a). The SA1 areas are the smallest unit for release of Census data. The SA1 boundaries combine to form the boundary of the Macquarie floodplain economy and the Macquarie urban floodplain areas. The Macquarie rural floodplain area is defined as parts of 13 SA1 areas. Regional population trends for the LGAs have been drawn from the ABS Regional Population Growth 2013 data (ABS 2013).

Information on the relative socio-economic advantage and disadvantage rankings for the LGA and SA1 areas is drawn from the ABS Census of Population and Housing 2011 Socio-economic Indexes for Areas (SEIFA) (ABS 2011b).

Agricultural production is a significant component of the Macquarie floodplain economy. The ABS Agricultural Census 2011 (ABS 2011c) provides comprehensive data on dry land and irrigated agricultural production at the Statistical Area level 2 (SA2). SA2 areas are a general-purpose, medium-sized area built from whole SA1s. The SA2 communities of the Macquarie floodplain economy include parts of the SA2 regions of Nyngan – Warren, Coonamble, Walgett – Lightning Ridge, Narromine, and Bourke – Brewarrina.

Demographic profiles

The demographic data in Table 9 includes information on the population, percentage of the population living in towns, percentage of the community who are Aboriginal, gender ratio and the dependency ratio for each geography, alongside the state average.

Table 9: Demographic information per socio-economic geography

Geography	Population	Living in towns	Aboriginal community	Gender ratio (M to F)	Dependency ratio (not working vs working)
Macquarie floodplain economy[1]	12,700	65%	22.2%	0.99	0.66[2]
Macquarie Rural floodplain	1,410[3]	n/a	8.3%	1.05	0.55[2]
Macquarie Urban floodplain	8,230	n/a	22.0%	0.96	0.74[2]
State average	n/a	n/a	2.5%	0.97	0.52

[1] The information about population is based on ABS collection district (CD) boundaries that do not match the boundary of the Macquarie Floodplain economic areas (rural and urban floodplain). As such, the total of the Macquarie rural and urban populations does not equal the overall Macquarie floodplain economy.

[2] May be overstated.

[3] Based on 11 people per 100 square kilometres, according to the ABS Census 2011.

The age-by-sex distribution of the Macquarie floodplain economy and the Macquarie rural floodplain community reveals an under-representation in the 15-to-45 age group, as compared to the under-15 and over-45 age groups of the NSW population. The Macquarie urban floodplain community has an under-representation in the 15-to-39 age group, but to a lesser degree than observed in the Macquarie rural floodplain community.

Employment by industry

Employment in the Macquarie floodplain economy is predominantly within the agricultural, forestry and fishing sector, which represents 27.5% of employment (1,480 persons, a number that includes employment in a large agricultural area that is not on the Macquarie rural floodplain). In contrast, the NSW state agriculture sector engages 2.2% of the workforce. The next most significant employment sectors are health care and social assistance, education and training, and retail trade, with 10.8%, 8.9% and 8.3% of employment respectively.

Employment in the Macquarie rural floodplain is dominated by the agriculture, forestry and fishing sector; 55.8% of the workforce – 440 people – work in this industry. In contrast, employment in the Macquarie urban floodplain is reasonably evenly distributed across sectors; a significant proportion of the workforce is employed in the service sectors of health care and social assistance; retail trade; education and training; and public administration and safety.

Income

The proportion of low-income households in the Macquarie floodplain economy, the Macquarie rural floodplain and the Macquarie urban floodplain was 34%, 24% and 37% respectively, compared with the NSW state proportion of 23%.

Medium-income households made up 57% of the Macquarie floodplain economy, 64% of the Macquarie rural floodplain and 56% of the Macquarie urban floodplain, all of which are close to the NSW proportion of 56%.

The proportion of high-income households within these 3 areas (9%, 12% and 7% respectively) are each lower than the NSW state proportion of 21%.

Economic wellbeing indicators

The Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) uses 25 variables to rank areas in terms of relative socio-economic advantage and disadvantage. An area with a high score on this index has a relatively high incidence of advantage.

The IRSAD scores for key regions are (see Appendix 10):

- LGAs of Bogan (A), Brewarrina (A), Coonamble (A), Narromine (A), Walgett (A) and Warren (A) are in the first to fourth decile of NSW, demonstrating distinct relative disadvantage.
- The rural floodplain areas are generally within deciles 5 to 8, indicating that they are neither advantaged nor disadvantaged, or are relatively advantaged, excepting the SA1 surrounding Brewarrina (in the first decile), which is substantially disadvantaged.
- The index scores for the smaller SA1 areas representing the townships of Narromine, Warren, Nyngan and Trangie are all within deciles one to 3 – indicating that they are relatively disadvantaged – except for one SA1 on the south east of Narromine.

Production

Agricultural production is the significant economic activity of the region's economy, occupying 97% of the farm holdings in the Macquarie Valley FMP 2021 area. In 2010–11, the gross value of agricultural production (GVAP) in the Macquarie Valley FMP 2021 area, using a farm holding area of 972,800 hectares, was estimated to be $180 million or 1.9% of total NSW GVAP. The gross value of broadacre cropping, estimated at $140 million, constitutes 78% of the GVAP of the FMP area, using 275,400 hectares or 28% of the area.

The individual broadacre crops that produce the highest value are wheat-yielding crops ($79 million or 44% of the total FMP area GVAP), and cotton-yielding crops ($26 million or 14%). Livestock and livestock products yield $40 million, accounting for 22% of GVAP while using 69% of the area.

In 2010–11, there was an estimated total of 15,800 hectares of irrigated land in the Macquarie Valley FMP 2021 area. This area of irrigated land constitutes approximately 2% of the Macquarie Valley FMP 2021 farm holding area. It is estimated that in 2010–11 alone, 76,000 ML of water was extracted for agricultural irrigation across the region. The majority of this was applied to cotton, using 60,700 ML or 80%, at an estimated average rate of 5.9 ML per hectare.

Step 7: Delineate management zones

In Step 7, the nature and location of the draft management zones for the Macquarie valley floodplain was determined using hydraulic, ecological and cultural criteria, as well as criteria to ensure the draft plan reflects current floodplain management arrangements. This approach considered the impact of existing and future development on flooding in rivers and floodplains; the flood risk to life and property; the flood connectivity of floodplain assets; and the social and economic impacts of restricting flood work development.

The above approach resulted in 6 management zones for the Macquarie Valley FMP 2021.

Description of management zones

The Macquarie Valley FMP 2021 contains 6 management zones (MZs) (Figure 26):

- MZ A – major discharge areas (204,800 hectares or 17% of the floodplain)
- MZ BH – major discharge areas in high-level floodway areas (18,500 hectares or 2% of the floodplain)
- MZ B – flood storage and secondary flood discharge areas (314,900 hectares or 25% of the floodplain)
- MZ C – flood fringe and flood-protected developed areas (626,100 hectares or 50% of the floodplain)
- MZ CU – urban areas managed by local councils (6,000 hectares or less than 1% of the floodplain)
- MZ D – special environmental and cultural protection areas (70,200 hectares or 6% of the floodplain)

A map of the MZs is shown in Figure 27 and a summary description is provided below. More detailed maps are provided in Appendix 11.

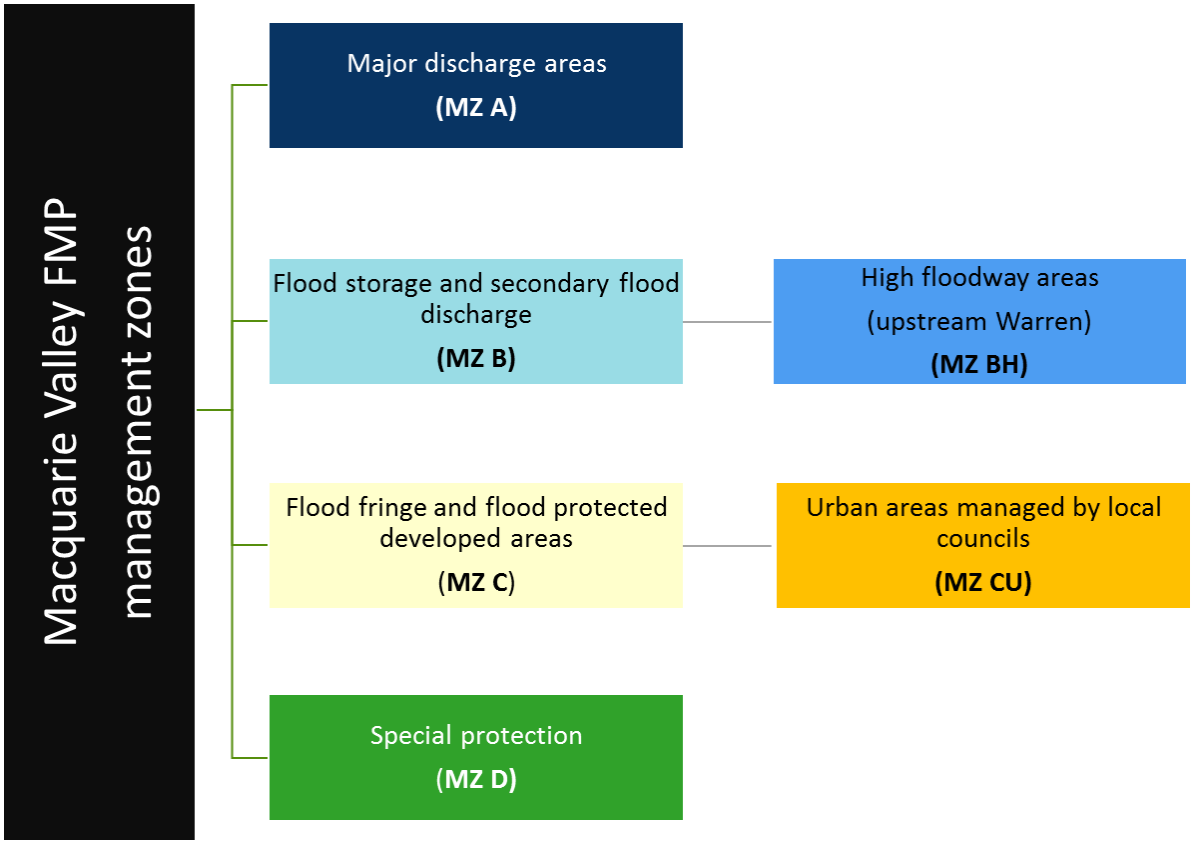

Figure 26: Macquarie Valley FMP 2021 management zones

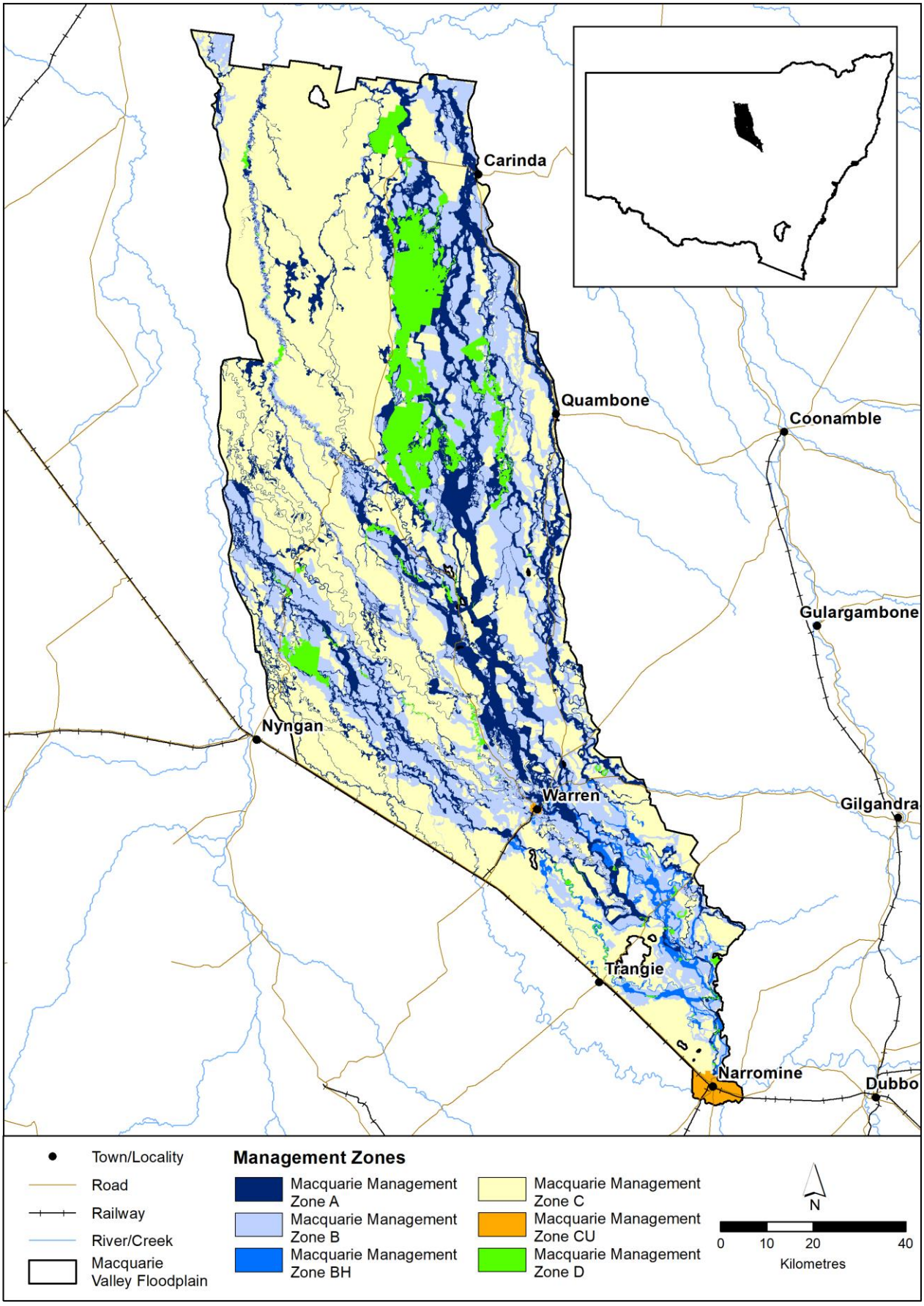

Figure 27: Map of the management zones in the Macquarie valley floodplain

Management Zone A – major flood discharge areas

MZ A covers 204,800 hectares or 17% of the floodplain. It includes defined floodways with major drainage lines, and other areas where a significant discharge of floodwater occurs during all flood events. These floodways are the areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood level. These areas are generally characterised by relatively high flood-flow velocity and DVP thresholds.

MZ A includes floodways that have a DVP threshold of greater than 0.1 square metres per second for the 1990 large design flood in areas downstream of Warren, and greater than 0.1 square metres per second for the 2000 large design flood in areas upstream of Warren.

Floodplain connectivity is provided for in MZ A by incorporating parts of the small design flood extent (2012).

MZ A includes areas where uncoordinated flood work development may have a high adverse impact on flood behaviour. It was designed to reduce the risk to life and property by limiting flood work development to prevent flood-flow redistribution, increased flood velocities and higher flood levels. MZ A was designed to ensure there is continuity of flow and flow paths, and to assist in maintaining the overall flow distribution on the floodplain.

MZ A is also important for the conveyance of floodwater to highly flood-dependent ecological and cultural assets. MZ A includes a high proportion of the extent of semi-permanent wetland and key fish passage areas, to ensure connectivity to these significant assets that are highly dependent on flooding. MZ A was also designed to provide flood connectivity to floodplain wetland (flood-dependent shrubland wetlands) and flood-dependent forest/woodland (wetlands).

MZ A includes a large proportion of the extent of Aboriginal values that are highly flood-dependent. Certain trees that have been modified by Aboriginal people have also been included in MZ A. Such trees are scarred or carved trees, were found to be living, are in close proximity to floodways and require relatively frequent flooding to maintain their ecological character.

Rules in MZ A aim to ensure that only minor works will be built. This will prevent flood flow redistribution and ensure there is continuity of flow paths to help maintain the overall flow distribution on the floodplain.

Where the Macquarie valley floodplain joins the Barwon–Darling valley floodplain 2017, floodways in the Macquarie Valley FMP 2021 have been aligned to ensure floodway continuity and protection between floodplains.

Management Zone BH – major flood discharge areas in high-level floodways

MZ BH covers 18,500 hectares or 2% of the floodplain. It is only used upstream of Warren, where there are large areas of existing development subject to significant flood discharge during major flood events. It includes high floodway areas with major drainage lines and other areas where a significant discharge of floodwater occurs during the 1990 large design flood and larger floods. These areas are generally characterised by relatively large flood flow velocity and depth-velocity thresholds. MZ BH includes floodways that have a depth-velocity threshold of greater than 0.1 square metres per second for the 1990 large design flood, but which are outside the extent of the floodways defined by the 2000 large design flood (MZ A).

MZ BH includes areas where uncoordinated flood work development may have a high adverse impact on flood behaviour. It was designed to reduce the risk to life and property by regulating flood work development to prevent flood flow redistribution, increased flood velocities and higher flood levels, without having a significant socio-economic impact.

MZ BH includes ecological assets that have a high level of flood dependency that were not captured within MZ A. MZ BH may include highly water-dependent ecological assets such as semi-permanent wetlands and areas of key fish passage.

MZ BH also includes cultural assets such as modified trees that are likely to only be flood connected during moderate and large floods. Such trees are scarred or carved trees, were found to be living and are in close proximity to floodways.

Proposed rules for MZ BH will prevent flood-flow redistribution and ensure continuity of flow paths to help maintain the overall flow distribution on the floodplain while providing for appropriate flood work development.

Management Zone B – flood storage and secondary discharge areas for design floods

MZ B covers 314,900 hectares or 25% of the floodplain. It includes areas that are important for the conveyance of floodwater during large flood events and for the temporary storage of floodwaters. MZ B also includes areas that are protected by existing flood works that are of limited height and are overtopped by large floods.

The outer boundary is defined by the modelled inundation extent of the 1990 large design flood.

MZ B included ecological assets that have a moderate level of flood dependency. MZ B may include areas of floodplain wetland (flood-dependent shrubland wetlands); flood-dependent forest/woodland (wetlands) that were not captured entirely within MZ A; and areas of flood-dependent woodlands. MZ B also includes cultural assets such as modified trees that are likely to only be flood connected during moderate and large floods.

