DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

NSW Border Rivers Long Term Water Plan Parts A and B

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Acknowledgement of Traditional Owners

The Department of Planning, Industry and Environment pays its respect to the Traditional Owners and their Nations of the Murray-Darling Basin. The contributions of earlier generations, including the Elders, who have fought for their rights in natural resource management are valued and respected.

In relation to the NSW Border Rivers catchment, the Department of Planning, Industry and Environment pays its respects to the Gomeroi (also known as Gamilaraay and the Kamilaroi) Traditional Owners, past, present and future. We look forward to building upon existing relationships to improve the health of our rivers, wetlands and floodplains including in recognition of their traditional and ongoing cultural and spiritual significance.

Figure 1 Severn River.
Photo: N. Foster.

Abbreviations

Basin Plan	Murray-Darling Basin Plan
BCT	Biodiversity Conservation Trust
BDL	Baseline diversion limit
BRC	Border Rivers Commission
BWS	Basin-wide environmental watering strategy
CAMBA	China-Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
DBH	Diameter at breast height
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DPIE-Water	Department of Planning, Industry and Environment – Water (NSW)
DPIE	Department of Planning, Industry and Environment (NSW)
DPIE-BC	Department of Planning, Industry and Environment – Biodiversity and Conservation Division (NSW)
DPIF	Department of Primary Industries Fisheries (NSW)
EEC	Endangered Ecological Community
EWAG	Environmental Water Advisory Group
EWR	Environmental water requirement
GL	gigalitre
HEW	Held environmental water
IQQM	Integrated Quantity and Quality Model
JAMBA	Japan-Australia Migratory Bird Agreement
LLS	Local Land Services (NSW)
LTAAE	Long-term average annual extraction
LTWP	Long Term Water Plan
MDBA	Murray-Darling Basin Authority
MER	Monitoring, evaluation and reporting
mg/L	milligrams per litre
ML	megalitre
ML/d	megalitres per day
m/s	metres per second
NPWS	National Parks and Wildlife Services (NSW)
NRAR	Natural Resources Access Regulator (NSW)
NSW	New South Wales
OEH	Office of Environment and Heritage (NSW) – *DPIE-BC as of 1 July 2019*
PEW	Planned environmental water
PU	Planning unit

RAS	Resource availability scenario
RoKAMBA	Republic of Korea-Australia Migratory Bird Agreement
SDL	Sustainable diversion limit
TEC	Threatened Ecological Community
WQMP	Water quality management plan
WRP	Water resource plan
WRPA	Water resource plan area
WSP	Water sharing plan

Glossary

Actively managed floodplain	The area of floodplains and wetlands that can be inundated by managed environmental water deliveries alone or in combination with other flows from regulated river systems (see 'Regulated river').
Adaptive management	A procedure for implementing management while learning about which management actions are most effective at achieving specified objectives.
Allocation	The volume of water made available to water access licence or environmental water accounts in a given year by DPIE-Water, which is determined within the context of demand, inflows, rainfall forecasts and stored water.
Alluvial	Comprised of material deposited by water.
Bankfull flow	River flows at maximum channel capacity with little overflow to adjacent floodplains. These flows engage the riparian zone, anabranches, flood runners and wetlands located within the meander train. They inundate all in-channel habitats including benches, snags and backwaters.
Baseflow	In perennial rivers, this is a reliable background flow level within a river channel that are generally maintained by seepage from groundwater storage, but also by surface inflows. Typically inundates geomorphic units such as pools and riffle areas.
Basin Plan	The Basin Plan as developed by the Murray-Darling Basin Authority under the *Water Act 2007*.
Biota	The organisms that occupy a geographic region.
Blackwater	Occurs when water moves across the floodplain and releases organic carbon from the soil and leaf litter. The water takes on a tea colour as tannins and other carbon compounds are released from the decaying leaf litter. Blackwater plays an important role in transferring essential nutrients, such as carbon, from wetlands into rivers and vice versa. Carbon is a basic building block of the aquatic food web and an essential part of a healthy river system.
Catch per unit effort (CPUE)	An indirect measure of the abundance of a target species.
Cease-to-flow	The absence of flowing water in a river channel. Partial or total drying of the river channel. Streams contract to a series of isolated pools.
Cease-to