MZ B is important for the conveyance of floodwater to floodplain assets during larger flood events. This zone includes areas where coordinating flood work development is important to manage the cumulative and local impact of works on flood behaviour.

Proposed rules for MZ B support the maintenance of flow paths and temporary storage of floodwaters while providing for appropriate flood work development.

Management Zone C – flood fringe areas and existing developed areas

MZ C covers 626,100 hectares or 50% of the floodplain. It contains flood fringe areas that are typically outside the extent of the design floods and flood-protected developed areas. Flood-protected developed areas are protected by flood works that are of unlimited height and are not overtopped by water during moderate to large floods.

Ecological assets that are highly flood-dependent were not recommended for inclusion in MZ C. However, ecological assets that occur in this zone may include areas of floodplain wetland (flood-dependent shrubland wetlands); flood-dependent forest/woodland (wetlands); and flood-dependent woodlands occurring adjacent to floodplain watercourses in flood fringe areas. Some of these assets may occur in developed areas that are potentially disconnected from flooding. All flood-dependent ecological assets in this management zone are to be considered during the assessment of flood work applications, to ensure that the proposed flood work can be constructed to maintain adequate flood connectivity to ecological assets and to facilitate fish passage.

MZ C also includes some cultural assets such as scarred trees. Generally, these trees are species that require infrequent flooding or where the record of the tree could not be verified. All cultural asset records in this management zone are to be considered during the assessment of flood work applications.

The rules and assessment criteria of MZ C are less restrictive than other management zones, as MZ C includes areas where flood work development is unlikely to have a significant effect on flood behaviour. Nevertheless, an assessment of flood connectivity to semi-permanent wetlands, floodplain wetlands (flood-dependent shrubland wetlands), flood-dependent forest/woodland (wetlands) and flood-dependent woodlands must be undertaken as part of the flood work assessment process in each of the management zones.

Management Zone CU – urban areas managed by local councils

MZ CU covers 6,000 hectares or less than 1% of the floodplain. It captures urban areas that are covered by a FS, FRMS or FRMP, or that are protected by flood mitigation works such as town levees.

It includes parts of the towns of Narromine, Warren and Quambone, where flood risk is managed by local councils through FRMPs and studies developed in accordance with the *Floodplain Development Manual* (NSW Government 2005).

Management Zone D – special environmental and cultural protection areas

MZ D covers 70,200 hectares or 6% of the floodplain. It is a special protection zone for areas of ecological and cultural significance. MZ D includes floodplain assets that are highly flood-dependent and have a high ecological value or high cultural value as determined from consultation with the Aboriginal community. Examples of MZ D areas in the Macquarie valley floodplain are provided in Figure 28 and Figure 29. To ensure the ongoing and improved health and condition of these significant assets, only flood works of a minor nature can be approved in MZ D. There are thirty MZ D areas, as listed in Appendix 12.

Rules in MZ D aim to ensure that only flood works with a positive outcome for the asset or value can be built in the area. This will help maintain flood connectivity to significant floodplain assets.

Figure 28: Goan Waterhole, Trangie – an example of an MZ D area in the Macquarie valley floodplain (S. Hunter, OEH, May 2017)

Figure 29: Monkeygar Swamp, Macquarie Marshes – an example of an MZ D area in the Macquarie valley floodplain (S. Hunter, OEH, May 2017)

Hydraulic criteria

Management zones were initially established based on hydraulic criteria, which were developed using information on flood behaviour contained in the floodway network (Table 6 and Figure 12). The following 4 hydraulic categories were the basis of MZ A, MZ BH, MZ B and MZ C:

- **floodways** are the hydraulic basis for MZ A
- **high-level floodways** are the hydraulic basis for MZ BH
- **inundation extent** up to the large design flood is the hydraulic basis for MZ B
- **flood fringe** (areas outside the floodway network) is the hydraulic basis for MZ C

MZ CU and MZ D are not derived specifically from the floodway network.

Ecological criteria

Floodplain water flows are crucial to maintaining the structure, function and long-term survival of flood-dependent ecological assets such as semi-permanent (non-woody) wetlands. Flood work development has the potential to change the passage of floodwater, which can have adverse impacts on flood-dependent ecological assets. To minimise the likelihood of this occurring, ecological criteria were developed to maintain flood connectivity to wetlands, floodplain ecosystems and areas of groundwater recharge. The criteria outline the optimum surface watering requirements for each asset, and the recommended management zone that aligns with these requirements (Table 10).

Ecological criteria were developed to ensure that wetlands, floodplain ecosystems and areas of groundwater recharge are not impacted by changes to the passage of floodwater caused by new flood works or amendments to existing flood works. Refinements were made to MZ A, MZ BH and MZ B to incorporate hydro-ecological functional groups based on optimum surface water requirements (Step 5).

Where there was hydraulic justification, the following ecological amendments were made to:

- MZ A and MZ BH – to capture all high-priority semi-permanent (non-woody) wetlands
- MZ A and MZ BH – to capture hydraulic connections to and through ecological assets identified as high-priority floodplain (flood-dependent shrubland) wetland and flood-dependent forest/woodland (wetlands)
- MZ A and MZ BH – to ensure floodways facilitate fish passage. Key fish passage areas were identified using NSW Fish Community Status and Threatened Fish Species Distributions (Aquatic Biodiversity Value Mapping Project) (NSW DPI 2016) based on the predicted current distributions of:
    - downstream of Warren (Oxley Highway):
        - Silver Perch (*Bidyanus bidyanus*)
        - Eel-Tailed Catfish (*Tandanus tandanus*)
        - Olive Perchlet (*Ambassis agassizii*)
    - upstream of Warren (Oxley Highway):
        - Silver Perch (*Bidyanus bidyanus*)
        - Eel-Tailed Catfish (*Tandanus tandanus*)
        - Olive Perchlet (*Ambassis agassizii*)
        - Trout Cod (*Maccullochella macquariensis*)
- MZ D – to capture ecological assets where that asset is a location or landscape feature with:
    - a high degree of floodwater dependency
    - a high degree of habitat complexity
    - a history of supporting a diversity or abundance of waterbird, native fish or frog populations
    - the functional capacity to act as an aquatic drought refuge
    - recognition in or the protection of a local, state or federal environmental policy or law.

No management zones were adjusted on the basis of groundwater recharge, due to the lack of information and the unreliable nature of data that was available.

Ecological criteria were finalised in discussion with TAG members and local experts. The breakdown of these management zone recommendations is presented in Table 10.

Table 10: Ecological criteria, including management zone recommendations for each ecological asset type

Asset	Description	Ideal frequency of watering	Management zone recommendation
Wetland*	Semi-permanent (non-woody) wetland	Annual or near annual	MZ A or MZ BH (entire mapped area)
Wetland*	Floodplain (flood-dependent shrubland wetland)	Every year to once every 5 years	MZ A or MZ BH (mapped area at least connected)
Other floodplain ecosystems	Flood-dependent forest/woodland (wetlands)	Once every 3 to 5 years	MZ A or MZ BH (mapped area at least connected)
Other floodplain ecosystems	Flood-dependent woodland	1 in <10 years	MZ B

Asset	Description	Ideal frequency of watering	Management zone recommendation
Areas of groundwater recharge	Likely recharge	n/a	MZ A, BH or B*

*Wetlands include lakes, lagoons, rivers, floodplains, swamps, billabongs and marshes. Due to limited groundwater recharge information, no modification of management zones could be undertaken.

The management zone recommendations, outlined in Table 10, were initially used to determine if ecological assets were captured in the recommended management zone.

Where ecological assets were not captured in the recommended management zone, the management zones were refined using interpretation of LiDAR-derived DEM, hydraulic modelling and inundation data (Fisher et al. 2016; Thomas et al. 2015; Thomas et al. 2010) (Figure 30).

Where a management zone could not be amended to connect recommended asset types (that is, where there was no hydraulic justification), these assets will be protected by applying the management zone rules and assessment criteria (Step 8) as part of the flood work assessment process.

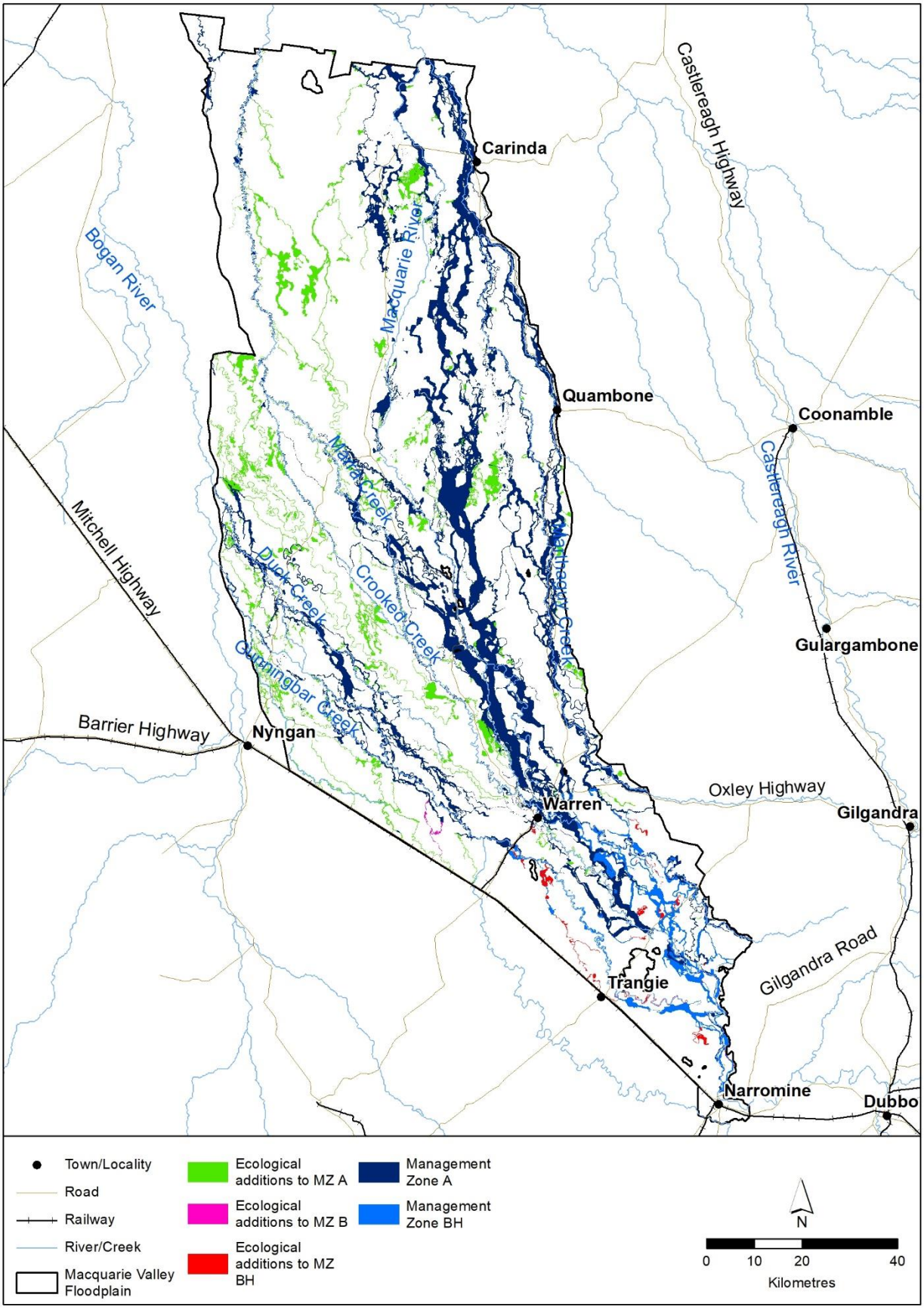

Figure 30: Refinements to Management Zone (MZ) A, MZ BH and MZ B based on ecological criteria

Cultural criteria

Cultural criteria were developed to ensure that flood-dependent Aboriginal heritage sites and values are not impacted by flood behaviour changes caused by flood work development (Table 11). Historic heritage sites that are not flood-dependent were not included as part of the cultural criteria for management zone delineation.

Cultural criteria were based on the flood dependency of Aboriginal values and heritage sites determined in Step 5. Cultural criteria were finalised in discussion with TAG members and local Aboriginal heritage experts. Three cultural criteria were used to refine MZ A and MZ BH (where there was hydraulic justification) to incorporate cultural assets:

1. Aboriginal values (excluding scarred and carved trees) that are highly flood-dependent, if they:
    - are listed on the department's AWIS database, or
    - are listed on the NSW AHIMS, or
    - were identified during direct community consultation with the local Aboriginal community.
2. Scarred or carved tree locations where the trees are:
    - living flood-dependent vegetation that generally requires flooding at least every 5 years to maintain their ecological character and cultural value
    - within 100 metres of hydraulic MZ A.
3. Heritage sites that are flood-dependent and are cultural heritage objects and places as listed on federal, state and local government heritage registers.

Table 11: Cultural criteria to include cultural assets in recommended management zones

Asset	Type	Description	Management zone recommendation	Criteria for management zone inclusion
Aboriginal values	Scarred or carved trees	Living, flood-dependent vegetation	Variable – refer to vegetation	Include area in recommended MZ if within 100 metres
Aboriginal values	Places identified by the community	Some flood-dependent, others linked to flooding.	MZ D	Include whole of mapped area in MZ D
Heritage sites	Bridges	Not flood-dependent	n/a	n/a
Heritage sites	Weirs	Not flood-dependent	n/a	n/a
Heritage sites	Locks	Not flood-dependent	n/a	n/a

To ensure management zone refinements represent on-ground conditions and to account for data accuracy and confidence, the above criteria were validated in the field against expert recommendations. Where there is no hydraulic justification for amending the management zones, applying management rules and assessment criteria as part of the flood work assessment process will protect flood connectivity of these assets (Step 8).

In addition to the refinements made to MZ A and MZ BH, cultural criteria were developed to include floodplain assets in MZ D. Criteria for classifying a cultural asset as MZ D required that the asset was a location or landscape feature with a high degree of:

- floodwater dependency, such as swamps, marshes, lagoons, billabongs, rocky bars or warrumbools that are strongly dependent on the passage of floodwater, or

- cultural significance to the Aboriginal community – including spiritual, archaeological or resource use-values – and are listed on a heritage register or by a scientific publication.

Due to cultural sensitivities surrounding MZ D cultural assets, a map of the cultural refinements made to management zones is not provided.

Non-flood-dependent cultural assets

The design of the management zones did not deal with cultural assets:

- vulnerable to the effect of erosion associated with the redistribution of flood flow
- vulnerable to the direct impacts of the installation of new flood works, or
- affected by the modification of current works.

Where identified, these cultural assets will be an additional consideration when assessing flood work applications.

Criteria to reflect current floodplain management arrangements

The purpose of this stage was to amend management zones to reflect current floodplain management arrangements. Management zones were reviewed for consistency with the Macquarie River FMP 2008 and urban areas were reviewed for consistency with existing floodplain management arrangements. This included reviewing and considering identified floodway areas within the Macquarie River FMP 2008 when developing and refining the boundaries of MZ A.

In areas where current and proposed floodplain management arrangements could not be aligned, as outlined in Step 9, the changes reflect improvements in understanding the floodplain and flood behaviour, improvements in spatial knowledge of existing flood work development and a more consistent approach to floodplain management across the floodplain.

MZ A and MZ B were also amended to ensure the zones were congruent with the management zones for the neighbouring Barwon–Darling Valley Floodplain Management Plan 2017.

Macquarie River FMP 2008 – existing flood works

It was found that a significant number of existing flood works within the Macquarie valley floodplain are unapproved and do not comply with existing floodplain management arrangements. This primarily involved considering flood works located within the Macquarie River FMP 2008 floodway network, representing existing floodplain management arrangements (Step 9 contains more information on existing floodplain management arrangements). These works are non-compliant with existing floodplain management arrangements and require supporting flood studies to determine their impact and subsequent modifications. While many of these works may be acceptable and may cause minimal impact to flood behaviour in areas within the 2008 floodway network and surrounding developed areas, a process was required to determine which works were causing significant hydraulic impacts and how these would be considered in finalising the hydraulic criteria for the management zones.

This process relied on developing a ‘works removed’ version of each hydraulic model, where every flood work that did not comply with existing floodplain management arrangements was removed from the model topography. Results from this scenario were then compared to the corresponding existing ‘works in place’ scenario for each hydraulic model using a comparison of DVP results for the 1990 large design flood. A decision tree was developed to identify those parts of the floodplain where management zones should be altered based on DVP impacts, and whether these impacts were localised or affecting the surrounding floodplain, including developed areas.

The decision tree is shown in Appendix 13 and considers whether removing the works:

- results in a significant increase in the DVP (more than 0.1 square metres per second)
- affects neighbouring properties
- impacts areas within the Macquarie River FMP 2008 floodway network
- impacts developed areas
- affects areas identified as 'Regional Hydraulic Areas of Concern' in the Macquarie River FMP 2008.

The existing works assessment identified 14 areas (about 20,000 hectares) where existing unapproved works were removed from hydraulic models to finalise the design of the management zones.

Unapproved flood works were only removed from the 'works removed' hydraulic models used to develop the management zones for the 14 critical areas described above. In all other floodplain areas, unapproved flood works were zoned using an existing works model. Where unapproved works excluded flood water in the existing works model, the area was reviewed against multiple lines of evidence to determine if the area without the work in place would be considered flood-prone. Flood-prone areas protected by unapproved flood works were zoned MZ B. Evidence included available pre-development and 'works removed' hydraulic modelling outputs, flood imagery, ecological assets and cultural assets.

Approved flood works designed to be overtopped during moderate to large floods were made MZ B. Approved flood works that are designed to not be overtopped during flooding were made MZ C.

Urban areas in the floodplain (MZ CU)

MZ CU includes urban areas where flood risk is managed by local councils in accordance with Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act). For an urban area to be declared as MZ CU:

- a town levee must protect the urban area, or
- the urban area that is not flood-protected must be covered by a FS, FRMS or a FRMP.

In the Macquarie Valley FMP 2021, the following towns are included in MZ CU:

- Narromine (5,600 hectares)
- Quambone (81 hectares)
- Warren (400 hectares).

Summary of management zone criteria

The configuration of management zones in the Macquarie valley floodplain was based on 4 categories of management zone criteria (Figure 31):

- hydraulic criteria
- ecological criteria
- cultural criteria
- criteria to better reflect current floodplain management arrangements.

MZ A, MZ BH, MZ B and MZ C were primarily based on hydraulic criteria with some modifications made based on ecological criteria and criteria to better reflect existing planning arrangements.

MZ CU was based on towns managed by local councils identified as part of the criteria to better reflect current floodplain management arrangements.

MZ D was based on ecological and cultural assets identified using ecological and cultural criteria.

A breakdown of the criteria for each management zone, represented as a percentage, is provided in Figure 31.

Note that within each zone there are areas that meet the definition of multiple assessment criteria. For example, a location in MZ A downstream of Warren may have a DVP greater than 0.1 square metres per second for the 1990 large design flood, but also be identified as a key fish passage area. The area meets both the hydraulic and ecological criteria for MZ A, but would be included as hydraulic MZ A in Figure 31 because the basis for MZ A is primarily hydraulic.

Figure 32 outlines the percentage that each management zone occupies in the Macquarie valley floodplain. MZ C is the largest zone, occupying 50% of the total floodplain area. MZ CU and MZ BH are the smallest zones, occupying less than 1% and 2% of the total floodplain area respectively.

A summary of the criteria for delineating management zones is provided in Table 12.

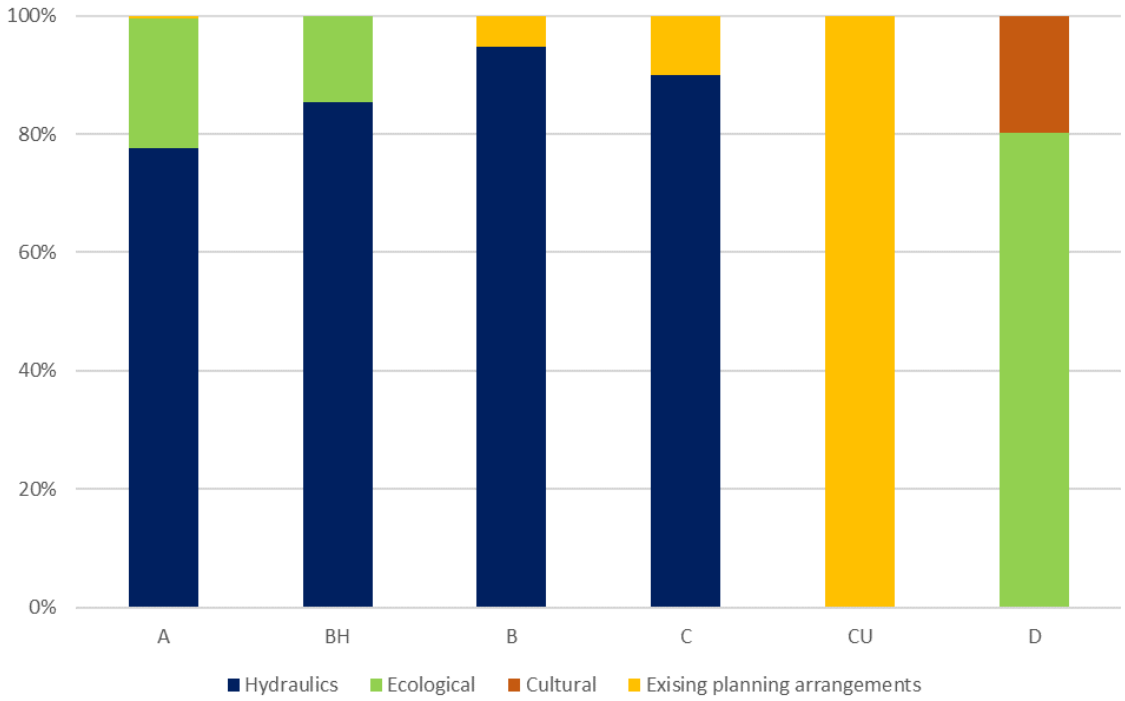

Figure 31: Percentage breakdown of criteria used to delineate each management zone

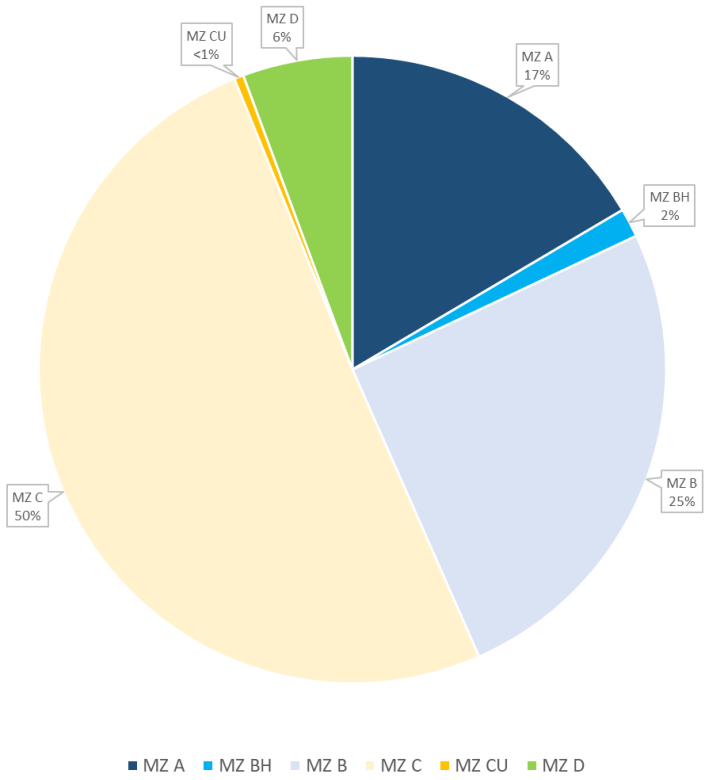

Figure 32: Percentage of each management zone in the Macquarie valley floodplain

Table 12: Compilation of management zone criteria

Management zone	Criteria	Description
A	Hydraulic	**Upstream of Warren** MZ A includes major discharge areas that have a DVP of greater than 0.1 m^2/s for the 2000 large design flood. Floodplain connectivity was provided for by incorporating parts of the 2012 small design flood extent. To ensure conditions on the ground are adequately represented, the above criteria were road tested against the following additional data: • flood aerial photography and satellite imagery from design floods • spatial watercourse layers, topographical mapping, ADS40 DEM and LiDAR-derived DEM • previous floodplain management plans and development guidelines • local knowledge obtained from floodplain communities and floodplain/environmental managers. **Downstream of Warren** MZ A includes major discharge areas that have a DVP of greater than 0.1 m^2/s for the 1990 large design flood. Floodplain connectivity was provided for by incorporating parts of the 2012 small design flood extent. To ensure conditions on the ground are adequately represented, the above criteria were road tested against the following additional data: • flood aerial photography and satellite imagery from design floods • spatial watercourse layers, topographical mapping, ADS40 DEM and LiDAR-derived DEM • previous floodplain management plans and development guidelines • local knowledge obtained from floodplain communities and floodplain/environmental managers.
A	Ecological	MZ A includes, where there is hydraulic justification: • semi-permanent wetland • connections to or through floodplain wetland (flood-dependent shrubland wetlands) and flood-dependent forest/woodland (wetlands) • key fish passage areas identified using NSW Fish Community Status and Threatened Fish Species Distribution Data – Aquatic Biodiversity Value Mapping Project (NSW DPI 2016) • a 40-metre buffer applied to the high-water mark of ecological assets.
A	Cultural	MZ A includes, where there is hydraulic justification: • floodplain areas with Aboriginal values that are highly flood-dependent, that were identified during direct community consultation with the local Aboriginal community or are listed on the AWIS and AHIMS databases • locations for scarred or carved trees that are living, flood-dependent vegetation that generally require flooding to maintain their ecological character and cultural value • locations for heritage sites that are flood-dependent and are cultural heritage objects and places listed on federal, state and local government heritage registers.

Management zone	Criteria	Description
A	Existing floodplain management arrangements	The Macquarie River FMP 2008 was reviewed, and some changes were made to MZ A to provide consistency. In some areas, MZ A differs to the Macquarie River FMP 2008 floodway network due to improvements in the knowledge of flood behaviour and available data. MZ A was made congruent with MZ A of the bordering Barwon–Darling Valley FMP 2017. A 'works removed' version of the hydraulic model was also run to assess the hydraulic impact of Macquarie River FMP 2008 non-complying flood works, this resulted in adjustments to MZs in 14 critical areas due to updated hydraulic criteria using the decision tree in Appendix 13.
BH	Hydraulic	**Upstream of Warren** MZ BH includes major discharge areas that have a DVP of greater than 0.1 square metres per second for the 1990 large design flood, but are outside the extent of the floodways defined by the 2000 large design flood in MZ A. Floodplain connectivity was provided for by incorporating parts of the 2012 small design flood extent. To ensure conditions on the ground are adequately represented, the above criteria were road tested against the following additional data: • flood aerial photography and satellite imagery from design floods • spatial watercourse layers, topographical mapping, ADS40 DEM and LiDAR-derived DEM • previous floodplain management plans and development guidelines • local knowledge obtained from floodplain communities and floodplain/environmental managers.
BH	Ecological	MZ BH includes, where there is hydraulic justification: • semi-permanent wetland • connections to or through floodplain wetland (flood-dependent shrubland wetlands) and flood-dependent forest/woodland (wetlands) • key fish passage areas identified using NSW Fish Community Status and Threatened Fish Species Distribution Data – Aquatic Biodiversity Value Mapping Project (NSW DPI 2016).
BH	Cultural	MZ BH includes, where there is hydraulic justification: • floodplain areas with Aboriginal values that are highly flood-dependent that were identified during direct community consultation with the local Aboriginal community or are listed on the AWIS and AHIMS databases • locations for scarred or carved trees that are living, flood-dependent vegetation that generally require flooding to maintain their ecological character and cultural value • locations for heritage sites that are flood-dependent and are cultural heritage objects and places listed on federal, state and local government heritage registers.
BH	Existing floodplain management arrangements	MZ BH includes some areas of the floodplain upstream of Warren where the Macquarie River FMP 2008 requires that new flood works are designed to be overtopped during large floods. A 'works removed' version of the hydraulic model was used to apply the hydraulic criteria in the 14 critical areas identified using the decision tree in Appendix 13.

Management zone	Criteria	Description
B	Hydraulic	MZ B includes the inundation extent of the small and large design floods, and any areas protected by existing flood works that are overtopped by the large design flood. To ensure conditions on the ground are adequately represented, the above criteria were road tested against the following additional data: • flood aerial photography and satellite imagery from design floods • spatial watercourse layers, topographical mapping, ADS40 DEM and LiDAR-derived DEM • previous floodplain management plans and development guidelines local knowledge obtained from floodplain communities and floodplain/environmental managers.
B	Ecological	MZ B includes, where there is a hydraulic justification, flood-dependent woodland and, to a lesser degree, flood-dependent forest or woodland where there was no hydraulic justification for inclusion in MZ A.
B	Cultural	MZ B includes, where there is hydraulic justification, locations for scarred or carved trees that are living and located within flood-dependent woodland.
B	Existing floodplain management arrangements	MZ B was made congruent with MZ B of the bordering Barwon–Darling Valley FMP 2017. MZ B includes some areas of the floodplain upstream of Warren where the Macquarie River FMP 2008 requires that new flood works are designed to be overtopped during large floods. MZ B may include areas of the floodplain that are enclosed by existing approved flood works designed to be overtopped during moderate to large floods. MZ B may also include areas of the floodplain enclosed by existing unapproved works that would otherwise be flood prone. A ‘works removed’ version of the hydraulic model was used to apply the hydraulic criteria in the 14 critical areas identified using the decision tree in Appendix 13.
C	Hydraulic	MZ C includes flood fringe areas of the floodplain that are outside the extent of the 1990 large design flood, and areas enclosed by existing flood works that are not designed to be overtopped during flooding. To ensure conditions on the ground are adequately represented, the above criteria were road tested against the following additional data: • flood aerial photography and satellite imagery from design floods • spatial watercourse layers, topographical mapping, ADS40 DEM and LiDAR-derived DEM • previous floodplain management plans and development guidelines • local knowledge obtained from floodplain communities and floodplain/environmental managers.
C	Ecological	The basis of MZ C was not ecological. However, some ecological assets that have been enclosed by existing approved flood works are located in MZ C.
C	Cultural	The basis of MZ C was not cultural. However, some cultural assets that have been enclosed by existing approved flood works are located in MZ C.

Management zone	Criteria	Description
C	Existing floodplain management arrangements	MZ C incorporate existing approved flood work development that is not designed to be overtopped during flooding. A 'works removed' version of the hydraulic model was used to apply the hydraulic criteria in the 14 critical areas identified using the decision tree in Appendix 13.
CU	Hydraulic	The basis for MZ CU was not hydraulic.
CU	Ecological	The basis of MZ CU was not ecological. If any assets fall within MZ CU, ecological asset mapping will be provided to the relevant local government authority for consideration in land-use planning and assessment of development applications.
CU	Cultural	The basis of MZ CU was not cultural. If any assets fall within MZ CU, the relevant local government authority will be notified and provided with relevant contact details.
CU	Existing floodplain management arrangements	MZ CU includes floodplain areas that are covered by an existing urban FS, FRMS or FRMP, or that are protected by flood mitigation works such as town levees.
D	Hydraulic	The basis for MZ D was not hydraulic.
D	Ecological	MZ D includes assets that are a location or landscape feature – such as a swamp, marsh, lagoon, anabranch or billabong – with a high degree of floodwater dependency and: • a high degree of habitat complexity • a history of supporting a diversity or abundance of waterbird, native fish or frog populations • the functional capacity to act as an aquatic drought refuge • recognition in or protected by a local, state or federal environmental policy.
D	Cultural	MZ D includes areas that have a high degree of floodwater dependency – such as swamps, marshes, lagoons, billabongs, rocky bars or warrambools – and have significance to the Aboriginal community, including spiritual, archaeological or resource use-values. These areas were listed on a heritage register or were recognised for their cultural significance by several senior knowledge holders in the Aboriginal community.
D	Existing floodplain management arrangements	MZ D was reviewed for consistency with the Macquarie River FMP 2008. Some of the existing planning requirements specified in the Warren Shire Council LEP 2012 were considered when developing MZD.

Modifying a management zone

The Macquarie Valley FMP 2021 (Part 10 Amendment of this Plan) provides opportunity for landholders to seek to modify a management zone.

Amendments may be made to modify the area to which the plan applies or any management zone, using any of the following information, or supporting information as determined by the Minister for Water, Property and Housing. This information can include:

- an aerial photograph or equivalent satellite image showing flood inundation at the property scale of either the small design flood or the large design flood

- oblique photos showing flood inundation of either the small design flood or the large design flood that contain verifiable landmarks
- oblique photos of flood survey marks that can be verified for either the small design flood or the large design flood.
- a hydraulic study that provides velocity and depth information for the large design flood may be used to support this information.

Step 8: Determine rules

The management zones and rules (including assessment criteria) together provide the legal framework for assessing flood work applications. Step 8 was undertaken to develop specific rules for defining the type, nature and construction of flood works that can occur in each management zone. The rules vary between management zones to reflect differences in flood behaviour and the floodplain environment. Step 8 was also undertaken to develop rules for licensing or modifying existing licences for eligible existing flood works in MZ A and MZ D.

The draft rules can be split into 4 general types, including those that:

- specify the physical nature of permissible flood works
- are advertising requirements
- are assessment criteria for determining the acceptable impacts of flood works
- relate to existing flood structures and works in MZ A and MZ D.

Assessment guidelines will support the finalised Macquarie Valley FMP 2021 to help apply the rules to applications.

The rules proposed in Step 8 should be considered in conjunction with the state-wide exemptions, as set out in the Water Management (General) Regulation 2011 (see 'Exemptions to flood work approvals' below for further information).

Permissible flood works

Permissible flood works are those for which an application for an approval will be accepted. Applications for permissible flood works must still go through the assessment process to receive an approval. Applications for non-permissible flood works will not be approved.

In MZ B/BH and MZ C/CU, all works are permissible (Table 13). In MZ A and MZ D, only minor works are permissible (Table 13). This reflects the relative risk of flood works affecting flood behaviour or the floodplain environment.

Permissible works were determined by considering the optimal balance between hydraulic, ecological, cultural and socio-economic considerations on the floodplain. They were selected to be sympathetic to landholder needs, and any decisions were checked against:

- works likely to be approved under existing floodplain management planning arrangements (Step 9 and Step 10: Phase 1)
- targeted consultation with the community and interagency officers.

Seven types of flood works were identified for the Macquarie valley floodplain:

- Aboriginal value, ecological and heritage site enhancement works – to provide a positive outcome for an ecological or cultural asset that is mapped by, recognised in or protected by the Macquarie Valley FMP 2021 or a local, state or federal environmental policy or law
- infrastructure protection works – to minimise risk to life and property
- private access roads – to ensure landholders have basic provisions to access property
- stock refuges – to account for animal welfare and minimise a landholder's potential to lose stock to floodwaters

- supply channels – to ensure supply channels reach water sources so landholders can access water rights
- waterponding works – to remediate scalded claypans and halt soil erosion
- other (non-specified) flood works – generally used for crop and land protection.

The rules in the Macquarie Valley FMP 2021 specify the physical nature of permissible flood works in MZ A and MZ D. These rules ensure that works likely to be approved are fit-for-purpose. They are also easy to interpret and apply without detailed technical assessment and are described in detail below.

The types of permissible flood work in each management zone are outlined in Table 13.

Table 13: Rules for permissible works by management zone

Management Zone	No.	Permissible flood work	Plan order reference
A	1	Aboriginal cultural value enhancement work	Part 8 Clause 36 (8)(a)–(e)
A	2	Access road	Part 8 Clause 36 (3)(a)–(c)
A	3	Ecological enhancement work	Part 8 Clause 36 (7)(a)–(i)
A	4	Heritage site enhancement work	Part 8 Clause 36 (9)(a)–(g)
A	5	Infrastructure protection work	Part 8 Clause 36 (6)(a)–(b)
A	6	Stock refuge	Part 8 Clause 36 (5)(a)–(c)
A	7	Supply channel below the natural ground surface	Part 8 Clause 36 (4)(a)–(b)
D	1	Aboriginal cultural value enhancement work	Part 8 Clause 46 (7)(a)–(e)
D	2	Access road	Part 8 Clause 46 (3)(a)–(c)
D	3	Ecological enhancement work	Part 8 Clause 46 (6)(a)–(i)
D	4	Heritage site enhancement work	Part 8 Clause 46 (8)(a)–(g)
D	5	Infrastructure protection work	Part 8 Clause 46 (5)(a)–(b)
D	6	Stock refuge	Part 8 Clause 46 (4)(a)–(c)
BH	1	All types of flood works are permissible.	Part 8 Division 3
B	1	All types of flood works are permissible.	Part 8 Division 4
C	1	All types of flood works are permissible.	Part 8 Division 5
CU	1	All types of flood works are permissible.	Part 8 Division 6

The rules that specify the physical nature of permissible flood works in MZ A and MZ D are described in detail below.

Ecological enhancement work

In MZ A and MZ D, ecological enhancement works must provide a positive outcome for an ecological asset that is mapped by, recognised in or protected by this Macquarie Valley FMP 2021, or by a local, state or federal environmental policy or law.

Justification for specifications

An ecological enhancement work is a type of flood work that provides a positive outcome for the environment. These types of works are permissible in MZ A and MZ D as they will provide a positive outcome for the environment, consistent with the WM Act additional provision 30(c), which allows for an FMP to allow for the restoration or rehabilitation of land and water sources or their dependent ecosystems, in particular in relation to:

- the passage, flow and distribution of floodwater
- existing dominant floodways and exits from floodways
- rates of flow, floodwater levels and duration of inundation
- downstream water flows
- natural flood regimes, including spatial and temporal variability.

Aboriginal value enhancement works

In MZ A and MZ D, an Aboriginal value enhancement work must provide positive outcomes for an Aboriginal value asset that is listed on one of the following databases:

- NSW AHIMS
- MDBA Aboriginal Submissions Database
- NSW State Heritage Register
- Australian Heritage Database (also referred to as the Commonwealth Heritage Register)
- any other source deemed relevant by the Minister for Water, Property and Housing.

Justification for specifications

An Aboriginal value enhancement work is a type of flood work that enables the protection of locations or landscape features that have Aboriginal value. These types of works are permissible in MZ A and MZ D areas as they will provide a positive outcome for locations or landscapes that contain Aboriginal values. This rule is consistent with the objects of the WM Act clauses 3(c)(iii) and (iv), which ensure that culture and benefits to Aboriginal people in relation to their spiritual and customary use of land and water are recognised and incorporated into sustainable water resource management. As Aboriginal values are linked with ecological assets, this rule is also consistent with the WM Act additional provision 30(c), which allows for an FMP to allow for the restoration or rehabilitation of land and water sources or their dependent ecosystems, as outlined above.

Heritage site enhancement works

In MZ A and MZ D, a heritage site enhancement work must provide a positive outcome for a heritage site asset that is listed in one of the following databases:

- NSW AHIMS
- MDBA Aboriginal Submissions Database
- NSW State Heritage Register
- NSW State Heritage Inventory
- Historic Heritage Information Management System
- Australian Heritage Database (also referred to as the Commonwealth Heritage Register)
- any other source deemed relevant by the minister.

Justification for specifications

A heritage site enhancement work is a type of flood work that enables the protection of Aboriginal or heritage locations that are in the floodplain and have recognised significance. These types of works are permissible in MZ A and MZ D areas, as they will provide a positive outcome for flood-dependent heritage sites. This rule is consistent with the objects of WM Act clauses 3(c)(iii) and (iv), which ensure that culture and heritage, and benefits to Aboriginal people in relation to their spiritual and customary use of land and water are recognised and incorporated into sustainable water resource management. As some heritage sites are linked with ecological assets, this rule is also consistent with the WM Act additional provision 30(c), which enables an FMP to allow for the restoration or rehabilitation of land and water sources or their dependent ecosystems, as outlined above.

Access roads

In MZ A, access roads must be:

- no more than 30 centimetres in height above the natural surface level at any location, or
- a primary access road no more than 50 centimetres in height above the natural surface level

AND

- have causeways at or below the natural surface level at least every 200 metres of road length, and that the total causeway length should be at least 10% of the total road length that is within MZ A, or
- constructed in such a way as to allow for the adequate passage of floodwater and to adequately prevent the diversion of floodwater from natural flow paths

AND

- constructed so that the borrow associated with the construction and maintenance of the access road is located on the downstream side of the road and is of no greater depth than 30 centimetres below the natural surface level.

A primary access road is a road providing access from a public road to a permanently occupied fixed dwelling via a direct route.

In MZ D, access roads must be:

- no more than 30 centimetres in height above the natural surface level

AND

- have causeways at or below the natural surface level at least every 200 metres of road length, and that the total causeway length should be at least 10% of the total road length that is within MZ A, or
- constructed in such a way as to allow for the adequate passage of floodwater and to adequately prevent the diversion of floodwater from natural flow paths

AND

- constructed so that the borrow associated with the construction and maintenance of the access road is located on the downstream side of the road and is of no greater depth than 15 centimetres below the natural surface level.

Justification for specifications

Access road rules in MZ A and MZ D allow for floodplain access with minimal impact on flood behaviour by limiting access road height to 30 centimetres. However, the rules for MZ A also allow for larger, 50-centimetre primary access roads to improve the reliability of road access to a permanently occupied fixed dwelling, such as a farmhouse, during small to medium floods. This additional rule in MZ A acknowledges that the demand for the use of primary access roads during times of flood is of higher priority than the demand for the use of general access roads. Fifty centimetres is an appropriate compromise between providing reliable access and providing for the adequate passage of floodwater and local drainage during small to medium floods. An equivalent rule using different height thresholds for general access roads and primary access roads is included in the Barwon–Darling Valley FMP 2017.

The causeway requirements are to allow unimpeded flood flow during small flood events. The causeways also allow for connectivity that is important for fish passage. The requirements for causeways are consistent with the Gwydir Valley FMP 2016 (NOW 2015), which were originally adopted from the Lower Gingham Watercourse FMP (Department of Natural Resources 2006).

Causeways are included to ensure that access roads will not block or divert flood flows, which are important for flood-dependent ecological and cultural assets.

In the rule stating that access roads must 'allow for the adequate passage of floodwater and adequately prevent the diversion of floodwater from natural flow paths', the types of causeways required in the road are not specified. It is therefore expected that the applicant would provide a flood study to prove that the adequate passage of floodwater and local drainage is provided for within the design of the access road as part of their application. In this way, applicants can negotiate the standards for the inclusion of causeways associated with the construction of access roads. This requirement for causeways is consistent with the Barwon–Darling Valley FMP 2017.

Rules relating to borrow pits were developed for the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017) and represent current best-practice principles. The positioning of the borrow pit on the downstream side and limiting the depth to 30 centimetres for MZ A and 15 centimetres for MZ D was selected to facilitate the passage of floodwater, prevent diversion of floodwater, minimise soil erosion and reduce disruption to access by maintaining the stability of the roadway.

Infrastructure protections works

In MZ A and MZ D, infrastructure protection works (IPWs) must:

- on landholdings less than or equal to 20 hectares, be no more than 10% of the total area of the landholding

OR

- on landholdings greater than 20 hectares, be no more than the greater of the following:
    - 2 hectares, or
    - 1% of the size of the landholding.

AND

- on all landholdings, not block more than 5% of the width of MZ A or MZ D at the location of the works.

Justification for specifications

IPWs are flood works that provide for the protection of life and property from the effects of flooding. The thresholds selected for the works ensure that flood behaviour is not significantly affected by a work of this nature.

IPWs can be built to different sizes depending on the total area of the landholding where the work is being built. This is to cater for the practicality of larger properties being likely to have more infrastructure servicing their land.

On properties not larger than 20 hectares, IPWs can cover an area that is up to 10% of the area of the property. For example, if a property is 10 hectares, proposed IPWs can cover an area that is no more than one hectare. This rule was made to be consistent with the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017).

On properties larger than 20 hectares, IPWs can be whichever is the larger of the following 2 options:

- 2 hectares in size, or
- 1% of the total area of the property.

For example, if a property is 25 hectares, the proposed IPW can be no more than 2 hectares in size. Whereas, if a property is 300 hectares in size, the proposed IPW can be no more than

3 hectares in size. This rule was made to be consistent with the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017).

The rule requiring IPWs to not block more than 5% of the width of MZ A or MZ D at the location of the works was referenced from the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017) and was used in interim working policies adopted by the former Department of Industry before this. This rule provides greater certainty to landholders wishing to construct an IPW by specifying a threshold for how much of MZ A can be blocked.

Stock refuges

In MZ A and MZ D, stock refuges must be no more than:

- 10 hectares in area in any single location within MZ A or MZ D, and
- 5% of the total area of the landholding, and
- 5% of the width of MZ A or MZ D at the location of the works.

Justification for specifications

To avoid flood flow redistribution impacts, stock refuges are regulated and subjected to an assessment process. The thresholds are consistent with those used in the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017).

Supply channels

In MZ A, supply channels must be:

- below the natural ground surface
- constructed in such a way as to allow for the adequate passage of floodwater and to adequately prevent the diversion of floodwater
- constructed and maintained so that the spoil is windrowed parallel to the direction of flow such that it does not block more than 5% of the width of MZ A or is levelled to no more than 10 centimetres in height.

Justification for specifications

Ensuring that supply channels are below the natural ground surface level reduces the potential for the work to affect the distribution or flow of floodwater during flood events. However, it is still a requirement to construct the supply channel in a way that facilitates adequate passage of floodwater and that also prevents the diversion of floodwater. This is because, during small floods, a supply channel could potentially capture and divert flow from its natural flow path. It may be required that a siphon or gate be put in place at the low point(s) of the supply channel to enable timely floodwater passage and/or drainage on the floodplain. Construction of siphons or equivalent structures will enable floods to pass through or under these works. It is also possible that the spoil from the construction and maintenance of a supply channel will act as an above-ground flood work. To minimise the chance of spoil influencing flood flow, it is required to windrow the spoil to the specifications in the rules or to ensure it is levelled to no more than 10 centimetres in height. It is also required that the encroachment of spoil into active discharge areas is limited to minimise any impacts on flooding.

In the Macquarie valley floodplain, below-ground supply channels did not require approval if they had an existing approval under Part 2 of the Water Act. As for the Gwydir Valley FMP 2016 (NOW 2015), it was proposed to assess below ground supply channels as a flood work because of their potential to impact on flooding behaviour. This assessment would be consistent with Part 2 practice, which would place a condition that water supply works could not impact flooding. The regulation of this type of work as a flood work better ensures flood connectivity during small floods. This rule is consistent with the Barwon–Darling Valley FMP 2017 (NOW 2017).

Advertising requirements

The Macquarie Valley FMP 2021 does not require advertising for works deemed to be minor in nature in most management zones. Advertising requirements were determined by considering the level of impact flood works would likely have on flood behaviour, floodplain connectivity and on neighbouring properties.

The types of flood works that can be applied for in MZ A and MZ D are minor in nature and therefore flood work applications in these management zones do not need to be advertised.

There are no restrictions on the types of flood works that can be applied for in MZ BH and MZ B. As MZ BH is a significant discharge area for the 1990 large design flood, there is a reasonable risk that a flood work in this zone may impact on flood behaviour and floodplain connectivity. Consequently, rules for MZ BH require all flood work applications to be advertised. MZ B is a major flood storage and secondary flood discharge area where there is a reasonable risk that some flood works may impact on flood behaviour and floodplain connectivity. Accordingly, the rules for MZ B divide flood work applications into:

- flood work applications that do not require advertising
- flood work applications that do require advertising, which are all other flood work applications (non-specified flood works) not listed as requiring advertising.

In MZ B, a flood work does not require advertising if it is:

- no more than 40 centimetres in height
- used as a stock refuge and is no more than 5% cent of the total area of the landholding, and no more than 10 hectares in size in any single location in MZ B
- used to protect infrastructure and the area enclosed by the flood work accounts for no more than 1% of the total area of the landholding.

In MZ C, there are no restrictions on the types of permissible flood works. As MZ C includes flood fringe and existing developed areas, flood work applications do not require advertising as there is a low risk that flood works will impact third parties.

In MZ CU, there are no restrictions on the types of permissible flood works. The majority of flood works likely to be applied for in MZ CU will be exempt from requiring a flood work approval under the WM Act (see ‘Exemptions to flood work approvals’). For those works that are not exempt, flood work applications will be assessed under MZ C assessment criteria. This means that such flood work applications do not need to be advertised unless requested by the Minister for Water, Property and Housing.

Assessment criteria

Assessment criteria relating to the acceptable impacts of flood works have been designed to consider the potential for a flood work to have:

- Aboriginal, ecological and heritage site impacts
- social (drainage) impacts
- local hydraulic impacts
- cumulative hydraulic impacts.

The above categories of impacts are considered in the assessment criteria in different ways, depending on the management zone for which a flood work application is made (Table 14).

Table 14: Categories of impacts that flood work applications must be assessed against to be approved by management zone

Assessment criteria	Type	MZ A	MZ BH	MZ B	MZ C/CU	MZ D
Ecological and cultural impacts	Flood connectivity to ecological assets (including fish passage), Aboriginal values and heritage sites	☑	☑	☑	☑	☑
Ecological and cultural impacts	Heritage site impacts	☑	☑	☑	☑	☑
Social (drainage) impacts	Drainage impacts	☑	☑	☑	☑	☑
Local hydraulic impacts	Redistribution	^	☑	☑#	^	^
Local hydraulic impacts	Flood levels	^	☑	☑#	^	^
Local hydraulic impacts	Velocity	^	☑	☑#	^	^
Cumulative hydraulic impacts	Redistribution	☑	☑	☑#	^	☑

^ Assessment criteria are discretionary

Assessment criteria are discretionary for minor works that do not require advertising. For flood works that require advertising, all assessment criteria are mandatory.

Assessment criteria relating to the acceptable impacts of flood works follow a merit-based assessment approach and require technical assessment to interpret and apply. Flood work applications may require supporting information to assist with interpretation during the determination. Flood events (known as 'flood scenarios' in the Macquarie Valley FMP 2021) are considered when applying the assessment criteria. The types of flood scenarios depend on the management zone and the type of assessment criteria as outlined in the Macquarie Valley FMP 2021. More information on each of the 4 assessment criteria categories is found below.

Ecological and cultural impacts

Description of the criteria

The ecological and cultural impacts assessment criteria are designed to ensure that flood connectivity to ecological and cultural assets is considered when determining a flood work approval. Criteria were also developed to ensure that areas of cultural heritage significance are not disturbed during construction of flood works.

Flood connectivity to assets

In all management zones, a flood work must be constructed to maintain adequate flood connectivity to:

- ecological and cultural assets
- facilitate fish passage
- Aboriginal values
- heritage sites

Such flood connectivity must be maintained under a range of flood scenarios, including at a minimum, scenarios for the relevant small (2012) and large design floods (1990 and 2000).

Heritage site impacts

In all management zones, the construction of a flood work must not disturb the ground surface of a heritage site or cause more than minimal erosion to a heritage site.

Why ecological and cultural impacts are considered

Potential ecological and cultural impacts were considered to ensure that flood-dependent assets are not harmed by changes to flood connectivity caused by flood works. This assessment criteria was considered because the management zones were designed at a strategic scale. It is therefore necessary to have assessment criteria to account for the complex network of flow paths at the property scale that may have been missed in the management zone map. Many of these smaller flow paths are important for maintaining the ecological or cultural character of flood-dependent ecological assets, Aboriginal values and heritage sites. This assessment criteria ensures that flood works will not block these critical flow paths.

TAG and agency experts determined that fish habitat on the floodplain is a significant asset that requires additional protection measures. The studies of Rayner et al. 2009 and Rayner et al. 2015 document fish responses to floodplain inundation and highlight the importance of refugia for native fish in the Macquarie Marshes. Regulatory structures and flow alteration have contributed to a significant decline in the abundance and distribution of native fish in the Murray–Darling Basin (Cadwallader 1978; Horwitz 1999; Thorncraft & Harris 2000; Humphries, Serafini & King 2002). Therefore, flood works must be constructed to maintain adequate flood connectivity that facilitates fish passage, and this will be specifically dealt with in the assessment criteria.

Consultation with the ATWG and agency experts identified that some heritage sites are at risk from being impacted during the construction of a flood work or as a result of erosion from changes to flood behaviour caused by a flood work. Sites that may be potentially impacted by flood work development were identified in the FMP and will be considered as part of the flood work application assessment process. If a flood work is proposed in the vicinity of such a site, the *National Parks and Wildlife Act 1974* will be triggered, and a due diligence assessment will be required to be undertaken to ensure the sites are not impacted by the proposal.

How the criteria were determined

The criteria were determined by considering existing floodplain management arrangements (Macquarie River FMP 2008 and the Water Act) and after discussions with the Fisheries NSW representative of the TAG and the ATWG. These assessment criteria are also in the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017).

How the criteria will be assessed

Ecological and cultural impact assessment criteria will be assessed using spatial floodplain asset datasets and site observation data. State and federal heritage registers will also be checked to identify any heritage sites within the local area of a flood work application. Flow paths across a range of flood scenarios may be considered to ensure flood connectivity is maintained to ecological and cultural assets.

There may be instances where the flood work proposal triggers the need for the applicant or the assessing officer to seek advice, permits or to notify external agencies of a flood work application. Referrals will be an integral part of meeting these assessment criteria due to the overlap of the assessment requirements of the WM Act and other legislation relevant to flood work approvals, including the *Environmental Planning and Assessment Act 1979*, the *Fisheries Management Act 1994*, the *National Parks and Wildlife Act 1974* and the *Biodiversity Conservation Act 2016*.

Referrals will improve the assessment of flood work applications against the assessment criteria by strengthening links with other agencies or groups that have a responsibility or function to contribute to the assessment of the impacts under related legislation.

In some cases, additional detailed ecological and cultural assessments may be required to support a flood work application.

If an application is required to be supported by a FS, there will be specific requirements that the applicant (or consultant on behalf of the applicant) will be required to address to demonstrate that flood connectivity is adequately maintained to flood-dependent ecological and cultural assets.

Social (drainage) impacts

Description of the criterion

The drainage impacts assessment criterion was designed to ensure that local drainage on neighbouring properties is maintained.

In all management zones, a flood work must maintain adequate drainage on adjacent landholdings and other landholdings that may be affected by the proposed flood work.

Why drainage impacts are considered

Drainage impacts are considered because the management zones were designed on a strategic scale that may not account for a flood work impacting on local drainage in such a way as to cause a significant disruption to the daily life of surrounding landholders. For instance, changes to local drainage may cause considerable local issues, nuisance or conflict, or property access may be disrupted.

How the criterion was determined

The criterion was determined by considering current floodplain management arrangements (Macquarie River FMP 2008 and the Water Act). This assessment criterion was also in the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017).

How the criterion will be assessed

The flood work applicant will need to demonstrate that flood water will not remain in the local area for an excessively long time compared to existing floodplain conditions. Consideration will also need to be given to avoiding peak travel time being unduly accelerated to downstream users.

Assessment of this criterion will involve giving key consideration to pondage times, peak travel time downstream and soil types which may influence permeability (that is, potential waterlogging of land). A range of spatial datasets will be used to assist with this assessment, including contours, slope, soils information as well as site observation data.

If a FS is available, information from the study will be used during the assessment. The assessment will also consider additional data such as floodplain asset datasets to ensure that changes to drainage do not have a significant effect on flood connectivity to sensitive wetland areas. Local topography will be considered to minimise the likelihood of new flood works changing local drainage lines in a disruptive manner. Local flooding patterns across a range of floods may also be considered, including the small and large design floods.

Local hydraulic impacts

Description of the criteria

The local hydraulic impacts assessment criteria were designed to ensure that within the local area, a flood work application has a minimal impact (thresholds apply) on:

- redistribution of peak flood flow
- flood levels
- flow velocity

The ‘local’ area is generally defined as the adjacent landholdings and other landholdings that may be affected by the proposed flood work.

The use of the local hydraulic assessment criteria to assess applications for works that do not require advertising in MZ B and for all types of works in MZ C and MZ CU is discretionary. For flood work applications in MZ BH and those that that require advertising in MZ B, the assessment criteria are mandatory.

In MZ BH, applications for flood works must demonstrate that the work is unlikely to:

- redistribute the peak flood flow by more than 2% in the local area when compared to the peak flood flow under existing development conditions for a range of flood scenarios including, at minimum, the 1990 large design flood
- increase flood levels by more than 10 centimetres in the local area when compared to flood levels under pre-development and existing development conditions for a range of flood scenarios including, at minimum, the 1990 large design flood
- increase flood levels such that they impact high-value infrastructure when compared to flood levels under pre-development and existing development conditions for a range of flood scenarios including, at a minimum, the 1990 large design flood
- increase flow velocity by more than 25% on the landholding under application or in the local area when compared to flow velocity under pre-development and existing conditions for a range of flood scenarios including, at minimum, the 1990 large design flood, unless:
    - increases by more than 25% are in isolated areas where the landholder mitigates the impact of the flood wave so that the average impact across the landholding under application is no greater than 25%, and
    - flow velocity is not increased by more than 25% at the boundary of the landholding under application
- increase flow velocity by an amount that is likely to have more than minimum impact on soil erodibility, taking into account the ground cover, on the landholding under application or in the local area.

In MZ B, applications for flood works that require advertising must demonstrate that the work is unlikely to:

- redistribute the peak flood flow by more than 5% in the local area when compared to the peak flood flow under existing development conditions for a range of flood scenarios including, at minimum, the 1990 large design flood
- increase flood levels by more than 10 centimetres in the local area when compared to flood levels under pre-development and existing development conditions for a range of flood scenarios including, at minimum, the 1990 large design flood
- increase flood levels such that they impact high-value infrastructure when compared to flood levels under pre-development and existing development conditions for a range of flood scenarios including the 1990 large design flood
- increase flow velocity by more than 50% on the landholding under application or in the local area when compared to flow velocity under pre-development and existing conditions for a range of flood scenarios including, at minimum, the relevant large design flood, unless:
    - increases by more than 50% are in isolated areas where the landholder mitigates the impact of the flood wave so that the average impact across the landholding under application is no greater than 50%, and
    - flow velocity is not increased by more than 50% at the boundary of the landholding under application
- increase flow velocity by an amount that is likely to have more than minimum impact on soil erodibility, taking into account the ground cover, on the landholding under application or in the local area.

In MZ C (and for non-exempt works in MZ CU), applications for flood works may be required by the minister to demonstrate that they adhere to the assessment criteria specified above for MZ B. The flood scenarios used to assess the application are not prescriptive and may be determined by the minister.

Why local hydraulic impacts are considered

Local hydraulic impacts assessment criteria were developed to ensure that flood work applications do not significantly change key hydraulic parameters in the local area and in some instances, on the landholding under application. To best assess impacts on local hydrology, each relevant flood work application must be assessed on a case-by-case basis. This assessment will reduce the likelihood that flood works will impact on flood behaviour, including the potential to redistribute peak flood flows, increase the flood risk and inundation extents by raising flood levels, and increase the potential for erosion and siltation by increasing flood-flow velocities.

How the criteria were determined

The criteria were determined by considering existing floodplain management arrangements (Macquarie River FMP 2008 and the Water Act) the Gwydir Valley FMP 2016 (NOW 2015), and the Barwon–Darling Valley FMP 2017 (NOW 2017).

How the criteria will be assessed

Assessment against hydraulic local impacts criteria will occur when an application is required to be supported by a FS. In most cases, a FS will be required to report on and be supported by hydraulic modelling. A FS will only be accepted if the assessing officer considers that the FS meets appropriate reporting requirements, document standards and technical standards for hydraulic modelling. The FS must clearly demonstrate that the results are within the thresholds for the hydraulic local impacts assessment criteria.

Typically, the criteria will be assessed by comparing key modelled hydraulic parameters (flood-flow redistribution, flood levels and flow velocity) for proposed development conditions against flood study results for pre-development and/or existing development conditions, under relevant flood scenarios (such as the large design flood or the 1% AEP flood). Incremental changes brought on by the various stages of floodplain development over time (as represented by the various modelled floodplain conditions) will need to be reported in the FS for subsequent consideration in any final assessment of whether nominated criteria thresholds are exceeded.

For the purposes of assessing a flood work application, the following definitions apply:

- pre-development conditions – derived from running a model with the floodplain without flood work development on the landholding under application
- existing development conditions – derived from running a model with the accepted level of flood work development at the time the application is made
- proposed development conditions – derived from running a model with the floodplain, the accepted level of flood work development at the time that the application is made and the flood work proposal.

In regard to assessing flow velocity impacts, soil erodibility will be assessed by ensuring that velocities are within the maximum permissible for the Macquarie valley floodplain. This assessment criterion provides flexibility to consider ground cover when assessing the potential impact of a flood work on soil erodibility. It is likely that soil types will be a consideration; for instance, maximum permissible velocities may be relaxed for applicants who can prove the soil type is not highly erodible.

Cumulative hydraulic impacts

Description of the criteria

In MZ BH, MZ B, MZ C and MZ CU, the intent of the cumulative hydraulic impact assessment criteria is to limit the redistribution of flood flows across the floodplain to acceptable thresholds. Flood flow distributions are quantified at given peak discharge calculation locations (Appendix 14). The use of this assessment criteria to assess applications for works that do not require advertising

in MZ B and for all types of works in MZ C and MZ CU is discretionary. For flood work applications in MZ BH and those that require advertising in MZ B, the assessment criteria is mandatory.

In MZ A and MZ D, consideration of cumulative effects of proposed flood works must take into account any hydraulic impacts on the adjacent floodplain as well as environmental impacts. No specific thresholds apply. All flood works in MZ A and MZ D must be assessed against this criterion.

When evaluating the cumulative impacts of a proposal on the floodplain environment, consideration will be given to those impacts that are likely to combine with each other or with impacts of other activities to produce a beneficial or adverse effect. Impacts should be considered in terms of:

- the relationship of the activity to other proposals or developments in the area
- synergistic effects of individual developments when considered in combination
- any known environmental stresses in the affected area and the likely contribution of the proposed activity to increasing or decreasing those stresses.

Peak discharge calculation locations represent the peak discharge occurring in that section of the floodplain and will generally represent peak discharge in a river as well as in the floodplain areas adjacent to the river.

Peak flood flow distribution was selected to measure cumulative impacts because distribution of flood waters is an important flood parameter and any significant changes to distribution may signify changes to other flood parameters such as velocity and depth.

The use of this assessment criteria to assess applications for minor works (that is, those that do not require advertising) in MZ B is discretionary. All flood work applications received for MZ BH must be assessed against this criterion. The large design flood is to be used for these assessments.

Flood works in MZ C or MZ CU only need to be assessed against the criteria if required by the minister and these assessments would typically use floods larger than the design floods such as the 1% AEP flood.

In MZ A and MZ D, the minister must consider the cumulative effect that the proposed flood work and other existing works on the landholding may have on adjacent landholdings, other landholdings and the floodplain environment.

Additionally in MZ BH, applications for flood works must demonstrate that the work is unlikely to redistribute peak flood flow by more than 2% at any of the peak discharge calculation point locations or any other location as defined by the minister, when compared to redistribution under existing development conditions for a range of flood scenarios including, at minimum, the 1990 large design flood.

In MZ B, applications for flood works that require advertising must demonstrate that the work is unlikely to redistribute the peak flood flow by more than 5% at any of the peak discharge calculation point locations or any other location as defined by the minister, when compared to redistribution under existing development conditions for a range of flood scenarios including, at minimum, the 1990 large design flood.

In MZ C (and for non-exempt works in MZ CU), flood work applications may be required to demonstrate that they adhere to the assessment criterion specified above for MZ B. The flood scenarios used to assess the application are not prescriptive and may be determined by the minister. These assessments would typically use floods larger than the design floods, such as the 1% AEP flood.

Why cumulative hydraulic impacts are considered

Current estimates are that the area protected by flood works (hereafter developed areas) makes up approximately 106,000 hectares (9%) of the Macquarie valley floodplain (Step 2). Typically, the developed areas are protected by levees, which are likely to impact on flooding behaviour in small and large floods.

The hydraulic models developed as part of Step 4 were used to estimate the distribution of floodwater under the existing level of development, recognising that existing flood work development has already altered the flow distribution between major branches of the Macquarie valley floodplain.

Further redistribution may have consequences from socio-economic, hydraulic, ecological and cultural perspectives. Therefore, the cumulative impact of proposed works must be assessed to ensure that the current flood flow distribution is maintained.

How the thresholds for the criteria were determined

The thresholds for the hydraulic cumulative impacts have been determined by comparing the modelling results from the existing floodplain conditions with a pre-development modelling scenario, where all flood works had been removed from the modelled floodplain.

The 2 floodplain scenarios were compared at cross-sections for key locations within the floodplain. The basis for the assessment was the peak flood flow for the 1990 large design flood event.

It was found that some redistribution has occurred due to existing flood works, and that this redistribution is likely to be variable across the floodplain. For practicable reasons and consistency, a uniform threshold of 5% has been set across the entire floodplain except for high floodway areas with major drainage lines upstream of Warren (MZ BH). A lower threshold of 2% has been set for MZ BH to reflect the high adverse impact that additional redistribution of floodwater may have in these areas. Thresholds are based on the magnitude of current Macquarie flood flow redistributions, and criteria adopted for the Gwydir Valley FMP 2016 (NOW 2015) and Barwon–Darling Valley FMP 2017 (NOW 2017).

How the criteria will be assessed

Assessment against hydraulic cumulative impacts assessment criteria will differ depending on if the application is required to be supported by a FS or not.

Where a FS is not required, the applicant must demonstrate that the flood work proposal has considered cumulative impacts of the proposal and other existing works by considering development in the surrounding area. When considering existing development, the applicant may need to determine if:

- the development is concentrated on one side of the floodplain, or
- there is any existing blockage to floodways or smaller flow paths important for flood connectivity to flood-dependent assets.

The rules for MZ A and MZ D alleviate the potential for cumulative impacts in these zones.

Where a FS is required, the applicant (or consultant on behalf of the applicant) will be required to report on changes to peak flood-flow distribution at specified locations by comparing proposed development conditions against existing development conditions.

Existing flood works and structures

Rules to either license eligible existing flood structures or to modify the licences of eligible existing flood works were required in MZ A and MZ D where the Macquarie Valley FMP 2021 restricts the types of permissible flood works.

The inclusion of these rules allows acceptance of applications for existing works that do not comply with the rules for MZ A or MZ D.

The rules for granting approval to an existing flood structure are outlined below.

Approval may be granted for an **existing *unlicensed* work** that does not comply with the rules for MZ A or MZ D if all of the following criteria are met:

- the flood structure was constructed as at the date this plan began
- the flood structure is an access road, infrastructure protection work, stock refuge or supply channel
- as at the date of application, the flood structure is not the subject of:
    - an undetermined controlled work application under Part 8 of the *Water Act 1912,* or
    - a previously refused Part 8 application under the *Water Act 1912*, or
    - an undetermined flood work application under the *Water Management Act 2000*, or
    - a previously refused flood work application under the *Water Management Act 2000*.

The rules for amending the flood work approval of an existing licensed flood work are outlined below.

An amendment to an **existing *licensed* work** in MZ A and MZ D may be granted for a flood work that does not comply with the rules for MZ A or MZ D if all of the following criteria are met:

- the flood work was constructed as at the date this plan began
- the proposed modification to the flood work will reduce the impact of the work on flow patterns (distribution of flows, drainage, depth or velocity) in MZ A or MZ D

In either scenario, to be granted a flood work approval, the work must be assessed against the assessment criteria outlined in MZ A or MZ D, whichever is applicable.

Exemptions to flood work approvals

An approval is required to construct or use a flood work under section 91D(1) of the WM Act. However, flood works that satisfy the exemption criteria outlined in the Water Management (General) Regulation 2011 do not require an approval. State-wide exemptions are for works or types of works that are considered low risk or are necessary for public safety, or that are more appropriately overseen by another government body such as a local council.

For more information on state-wide exemptions, refer to the Water Management (General) Regulation 2011.

Step 9: Consider existing floodplain management arrangements

Consideration of existing floodplain management arrangements was integrated throughout the planning process outlined in this document. Step 9 reports on how these arrangements were considered, including the occurrence of change between existing rural floodplain management arrangements and the Macquarie Valley FMP 2021.

The existing floodplain management arrangements are first described in Step 3 and shown in Figure 33. As highlighted in Figure 33 of the Macquarie valley floodplain, approximately:

- 38% is managed under the Macquarie River FMP 2008
- 17% is designated as the Lower Macquarie floodplain but not managed by a current FMP or guideline
- 45% is not part of a current rural FMP, guideline or designated rural floodplain.

Change was seen across the floodplain boundary, management zones and rules, including assessment criteria. The changes reflect improvements in understanding of the floodplain, improvements in management of flood work development, and a more consistent approach to floodplain management across the floodplain.

Floodplain boundary

Existing floodplains designated under the Water Act were a primary consideration when delineating the Macquarie valley floodplain boundary. The floodplain was partially aligned with the Macquarie River (Narromine to Oxley Station) floodplain and the Lower Macquarie floodplain (Figure 33). When compared to the existing designated floodplains, the overall extent of boundary change is significant, with the addition of 559,000 hectares. The rationale for the boundary changes is detailed in Step 1.

Management zones

The area managed by the Macquarie River FMP 2008 has a mapped floodway network that is the basis for assessing applications to construct flood works and therefore functions as a basic management zone. The remaining areas of the Macquarie valley floodplain do not have current mapped floodway networks.

The floodway network in the Macquarie River FMP 2008 was primarily based on hydraulic principles similar to those used to derive MZ A and MZ BH in the Macquarie Valley FMP 2021 (Step 4). The floodway network was also based on providing flood connectivity to flood-dependent areas of ecological and cultural significance.

Areas outside the floodway network in the Macquarie River FMP 2008 have a similar hydraulic basis to MZ B and MZ C in the Macquarie Valley FMP 2021. A key difference is that some ecological and cultural assets were prioritised and included in the design of MZ B.

MZ CU applies to urban areas covered by a FS, FRMS or FRMP, or protected by flood mitigation works. Under existing floodplain management arrangements flood works in these areas are exempt from WMA approval except on private landholdings larger than 0.2 hectares.

MZ D was created to provide additional protection for ecological and cultural assets of high significance from flood works negatively impacting their flood connectivity. In areas covered by the Macquarie River FMP 2008, MZ D corresponds to parts of the floodway network.

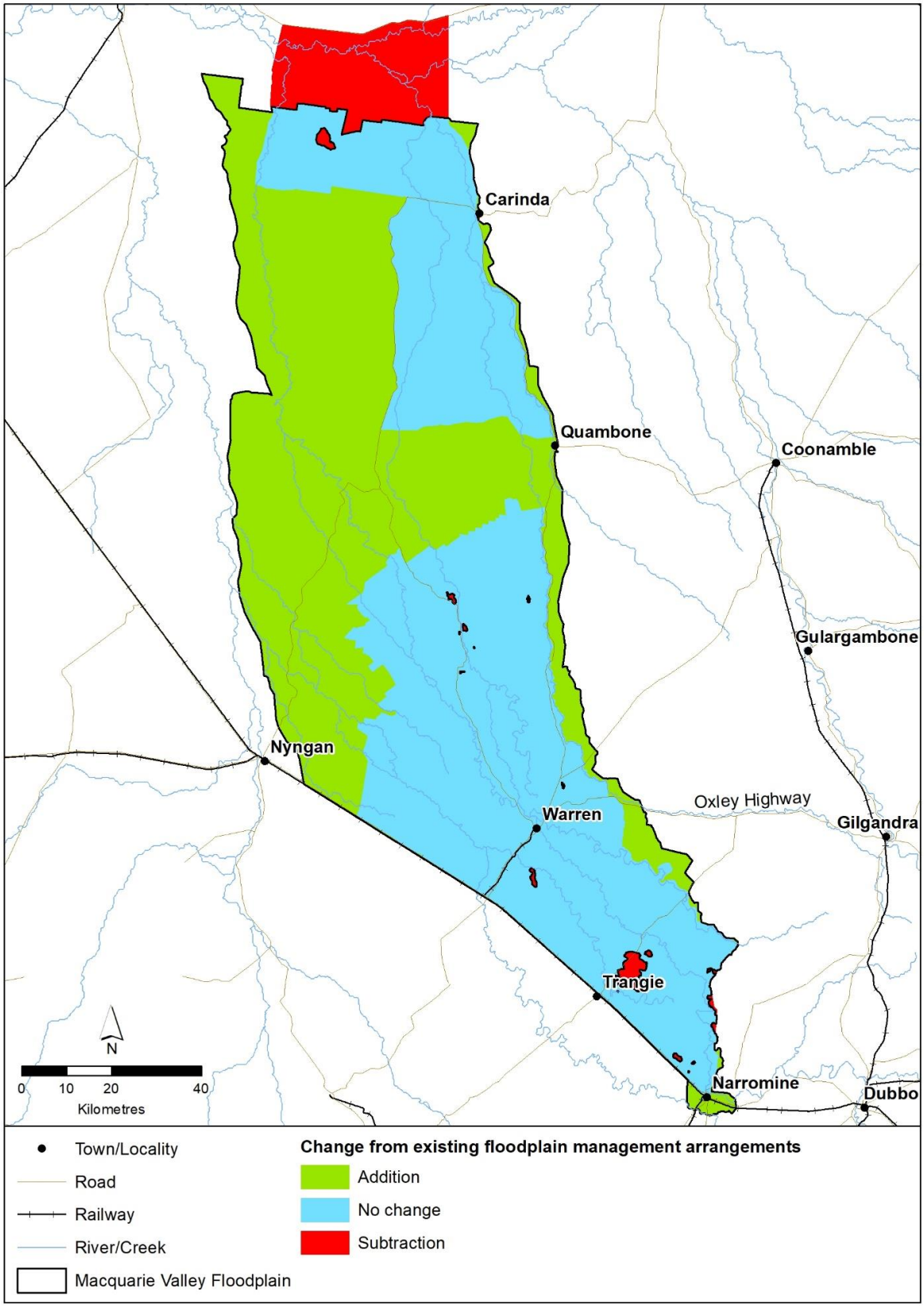

Figure 33: Change in the floodplain boundary when comparing the existing floodplain management arrangements with the Macquarie valley floodplain to be made under the *Water Management Act 2000*

As described in Step 7, the Macquarie valley floodplain has 6 different management zones. The proposed management zones in the Macquarie Valley FMP 2021 differ from existing floodplain management arrangements due to:

- the extension of the floodplain boundary to capture areas of major flooding
- a consistent floodplain management planning approach across the entire floodplain
- improved ecological and cultural data across a greater floodplain area
- strategic consideration of flood connectivity throughout the entire floodplain
- significantly more accurate hydraulic data (supported by new LiDAR) available from using the latest modelling techniques with new hydraulic models being developed and existing models being updated
- consideration of proposed new rules and assessment criteria.

Rules (including assessment criteria)

Change has occurred between the rules in existing floodplain management arrangements and the rules in the Macquarie Valley FMP 2021. The changes are described below.

Change to permissible flood works

Under existing floodplain management arrangements, there are currently no restrictions to the types of flood works that can be approved (permissible works). The Macquarie Valley FMP 2021 has restrictions on the types of permissible works in MZ A and MZ D as outlined below.

Management zone A

The Macquarie Valley FMP 2021 allows flood work applications in MZ A for 5 types of permissible works that need to meet specific rules including size limits (Step 8). Under existing arrangements, a landholder can apply for any type of flood work to be built in areas that correspond to MZ A. However, where an application is within the floodway network of the Macquarie River FMP 2008 (about 25% of MZ A), restrictive assessment criteria apply, and approval is likely to be limited to relatively minor works. By limiting applications to certain permissible works in the Macquarie Valley FMP 2021, landholders will save time and money by applying only for those works likely to be approved.

Management zone D

The Macquarie Valley FMP 2021 allows flood work applications in MZ D for 4 different types of permissible works that meet specific rules including size limits (Step 8). Under existing arrangements, a landholder can apply for any type of flood work to be built in areas that correspond to MZ D in the Macquarie Valley FMP 2021. However, where an application is within the floodway network of the Macquarie River FMP 2008, restrictive assessment criteria apply, and approval is likely to be limited to relatively minor works. By limiting applications to certain permissible works in the Macquarie Valley FMP 2021, landholders will save time and money by applying only for those works likely to be approved.

Changes to advertising requirements

Advertising flood works gives interested parties the opportunity to comment on a flood work application and for that comment to be considered during the assessment. The intention of the proposed rules is for works not to be advertised if they are:

- minor in nature
- in an area of the floodplain where the potential for the flood work to impact on flood behaviour is minimal

In areas covered by the Macquarie River FMP 2008, advertising is currently required for works:

- in the floodway network

- on the boundaries of the floodway network upstream of Warren that exceed 1990 flood design levels
- that are not modified in accordance with requirements in the FMP.

Elsewhere on the floodplain, advertising is required under existing arrangements as there is not sufficient information to determine the scale of flood behaviour impacts from proposed flood work applications.

Proposed changes to advertising requirements under the Macquarie Valley FMP 2021 reflect the new suite of management zones and the changes made to permissible flood works. Whereas currently works within the floodway network of the Macquarie River FMP 2008 require advertising, it is now proposed that works in MZ A and MZ D do not require advertising. This is because only minor works are permissible in these zones. There is no change to advertising requirements in areas of the Macquarie River FMP 2008 floodway network that are now covered by MZ BH as all work applications in this zone require advertising.

In parts of the Macquarie valley floodplain outside the Macquarie River FMP 2008 area where all work applications currently require advertising, it is now proposed that minor works in MZ B will not require advertising. This change aims to give greater clarity about which works need advertising and to better ensure that any flood work with more than minimal potential to impact on flood behaviour is advertised.

All flood works in MZ C and MZ CU are proposed to not require advertising. This is a change to existing arrangements in areas outside the Macquarie River FMP 2008 floodplain.

Changes in assessment criteria

Under existing floodplain management arrangements, there are no assessment criteria for flood work applications in areas outside the Macquarie River FMP 2008. However, licensing officers are required to consider the WM Act and in practice apply a set of floodplain management principles taken from the Macquarie River FMP 2008 when considering applications, as described below:

- Defined floodways must possess adequate hydraulic capacity and continuity to enable the orderly passage of floodwaters through the floodplain.
- Any system of defined floodways should conform as closely as is reasonable to the natural drainage pattern after taking into account the existing floodplain development.
- Floodway areas should be equitably distributed (between adjacent landholders) consistently with natural or historical flow paths.
- Environmental issues need to be identified and investigated, including developing strategies for flood-dependent ecosystems such as wetlands, riparian vegetation and other environmentally sensitive areas.
- The exit of floodwaters from defined floodways should be at rates and depths similar to those that would have been experienced under natural or historical conditions and should discharge as close as practicable to the location of natural or historical floodways.
- Sufficient pondage must be retained on the developed floodplain so that the flood peak travel time is not unduly accelerated to downstream users or its height increased.
- Velocities of flood flow in defined floodways should be minimised and be of an order that would not cause erosion or increased siltation under various land uses.
- There should be no detrimental impact from floodplain development on any individual landholder or community infrastructure, including increases in peak flood levels and increased drainage times.
- Floodplain development should not cause significant redistribution of floodwaters in terms of flow distribution, volumes or flow rates.

In the area covered by the Macquarie River FMP 2008, flood works proposed to be located within the floodway network are assessed as non-complying works. Non-complying works require a detailed investigation of the hydraulic, environmental, social and economic impacts of the proposal.

In many cases, applications for non-complying works are refused or require the modification or removal of works. The assessment criteria for non-complying works applications in the Macquarie River FMP 2008 are summarised in Table 15.

Flood works outside the Macquarie River FMP 2008 floodway network are generally assessed as complying. The landholder is required to provide the necessary supporting information to demonstrate the application is a complying work.

The intent of WM Act provisions has been captured in the Macquarie Valley FMP 2021. However, changes have been made to ensure the proposed assessment criteria:

- can be assessed in a quantitative rather than qualitative way, wherever possible
- are as consistent as possible with other rural valley FMPs that have begun or that are in development, such as for the Gwydir, Lower Namoi, Border Rivers and Barwon–Darling Valleys
- are relevant to each management zone.

Table 15 shows the thresholds for the proposed local hydraulic impacts assessment criteria in comparison to the Macquarie River FMP 2008 and the valley FMPs that have begun or are in preparation. While the proposed assessment criteria have some similarity to those in the Macquarie River FMP 2008, there are key differences that include:

- quantitative thresholds for velocity impacts that clarify the assessment process
- tighter limits on flow distribution
- allowable increases in flood height above the large design flood level (up to 10 centimetres).

Although the Macquarie River FMP 2008 provides more allowance for flood flow distribution than the proposed assessment criteria, it is important to note that its criterion allowing no increase in flood heights above design flood levels provides a general restriction on flood work development.

Proposed assessment criteria for MZ B, MZ C and MZ CU are consistent with the assessment criteria in other valley FMPs that have begun or are in development (Table 15). Proposed assessment criteria for MZ BH are more restrictive, reflecting the importance of this zone as a high-level floodway for the 1990 large design flood upstream of Warren.

Table 15: Comparison of proposed hydraulic assessment criteria with existing FMPs

Local hydraulic assessment criteria	Macquarie Valley FMP 2021 – MZ B, MZ C, MZ CU	Macquarie Valley FMP 2021 – MZ BH	Macquarie River FMP 2008	Valley FMPs: Gwydir, Barwon–Darling, Lower Namoi (draft) and Border Rivers (draft)
Redistribution	5%	2%	10%	10%
Flood levels: General	10 cm	10 cm	10 cm No increase in design flood levels	10 cm 20 (Barwon–Darling)
Velocity: General	50%	25%	No significant increase	50%
Velocity: Soil erodibility considered (yes/no)	Yes	Yes	Yes	Yes

The Macquarie River FMP 2008 requires that the cumulative impact of flood work proposals on flood characteristics is comprehensively addressed. In areas outside the Macquarie River FMP 2008 floodplain, there is no equivalent policy. The proposed cumulative hydraulic impacts assessment criteria signify a change as a new requirement and as a quantitative assessment of impact that provides greater clarity to the assessment process.

Proposed cumulative impact assessment criteria are consistent with criteria in other valley FMPs that have begun or are in preparation. It is expected that existing flood work development has altered the flow distribution between major flow paths of the Macquarie valley floodplain. Further redistribution may have consequences from socio-economic, hydraulic, ecological and cultural perspectives. Therefore, the cumulative impact of current and future works will require assessment to ensure that the current flood flow distribution is maintained. MZ A and MZ D also require that the potential cumulative effect of the proposed flood work and other flood works is considered; however, this approach is a qualitative assessment.

Existing flood works and structures

Under existing floodplain management arrangements, some types of works that do not meet the specifications to be a permissible work in proposed MZ A and MZ D may not have required an approval under the repealed Part 8 of the Water Act. The rules proposed in the Macquarie Valley FMP 2021 allow works that do not meet the specifications for a permissible work to be licensed, provided they meet certain criteria. This ensures that existing works within MZ A and MZ D that may not have previously required approval will not become illegal works.

For licensed works that do not comply with the rules of MZ A and MZ D, the draft plan allows amendment of these works that will reduce their impact on flow patterns. Under existing management arrangements, modification of such works that would result in an increased impact would unlikely have been approved, so this is not likely to represent any change from the current arrangements.

Step 10: Assess socio-economic impacts

Step 10 is split into 2 phases and examines the extent of change between the base case (floodplain without reform) and the Macquarie Valley FMP 2021 to determine the negative socio-economic impacts of the proposed plan. Phase one assessment was undertaken before community consultation. Phase 2 assessment is optional and only triggered if the Phase one assessment identified significant socio-economic impacts and/or socio-economic concerns are raised during public exhibition.

The assessment approach is based on the *Socio-economic Assessment Guidelines for River, Groundwater and Water Management Committees* prepared by the Independent Advisory Committee for Socio Economic Assessment (IACSEA 1998). This approach is being applied to the development and revision of WSPs in NSW.

The focus of this assessment is the enumeration of the negative effects of the implementation of the Macquarie Valley FMP 2021 on cultivated agriculture, quantified in 2011 dollars. Because benefits of the proposed FMP are not enumerated it was not a cost-benefit analysis. There are significant benefits from the implementation of the FMP that are expected to outweigh the negative impacts. Some of the benefit categories include: minimising impacts of flooding due to constructed flood works, reduced erosion and reduced sediment deposition, and ecological and cultural benefits. Benefit value types include use, existence and bequest values.

The detail of the methodology used in this analysis is included in the *Rural Floodplain Management Plans: Technical manual for plans developed under the Water Management Act 2000*.

Phase 1 assessment

The first phase is the preliminary assessment that was undertaken before community consultation. This phase adopted the following sequential analysis:

- Document the effect of change between the base case and the Macquarie Valley FMP 2021 construct on different sectors of the community across the whole floodplain.
- Assess the extent, likelihood, intensity and timing of the effects and document these in a socio-economic impact table.
- Provide a breakdown of the land capability of the floodplain and identify where the impacts of the Macquarie Valley FMP 2021 construct was quantifiable in 2011 dollars.
- Prepare a sensitivity analysis of the assessment.

Each stage of the Phase 1 analysis is described in more detail in the following sections.

Changes between the base case and the Macquarie Valley FMP 2021 construct

The base case is the socio-economic condition of the floodplain if the Macquarie Valley FMP 2021 had not been prepared. The base case is the condition where the following assumptions are made over the next 10 years (the period of the Macquarie Valley FMP 2021):

- Flood work approvals will continue under the floodplain management provisions of the WM Act.
- New FMPs will cover a greater area of floodplain in due course.
- Floodplain guidelines may be revised or upgraded to an FMP as better data and modelling become available.
- More emphasis will be put on environmental issues associated with flood work approvals as the community increases their general awareness of environmental issues.
- Flood works will continue to be approved in areas outside the floodway networks identified in FMPs and guidelines.

- The approval rate of flood works within the floodway networks identified in FMPs and guidelines will decline as cumulative impacts approach acceptable limits.

There is currently one FMP located within the Macquarie valley floodplain. The Macquarie River FMP 2008 was adopted in 2008 under Part 8 provisions of the Water Act and is currently a minister's plan under the WM Act. Figure 4 shows the location of the Macquarie River FMP 2008 floodplain in relation to the Macquarie valley floodplain. The Macquarie River FMP 2008 superseded the first-generation floodplain development guidelines that previously applied to the floodplain between Narromine and Oxley Station.

The impact of the Macquarie Valley FMP 2021 was assessed for the whole floodplain (covering 1.24 million hectares). Depending on the location of affected land, there may be particular areas that are anticipated to be relatively heavily impacted by the proposals.

A summary of the rules under the base case and for the Macquarie Valley FMP 2021 are presented in Table 16.

Table 16: Summary of rule changes between the base case and the Macquarie Valley FMP 2021

Base case	Macquarie Valley FMP 2021 construct
Flood works across the whole floodplain require application for an approval under the WM Act.	Flood works in the designated floodplain management area are subject to the FMP and require application for a flood work approval under the WM Act.
Floodway network In an identified floodway in an FMP area (including the Macquarie River FMP 2008), flood works are not prohibited but need to satisfy stringent hydraulic criteria. It is likely that only minor flood works would be approved due to the need to maintain natural flooding patterns for hydraulic and/or environmental requirements. Applications are deemed to be non-complying and require advertising and objections are to be considered before possible approval under the provisions of the WM Act.	**MZ A** provides for a flood work approval by application that is one of the following: • an access road up to 30 cm above natural surface level (or up to 50 cm for a primary access road), or • a supply channel below the natural surface level, or • a stock refuge, or • an infrastructure protection work, or • ecological, Aboriginal value and heritage site enhancement works, or • existing works – licensed and unlicensed. Applications do not require advertising. Applications need to meet specific assessment criteria. **MZ D** provides for a flood work approval by application that is one of the following: • an access road up to 30 cm above natural surface level, or • a stock refuge, or • an infrastructure protection work, or • ecological/cultural enhancement works, or • existing works – licensed and unlicensed. Applications do not require advertising. Applications need to meet specific assessment criteria. **MZ BH** provides for flood work approvals by application if they meet specific assessment criteria. All flood works applications must be advertised. State-wide exemptions apply in this zone. See www.industry.nsw.gov.au/water for the list of exemptions.

Base case	Macquarie Valley FMP 2021 construct
Non-floodway network area If the application is outside the identified floodway network in an FMP area, it is generally assessed as a complying work and a technical report identifying that the provisions of the WM Act are addressed is not required. In the Macquarie River FMP 2008, flood work applications that are not limited to 1990 design levels on the edge of the floodway network upstream of Warren are assessed as non-complying works and require a floodplain engineering assessment. Complying applications do not require advertising. Non-complying applications require advertising and objections are to be considered before possible approval under the WM Act. If the application is outside an FMP area, the applicant is required to provide a floodplain engineering report identifying that the WM Act provisions are addressed. These applications require advertising, and objections are to be considered before possible approval.	**MZ B** provides that a flood work approval or modification by application does not require advertising if it is one of the following: • no more than 40 cm in height above the natural surface level, or • stock refuge (within specified size limits), or • infrastructure protection works (within specified size limits). All other flood works require advertising. The application must not be approved if it exceeds assessment criteria defined in the FMP. State wide exemptions apply in this zone. See www.industry.nsw.gov.au/water for the list of exemptions. **MZ C** provides for flood work approvals by application if they meet specific assessment criteria. Applications do not require advertising. State wide exemptions apply in this zone. See www.industry.nsw.gov.au/water for the list of exemptions. **MZ CU** provides for flood work approvals in cases where state-wide exemptions in urban areas where floodplain management is administered by local government do not apply.

Impact of rule changes

Management Zone A

MZ A is defined by hydraulic as well as ecological and cultural criteria. The hydraulic criteria are used to determine areas of significant flood discharge (floodways) based on the DVPs generated by flood modelling. The ecological and cultural components of MZ A are referred to as ecological and cultural amendments.

MZ A includes land that under the base case would have been managed as a floodway network in the Macquarie River FMP 2008, or in other areas, as a creek or flood runners. Flood works in these areas would have been restricted to relatively minor works to meet the requirements of the Macquarie River FMP 2008 and WM Act provisions. Overall, it is unlikely that works more substantial that those permissible in MZ A would have been approved under the base case. Therefore, it is expected that flood work approvals in this area are not likely to be substantially negatively affected by the Macquarie Valley FMP 2021.

Land included as ecological or cultural amendments will be subject to significant change under the Macquarie Valley FMP 2021. Under the base case, it is likely that flood work proposals in these areas would have been assessed in general accordance with rules similar to MZ B. However, these areas are now subject to MZ A rules that only allow for restricted flood works including:

- limited height access roads, stock refuges, and infrastructure protection works within specified size limits
- below-ground supply channels
- ecological, Aboriginal value, and heritage site enhancement works

These changes are expected to impose costs on landholders due to lost option value on this land compared to the base case.

Flood work approvals in these areas are assessed to be significantly negatively affected by the Macquarie Valley FMP 2021. However, this assessment is likely to be conservative as all works

were assumed to have previously been considered against rules similar to those for MZ B, when in reality some would have been assessed under rules similar to those for MZ A.

Management Zone BH

MZ BH includes areas that convey significant discharge for the 1990 large design flood through higher floodways upstream of Warren. It is defined by hydraulic criteria based on DVP products generated by flood modelling and also by ecological and cultural amendments. MZ BH passes through major areas of existing development and was designed to allow applications for all types of flood works. This is in contrast to MZ A, which restricts the types of allowable flood works. Because of the importance of maintaining flood conveyance through the identified high floodways, applications in MZ BH must meet stringent hydraulic assessment criteria. All flood work applications in MZ BH must be advertised.

Approximately 60% of MZ BH is within the floodway network of the Macquarie River FMP 2008. In these areas, there is no change to advertising requirements compared with the base case. Additionally, assessment criteria in MZ BH are similar to those that apply to flood work applications located within the floodway network of the Macquarie River FMP 2008.

In parts of MZ BH located outside the floodway network of the Macquarie River FMP 2008, the area of land where flood work applications must be advertised has increased. Unlike in MZ B, there are no advertising exemptions for minor works in MZ BH. This change will result in some cost increases to landholders and the government relating to advertising and addressing objections. Overall, however, cost impacts are expected to be minor in line with impacts identified for MZ B.

Flood work applications in areas of MZ BH located outside the floodway network of the Macquarie River FMP 2008 will be subject to tighter hydraulic assessment criteria than under the base case. However, this change is not likely to impact flood work options as works meeting these criteria would generally need to be of limited height to allow overtopping of the 1990 large design flood. This is similar to the requirement under the Macquarie River FMP 2008 for flood works outside the floodway network upstream of Warren to be limited to 1990 design flood levels.

Management Zone B

MZ B is floodplain land that is outside MZ A, MZ BH and MZ D and is defined as flood storage and secondary flood discharge under the modelled 1990 large design flood.

Under the Macquarie Valley FMP 2021, land users in MZ B must advertise applications to undertake flood works, with only limited exclusions to this rule (see Table 16). Compared to the base case, there has been an increase in the area of land within the Macquarie River FMP 2008 that requires that land users advertise applications for flood works. However, the Macquarie Valley FMP 2021 has reduced advertising requirements through the specification of minor works in MZ B. Minor works such as limited height flood works, and stock refuge and infrastructure protection works subject to size conditions can be approved without advertising. This change is expected to provide additional benefits to landholders and streamline the assessment process. Flood works in excess of the size limits in MZ B will require advertising which is the same requirement as the base case.

For MZ B land outside the Macquarie River FMP 2008, there is no change between the base case and Macquarie Valley FMP 2021 to the area of land in which flood works require advertising.

Overall, the changes from the base case to the Macquarie Valley FMP 2021 will likely result in minor costs to landholders and the government from costs associated with advertising and addressing objections. The area and number of applications within MZ B that will be impacted by this rule is unknown as it is not feasible to forecast the exact number or complexity of applications, or the time required to advertise, assess objections, negotiate modifications and consider approval or rejection. Considering the maturity of the irrigation water resources in the area and that future expansion of the irrigation industry will depend on water use efficiency gains, the number of

applications is expected to decrease but the complexity of applications is expected to increase. This cost will not be estimated in this assessment.

Management Zone C

Areas above the modelled extent of the 1990 large design flood or afforded protection by works are in MZ C. Flood work applications in MZ C may require a technical report to meet assessment criteria but will not require advertising.

It is expected that flood work approvals in this area will not be substantially negatively affected under the Macquarie Valley FMP 2021.

Management Zone CU

MZ CU includes areas where local councils oversee floodplain management. The hydraulic, ecological and cultural criteria are not applicable in these areas.

It is expected that there will not be any substantially negative impacts in this area.

Management Zone D

MZ D is a special protection zone that includes highly significant ecological and cultural assets. The inclusion of this zone in the Macquarie Valley FMP 2021 is to ensure that flood connectivity to these assets is maintained and protected.

MZ D is defined by ecological and cultural criteria. It includes all assets associated with water bodies, riparian land, and an extensive area of the Macquarie Marshes. Given the recognised environmental significance of the Marshes, it is assumed that only minor flood works would be approved in this area under the base case. Outside the Marshes, approximately 50% of land identified as MZ D included areas that were modelled with significant discharge for the large design floods. Under the base case, flood work applications in these areas would either be assessed as non-complying works under the Macquarie River FMP 2008 or would need to undergo a technical assessment to demonstrate consistency with the WM Act. Overall, it is unlikely that works more substantial that those permissible in MZ D would have been approved under the base case in these areas.

Land in MZ D outside the Macquarie Marshes that was not modelled with significant discharge for the large design floods will be subject to significant change under the Macquarie Valley FMP 2021. Under the base case, it is likely that flood work proposals in these areas would have been assessed in general accordance with rules similar to MZ B. These areas are now subject to MZ D rules that allow for restricted flood works including limited-height access roads; stock refuges; infrastructure protection works within specified size limits; and ecological, Aboriginal value and heritage site enhancement works. These changes are expected to impose costs on landholders due to lost option value on this land compared to the base case.

Flood work approvals in these areas are assessed to be significantly negatively affected by the Macquarie Valley FMP 2021. However, this assessment is likely to be conservative as all works were assumed to have previously been considered against rules similar to those for MZ B, when in reality some would have been assessed under rules similar to those for MZ D.

Summary of negative impacts

Considering the changes from the base case to the Macquarie Valley FMP 2021, the negative impacts identified are:

- reduction in flood work options on all land zoned as ecological or cultural amendments to MZ A
- reduction in flood work options on all land zoned as ecological or cultural amendments to MZ D
- increased costs associated with the requirement to advertise flood work applications in MZ BH and MZ B.

The details of the impacts are presented in Table 17.

Table 17: Impact table of Macquarie Valley FMP 2021

Parameter	Impact 1: Ecological and cultural amendments to MZ A	Impact 2: Ecological and cultural amendments to MZ D	Impact 3: Land in MZ BH and MZ B
Total area	383 ha	241 ha	Unknown
Possible land use	Cropping	Cropping	Cropping and grazing
Representative land use	Wheat	Wheat	Wheat
Impact	Lost access to complying works other than infrastructure protection works, stock refuges, access roads, below-ground supply channels, and ecological and cultural enhancement works	Lost access to complying works other than infrastructure protection works, stock refuges, access roads, and ecological and cultural enhancement works	Lost access to non-advertising of former complying applications
Who is impacted	Landholder	Landholder	Landholder
Quantifiable ($)	Yes	Yes	No
Data sources	GIS – area; ABS – Wheat $ GVAP	GIS – area; ABS – Wheat $ GVAP	Unknown area and number of applications: not estimated
Scale : extent and intensity*	**Plan:** Negative, Low **Regional**: Negative, Low **Local**: Negative, Low **Owner**: Negative, Medium	**Plan:** Negative, Low **Regional:** Negative, Low **Local:** Negative, Low **Owner:** Negative, Medium	**Plan:** Positive, Low **Regional:** Positive, Low **Local:** Positive, Low **Owner:** Negative, Medium
Likelihood and duration*	**Plan:** Low, Permanent **Regional:** Low, Permanent **Local:** Low, Permanent **Owner:** Medium, Permanent	**Plan:** Low, Permanent **Regional:** Low, Permanent **Local:** Low, Permanent **Owner:** Medium, Permanent	**Plan:** Low, Permanent **Regional:** Low, Permanent **Local:** Low, Permanent **Owner:** Low, Permanent

* Impact: assess each factor with the other 3 factors held constant. Magnitude: Low, Medium, High.

Impacted area

MZ A

The total area of ecological and cultural refinements to MZ A (flood-dependent vegetation) from outside the modelled hydraulic floodway networks is estimated to be 45,714 hectares (3.7% of the total floodplain area). However, the Macquarie Valley FMP 2021 does not impact the whole area, as not all of the area is suitable for regular cultivation or flood irrigation.

Of the MZ A impacted area, land suitable for regular cultivation and flood irrigation is most likely to receive applications for flood works due to the value of protecting crops which cannot be moved. In contrast, land for grazing is not assumed to receive applications for flood works as livestock can be protected by moving them to higher ground. Moving livestock is assumed to be a lower cost alternative to building flood works.

On the land defined as ecological or cultural amendments to MZ A, 383 hectares (less than 1% of the total of 45,714 hectares) would otherwise have been suitable for regular cultivation or flood irrigation. This assessment was based on Land Capability data. It is acknowledged that, depending on the property size, affected areas may have a large impact on option value for individual landholders.

Regulations for flood work approvals in MZ A apply to the construction of flood works and do not prevent cultivation or grazing on the land. For the base case, it is assumed that if the Macquarie Valley FMP 2021 was not in place, all of the area defined as ecological and cultural amendments to MZ A with land capability suitable for regular cultivation or flood irrigation would be cropped. This provides an upper estimate of the annual gross value of production that might be lost (foregone revenue) with the introduction of the Macquarie Valley FMP 2021.

MZ D

MZ D is based on ecological and cultural criteria and includes land along rivers and creeks that would otherwise be included in the hydraulic floodway network. Of MZ D, 91% is within the Macquarie Marshes. Due to the recognised environmental significance of this land it is assumed that there would be no applications for flood works to protect cropping in this area. Land in MZ D outside the Marshes that includes ecological and cultural amendments is estimated to cover 5,591 hectares (0.5% of the floodplain).

Of the MZ D impacted area, land suitable for regular cultivation and flood irrigation is most likely to receive applications for flood works due to the value of protecting crops, which cannot be moved. On the land defined as ecological or cultural amendments to MZ D, 241 hectares (4.3% of the total of 5,591 hectares) would otherwise have been suitable for regular cultivation or flood irrigation. This assessment was based on the Land Capability data and it is acknowledged that, depending on the property size, affected areas may have a large impact on option value for individual landholders.

As with MZ A, regulations for flood work approvals in MZ D apply to the construction of flood works and do not prevent cultivation or grazing on the land. Once again, in the base case, it was assumed that if the Macquarie Valley FMP 2021 was not in place, all of the area defined as ecological and cultural amendments to MZ D with land capability suitable for regular cultivation or flood irrigation would be cropped. This provides an upper estimate of the annual gross value of production that might be lost (foregone revenue) with the introduction of the Macquarie Valley FMP 2021.

Estimated value of economic impacts

The economic impact of the Macquarie Valley FMP 2021 on landholders with land zoned as ecological or cultural amendments to MZ A and MZ D is estimated as lost revenue. The assumptions used in the central scenario are intentionally conservative. While they may not be

completely reflective of reality, they remain feasible and serve the purpose of clearly and fairly identifying negative socio-economic impacts.

Areas of ecological or cultural amendments to MZ A and MZ D are largely adjacent to or flowing to watercourses and are therefore likely to be exposed to frequent flooding. Some of these flood events are beneficial to the crop or pasture and some are devastating depending on the timing (relative to crop and pasture growth cycle), depth, duration and speed of the floodwater. As flood works to protect crops cannot be constructed in MZ A or MZ D, it is assumed that the outcome of these events is detrimental to crop production and causes an additional one crop failure in 3 years.

This is a conservative assumption of the impact of flooding because it does not consider the positive impacts of flooding. For landholders, flooding can potentially improve soil fertility, improve sub-soil moisture and improve water storage levels.

To simplify the analysis, and because it is unrelated to the change in management practices, it is assumed that other risks to crop production do not exist. In reality, crop yields and outputs are sensitive to a host of other risks such as pests and disease, extreme rainfall and temperature, as well as changes in inputs.

The analysis also assumes that the loss is total annual gross value of production. In reality, production costs are saved if the crop does not reach maturity. At the very least, production costs saved is the cost of crop harvest but may also include fertiliser and chemical applications.

Cropping in the Macquarie valley floodplain includes a variety of crop types and rotation sequences. The largest area of crop grown is wheat (142,335 hectares compared to 47,253 hectares of other non-cereals (legumes and oilseeds), 32,197 hectares of other cereals (such as barley, oats and triticale) and 6,643 hectares of cotton, ABS 2011). Consequently, the potential use of the area suitable for regular cultivation is assumed to be wheat. The crop mix in the Macquarie valley floodplain may have changed since 2011. As such, the sensitivity of the analysis to crop and other changes is tested in the sensitivity analysis below.

The potential revenue of land affected by the Macquarie Valley FMP 2021 with complete flood protection in the Macquarie valley floodplain is $0.35 million per year (383 hectares in MZ A plus 241 hectares in MZ D, all multiplied by the gross value of wheat per hectare of $558) . Without flood protection works, this land is estimated to produce $0.26 million per year (one in 4 crops lost, equivalent to 75% of $0.35 million). This implies a potential cost of approximately $90,000 per year on average in foregone revenue of $144 per hectare ($90,000 divided by 624 hectare). This equates to 0.05% of the total value of agricultural revenue in the entire Macquarie Valley FMP 2021 area (GVAP of $180 million, ABS 2011). While small in aggregate, the localised impact of the changes could be felt more intensely by individual landholders.

Sensitivity analysis

This analysis is sensitive to the assumed frequency of crop failure, the type of crop grown, the cropping area within the area of ecological and cultural amendments to MZ A and MZ D, and the impact on individual property owners.

Sensitivity to the frequency of crop failure

The loss due to the inability to construct flood works to protect these areas from flooding is an estimated additional one crop failure in 4 years. If the rate of additional crop failure due to flooding was to increase to one crop failure in 2 years, the estimated impact would rise to $180,000 or 0.1% of the regional GVAP. Conversely, if the rate of additional crop failure due to flooding was to decrease to one crop failure in 8 years, the estimated impact would be reduced to $45,000 or 0.03% of the regional GVAP.

Sensitivity to crop grown

The analysis has been completed assuming that the flood affected cropping area is all sown to wheat – the dominant crop grown in the Macquarie valley floodplain. Under this assumption, the loss is $90,000 or 0.5% of the regional GVAP. However, if the analysis is varied to assume that the entire flood affected cropping area is sown to cotton, then the loss increases to $600,000 or 0.33% of the regional GVAP.

Sensitivity to cropping area

The estimated impact is expected to be an overestimate due to the fact that much of the 624 hectares identified in the analysis as holding potential for continuous wheat production is currently used for grazing because it floods too often to be cropped reliably. In such cases, the farmer's assessment has been that the higher cost of cropping and the risk of loss are greater than the benefits of the more reliable option of pasture grazing, which has lower cost and lower risk, but smaller gain. If the area was reduced by one half to 312 hectares, due to incorrect classification as suitable for regular cropping or inability to crop due to other restrictions such as the *Native Vegetation Act 2003*, the estimated impact would be reduced to $45,000 or 0.03% of the regional GVAP.

A further sensitivity to cropping area can be prepared using ABARES land use data rather than the Soil Conservation Service land capability classification. ABARES estimates that the total area of MZ A and MZ D suitable for cropping is 1,921 hectares and 297 hectares respectively, giving a total of 2,218 hectares. Using the ABARES crop area estimate and assuming the entire area is planted to wheat, loss is $309,000 or 0.17% of the regional GVAP.

Sensitivity to the impact on individual property owners

Many landholders will not be impacted by the Macquarie Valley FMP 2021; however, there may be some individual farm level impacts that could be more significant depending on the proportion of their land that is affected. A counter balancing item is that the area of ecological and cultural amendments to MZ A and MZ D is likely to have a discounted land value due to flooding frequency.

Phase 2 assessment

A detailed analysis (phase 2) is to be undertaken if the preliminary analysis in phase 1 indicates that there may be significant socio-economic impact. Considering that, the estimated impact of the Macquarie Valley FMP 2021 rules (estimated to be a reduction of 0.05% of the total GVAP for the Macquarie valley floodplain area) is of low significance for the regional economy, no further investigation was proposed. In addition, there was no other major issue raised during the public exhibition period that warrants further detailed assessment.

Summary

Considering the changes from the base case to the Macquarie Valley FMP 2021, the following key negative impacts were identified:

- Lost opportunities to get approval in the area of ecological and cultural amendments in MZ A for works other than limited infrastructure protection works, stock refuges, access roads, below ground supply channels and ecological, Aboriginal value, and heritage site enhancement works.
- Lost opportunities to get approval in the area of ecological and cultural amendments in MZ D for works other than limited infrastructure protection works, stock refuges, access roads, and ecological, Aboriginal value, and heritage site enhancement works.

- Increased costs associated with the requirement to advertise applications for flood works for land in MZ BH and MZ B that is currently captured as part of the Macquarie River FMP 2008 area.

The impact of the Macquarie Valley FMP 2021 is estimated to be a small reduction of 0.05% for the core analysis assumptions of the total GVAP for the Macquarie valley floodplain and therefore no further investigation is currently proposed.

This is the estimated upper limit economic impact considering that it is unlikely that all of the area of ecological and cultural amendments within MZ A and MZ D suitable for regular cultivation could be cropped.

Many landholders will not be impacted by these estimated costs; however, there may be some individual farm level impacts that are more significant depending on where the land is situated in the landscape.

Role of socio-economics in plan development

This impact assessment concludes that there is a limited negative socio-economic impact from the Macquarie Valley FMP 2021. Therefore, no further investigation is currently proposed.

Socio-economic advice has influenced the development of the Macquarie Valley FMP 2021 zones, rules and assessment criteria. Substantial consideration was given to achieve a balance at each stage between flood behaviour and the environment, and social and economic outcomes. Some examples include:

- categorising the types of flood works enabled consideration of important information on the socio-economic benefits of flood works, along with the level of risk that a flood work type would significantly impact on flood behaviour (Step 3).
- ensuring socio-economic impacts were included in the criteria for ‘reasonable consistency’ with previous floodplain management arrangements (Step 9).
- incorporating, wherever possible, areas with approved existing flood work developments into MZ C (Step 4 and 7).
- weighing up the socio-economic impacts of development controls against the potential for different types of flood works to impact on flooding behaviour. The restrictions on the types of flood works that could be applied for were made to minimise the risk that flood works would impact flooding behaviour whilst being sympathetic to landholder needs. These decisions were checked against the works likely to be approved under existing floodplain management planning arrangements and discussions held during targeted consultation with the community and interagency officers (Step 8).
- the requirement to advertise proposed works provides local landholders with an opportunity to comment on any impact that a proposed flood work could have in causing or exacerbating flooding depth, duration or flow rate problems on their land.
- The non-advertising of proposed minor flood works enables landholders to construct approved flood works of a more minor nature without advertising their proposed works, which will save both money and time (Step 8).

Consultation and review of the plan

The department's Water Group was responsible for the review and consultation process throughout the development of the Macquarie Valley FMP 2021. The Environment, Energy and Science Group contributed technical expertise and local experience to the review and consultation process. All stakeholders and interested parties had an opportunity to review and provide comment on the Macquarie Valley FMP 2021 at key stages throughout the development of the FMP.

Consultation process

Consultation activities involved:

- **technical assessment**: consultation of regional and scientific experts to collect relevant data/knowledge, provide technical input and review the FMP planning approach and criteria for delineating management zones and rules
- **targeted consultation**: engagement of targeted community groups for feedback on the proposed boundary, management zones and rules
- **public exhibition**: formal public exhibition of the Draft Macquarie Valley FMP 2021, and collection, review and incorporation of feedback from formal submissions to finalise the FMP for ministerial approval and commencement.

Consultation with Aboriginal stakeholders was undertaken using the approach outlined in Appendix 15 to be in line with:

- Aboriginal People, the Environment and Conservation (APEC) principles (Department of Environment and Conservation 2006)
- an Aboriginal Community Engagement Framework for DECC (2007)
- working to protect Aboriginal cultural heritage (OEH 2011).

Technical assessment

Technical Advisory Group

The Technical Advisory Group (TAG) was responsible for providing expert knowledge and technical advice to the project team to help facilitate the development of the FMP. The TAG was composed of NSW Government agencies and other key agencies involved in water management in NSW, including the former Department of Industry, former OEH, NSW DPI—Agriculture, LLS and NSW DPI—Fisheries.

The TAG was engaged throughout the FMP development process through a combination of email correspondence and face-to-face meetings. The TAG officially met 5 times from December 2012 to October 2015 to identify and establish:

- the floodplain boundary
- draft management zones and rules
- ecological and cultural assets that are dependent on flooding
- watering requirements of flood-dependent assets
- cultural and ecological assessments and targets
- design floods and hydraulic modelling parameters
- socio-economic considerations

Information provided by the TAG was incorporated into the development of the Draft Macquarie Valley FMP 2021.

Aboriginal Technical Working Group

The Aboriginal Technical Working Group (ATWG) was created as a consultative group to provide strategic advice on the:

- type, scope and integration of flood-dependent Aboriginal values into the FMPs
- identification and prioritisation of cultural assets that require protection under the FMPs
- key contacts/knowledge holders in the Aboriginal community to consult with
- cultural knowledge on the history of flooding.

The ATWG comprised state and regional cultural heritage experts. It was designed to have flexible membership to adapt to the moving focus of plan development in different valleys. A number of workshops were held with the ATWG to:

- define and identify Aboriginal values that are dependent on flooding
- identify watering requirements of Aboriginal values and other floodplain assets that have Aboriginal value
- identify and document the significance of Aboriginal values and other floodplain assets that have Aboriginal value
- develop a community consultation process for identification of Aboriginal values in data gap areas
- review draft management zones, rules and assessment criteria.

Information provided by the ATWG was incorporated into the development of the draft FMP and is outlined in Steps 5, 7 and 8.

Aboriginal community

Local Aboriginal communities were engaged by an OEH Aboriginal Natural Resource Officer through informal meetings. The aim of these meetings with Aboriginal stakeholders was to identify issues of concern in the valley and to introduce the objectives of the FMP in the context of the issues raised. During this engagement, the former OEH collected spatial information on cultural assets dependent on flooding. These were later analysed as part of Step 5 and were factored into the management construct. These cultural assets were discussed with the community during targeted consultation to obtain further feedback. Refer to Steps 5, 7 and 8 for further information on how Aboriginal values from consultation were incorporated into the draft FMP.

Targeted consultation

Targeted consultation was an opportunity to ‘road test’ the Draft Macquarie Valley FMP 2021 boundary, management zones and rules. Targeted consultation was undertaken with stakeholders at Warren, the Macquarie Marshes and Dubbo in May 2017.

The objectives of targeted consultation were to:

- provide background to key stakeholders:
    - as to why and how the FMPs are being developed
    - what management zones and rules are proposed in the Draft Macquarie Valley FMP 2021
    - how stakeholders could provide feedback
- ‘road test’ the proposed Macquarie Valley plan boundary, management zones and rules.

Participation was at the invitation of the former OEH and drawn from a representative cross-section of industry groups. Targeted consultation involved the following key stakeholder groups and individuals within the Macquarie valley floodplain:

- landholder representatives, including graziers, dryland and irrigation landholders and organisations
- Aboriginal community representatives
- environmental representatives
- local and state government representatives
- representatives from Macquarie River Food & Fibre and NSW Farmers Association
- local agronomists and consultants.

As a proportion of the total items of inquiry received, 28% collectively related specifically to the Draft Macquarie Valley FMP 2021 boundary, management zones, rules and assessment criteria.

Suggested changes to the draft management zones were reviewed and incorporated as recommendations for consideration by the IRP following feedback from targeted consultation. Five minor changes were made to the draft management zones as a result of targeted consultation:

- four areas where the extent of MZ D was expanded to include additional wetland assets
- rezoning an existing supply channel from MZ A to MZ C.

Public exhibition

The Macquarie Valley FMP 2021 was on public exhibition from 16 July to 13 September 2018 (60 days). Over this period, 33 stakeholder events were held, with 109 participants, and 49 submissions were received, from which 413 items of inquiry were collated.

The objectives of this consultation were to provide background information to stakeholders on:

- why the FMP is being developed
- how the FMP has been developed to date
- what rules are proposed in the various areas
- how to make a formal submission.

The public exhibition of the plan was advertised in the *The Land, Western Magazine, Warren Weekly* and the *Koori Mail* during the week commencing Monday 16 July 2018, and on the NSW Government Have Your Say website. The department posted 585 letters to flood work approval holders, landholders who submitted floodplain harvesting registrations of interest (ROIs) and landholders whose properties intersected MZ A and MZ D of the Draft Macquarie Valley FMP 2021, notifying them of the exhibition period.

Display packages containing information about the draft plan were available for inspection throughout the exhibition period from locations in Warren, Quambone, Narromine, Nyngan, Carinda, Marra Creek, Trangie and Dubbo.

The department hosted information appointments and briefing sessions for stakeholders at:

- Warren (11 events)
- Quambone (2 events)
- Dubbo (3 events)
- Nyngan (2 events)
- Narromine (3 events)
- Moree

during the exhibition period to view the draft management zones at individual property scale at locations within the Macquarie Valley FMP 2021 area.

A suite of products was developed to support stakeholders in understanding the Draft Macquarie Valley FMP 2021, and this information was available to stakeholders in hard copy from each

display location (8), by post or email upon request, and for download from the department's website (Table 18).

Table 18. Macquarie Valley FMP: public exhibition display products

Document name	Description
Report cards for each management zone of the Draft Macquarie Valley FMP 2021	A summary of the draft rules and key factors developed for each management zone of the Draft Macquarie Valley FMP 2021
Map of the Draft Macquarie Valley FMP 2021	A colour map illustrating the floodplain boundary and management zones contained within the Draft Macquarie Valley FMP 2021
Draft rural floodplain management plans: technical manual	A general description of the method employed for development of floodplain management plans across rural New South Wales
Rural floodplain management plans: Background document to the Draft Floodplain Management Plan for the order Rivers Valley Floodplain 2017	A description of how the method presented in the technical manual has been applied across the Draft Macquarie valley floodplain and should be read in conjunction with the technical manual
Draft Floodplain Management Plan for the Macquarie Valley Floodplain 2017	The legal document that includes all of the rules and requirements in a statutory format
Floodplain management under the *Water Management Act 2000*: A guide to the changes	A guide to the transition of floodplain management planning from the *Water Act 1912* to the *Water Management Act 2000* in NSW
An overview of floodplain management plans under the *Water Management Act 2000*	A general, plain English explanation of the key provisions of floodplain management plans. The overview is a summary that should be read in conjunction with the Draft Macquarie Valley FMP 2021
Submission form for public exhibition	A template that stakeholders can use to provide comments on the Draft Macquarie Valley FMP 2021 during public exhibition

Submissions were accepted in writing, electronically and by post.

In addition to the targeted consultation and public exhibition processes, the preparation of the Macquarie Valley FMP 2021 was supported by the implementation of 2 additional consultation processes:

- ground-truthing (field validation)
- post-public exhibition consultation.

The purpose of the ground-truthing process was to gain a practical understanding of flood behaviour on the ground.

On 25 October 2019, the department wrote to 105 landholders whose properties were affected by the proposed property-scale changes and sought their feedback.

The department has written to all stakeholders who provided a submission to public exhibition and also those who responded to post-public exhibition consultation (56), describing the updates that have been made to the plan in response to the feedback received and providing a copy of the final draft of the management zones map for information.

Review

Interagency Regional Panel

The Interagency Regional Panel (IRP) was established to review the boundary, management zones and rules contained in the Macquarie Valley FMP 2021. The IRP consisted of one

representative each from the following groups within the Department of Planning, Industry and Environment:

- the Energy, Environment and Science Group to cover environmental interests
- the Water Group to cover water management interests
- the Department of Primary Industries to cover agriculture and fisheries interests.

Representatives from Local Land Services, WaterNSW, the Natural Resources Access Regulator and the department's economics branch also attended meetings (as observers) to provide advice on relevant matters within their area of expertise.

The key responsibilities of the IRP were to:

- ensure that proposed management rules achieve the objectives of the WM Act
- provide information and analysis
- bring a balanced approach to the development of the FMP: economic, social, environmental and cultural considerations.

The IRP provides whole-of-government oversight and review of the development of the Macquarie Valley FMP 2021 and met at key stages throughout the FMP development:

- before targeted consultation
- before public exhibition
- before finalisation and start.

Before targeted consultation

The IRP reviewed the Draft Macquarie Valley FMP 2021 in September 2016 and supported its release for targeted consultation.

Before public exhibition

The IRP reviewed the Draft Macquarie Valley FMP 2021 and feedback from targeted consultation in August 2017.

The IRP recommended that the draft management zones be updated to reflect feedback from targeted consultation.

The IRP also provided key considerations for the implementation of the Macquarie Valley FMP 2021. These considerations will be incorporated into assessment guidelines and used by licensing staff when assessing flood work applications.

Before finalisation and start

The IRP reconvened after public exhibition to:

- consider stakeholder feedback
- recommend changes to the draft management zones based on feedback
- review and endorse final boundary, management zones and rules before the FMP starts.

A total of 49 submissions were received in response to the public exhibition of the Draft Macquarie Valley FMP 2021. From the 49 submissions, 413 items of inquiry were identified and collated.

The IRP considered the feedback received during public exhibition before finalising the FMP. Changes supported by the IRP are reflected in the finalised products in this report and the Macquarie Valley FMP 2021 plan order.

On 3 October 2019, the IRP supported numerous property-scale changes to the management zones for the Draft Macquarie Valley FMP 2021 in response to the review process for internal and public feedback received to public exhibition.

On 5 May 2020, the IRP reviewed the feedback received to post-public exhibition consultation and supported changes to the management zones for the Draft Macquarie Valley FMP 2021 in response to the public feedback received to post-public exhibition consultation.

On 6 October 2020, the IRP approved the inclusion of a transitional provision for dealing with outstanding flood work applications for flood works that are located or proposed to be located in Management Zones A and D, that were lodged with WaterNSW before a cut-off date.

On 25 February 2021, the IRP met and approved several final property-scale minor management zone revisions.

Plan finalisation and commencement

After endorsement by the IRP in May 2020, the Macquarie Valley FMP was submitted to the Minister for Water, Property and Housing for in-principle approval and then to the Minister for the Environment to seek concurrence. The Macquarie Valley FMP 2021 was then returned to the Minister for Water, Property and Housing for final approval.

The Macquarie Valley FMP 2021 started on 24 September 2021. Copies of the FMP can be obtained from the NSW Legislation website.

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Glossary

Aboriginal cultural values are sites, objects, landscapes, resources and beliefs that are important to Aboriginal people as part of their continuing culture.

Aboriginal value enhancement work is a flood work that is constructed only to benefit Aboriginal value assets that are listed in the Aboriginal Heritage Information Management System (AHIMS), Aboriginal Water Initiative System (AWIS) (now inactive), Murray Darling Basin Authority Aboriginal Submissions Database, NSW State Heritage Register or Commonwealth Heritage Register.

annual exceedance probability is the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 megalitres per day (ML/day) has an AEP of 5%, it means there is a 5% (or one in 20) chance of a 500 ML/day or larger event occurring in any one year.

borrow is an area of land where material is excavated or removed to construct a flood work at another location. The removal of material from this area results in a depression or 'hole' in the ground.

connectivity refers to the unimpeded passage of floodwater through the floodplain. Connectivity is important for instream aquatic processes and biota and the conservation of natural riverine systems.

cultural asset is an object, place or value that is important for people to maintain their connections, beliefs, customs, behaviours and social interactions.

depth-velocity product is a hydraulic model output that can be used to indicate areas of a floodplain where a significant discharge of water occurs during floods; that is, areas where flow velocity and/or water depth are relatively high.

design flood is a flood of known magnitude or annual exceedance probability (AEP), that can be modelled. A design flood is selected to design floodway networks that are used to define management zones for the planning and assessment of the management of flood works on floodplains. The selection is based on an understanding of flood behaviour and associated flood risk. Multiple design floods may be selected to account for the social, economic and ecological consequences associated with floods of different magnitudes.

discharge (or flow) is the rate of flow measured in volume per unit of time (for example, megalitres per day = ML/day).

drought refuge is a depression area that is instream or across the floodplain that retains water for a significant period of time relative to the surrounding landscape and provides vital habitat for native water-dependent biota during dry spells, drought and low flow. Examples of aquatic drought refuge include wetlands, waterholes, pools.

ecological assets are a wetland or other floodplain ecosystem, including watercourses that depend on flooding to maintain their ecological character. Areas where groundwater reserves are recharged by floodwaters are also considered to be ecological assets. Ecological assets are spatially explicit and are set in the floodplain landscape.

ecological enhancement work is a flood work that is constructed for the improvement, conservation and protection of ecological assets and is not for an agricultural purpose.

ecological values (also known as ecological surrogates) are surrogates for biodiversity that are used to prioritise the ecological assets and included animals and animal habitat, vegetation communities and areas of conservation significance.

ecosystem is a biological system involving interactions between living organisms and their immediate physical, chemical and biological environment.

fish passage refers to connectivity that facilitates the movement of native fish species between upstream and downstream habitats (longitudinal connectivity) and adjacent riparian and floodplain areas (lateral connectivity). Areas that are important for fish passage include rivers, creeks and flood flow paths.

flood-dependent assets refer to assets that have been identified in the plan as having important ecological or cultural features that rely on inundation by floodwaters to sustain essential processes.

flood risk management plan identifies and determines options in consideration of social, ecological and economic factors relating to flood risk and the management of flood-prone land.

flood risk management study provides preferred options relating to flood risk and provides the information necessary for adequate forward planning of flood-prone land.

flood structure refers to any existing floodplain feature (such as a barrage, causeway, cutting or embankment) without a flood work approval for which a flood work approval is now required, from the start of the Macquarie Valley FMP 2021.

flood study is a comprehensive technical investigation of flood behaviour and defines the nature of flood risk.

flooding regime refers to the frequency, duration, nature and extent of flooding.

floodplain watercourses include:

(a) permanent flowing rivers and creeks, including those where the flow is modified by upstream dam(s)

(b) intermittent flowing rivers and creeks that retain water in a series of disconnected pools after flow ceases including those where the flow is modified by upstream dam(s), to the top of the natural bank regardless of whether the channel has been physically modified

(c) flood channels or flood runners that run across or along floodplains during high flow events.

flood work refers to any existing floodplain feature (such as a barrage, causeway, cutting or embankment) without a flood work approval for which a flood work approval is now required, from the start of the Macquarie Valley FMP 2021.

floodways are areas where a significant discharge of floodwater occurs during small and large design floods.

groundwater recharge areas are areas where water from a flood event leaks through the soil profile into the underlying aquifers.

heritage sites are cultural heritage objects and places as listed on federal, state and local government heritage registers.

heritage site enhancement work is a flood work that is constructed only to benefit heritage site assets that are listed in the Aboriginal Heritage Information Management System (AHIMS), Aboriginal Water Initiative System (AWIS), Murray–Darling Basin Authority Aboriginal Submissions Database, NSW State Heritage Register, NSW State Heritage Inventory, Historic Heritage Information Management Systems or Commonwealth Heritage Register.

high-value infrastructure includes but is not limited to houses/dwellings, infrastructure protection works, town levees, stockyards, sheds and pump sites. It does not include farm levee banks, irrigation development and fences.

infrastructure protection works are flood works that are for the protection of houses, stock yards and other major infrastructure, such as machinery sheds.

management zones are areas in the floodplain that have specific rules to define the purpose, nature and construction of flood works that can occur in those areas.

MIKE is a suite of water modelling software developed by DHI Group. Further information about the software packages used to develop the hydraulic models for the Macquarie valley floodplain is available in Appendix 3.

natural surface level is the average undisturbed surface level in the immediate vicinity.

peak discharge calculation location is a section of the floodplain where flow is calculated for the purpose of assessing the change in flow behaviour due to proposed flood works.

permissible flood work is a type of flood work that can be applied for in a particular management zone. Applications for permissible flood works must still be assessed to receive an approval.

pre-development conditions refers to natural flooding regimes.

primary access road is a road providing access from a public road to a permanently occupied fixed dwelling via a direct route.

recharge means the addition of water, usually by infiltration, to an aquifer.

spoil refers to waste material (such as dirt or soil) that is produced during the construction or modification of a flood work.

SPOT is a commercial high-resolution optical imaging Earth observation satellite system operating from space.

wetland refers to areas of land that are wet by surface water or groundwater, or both, for long enough periods that the plants and animals in them are adapted to, and depend on, moist conditions for at least part of their lifecycle. They include areas that are inundated cyclically, intermittently or permanently with fresh water, brackish or saline water that is generally still or slow moving except in distributary channels. Examples of wetlands include lakes, lagoons, rivers, floodplains, swamps, billabongs and marshes (adapted from the Wetland Policy definition in DECCW 2010).

windrow refers to a row or line of material.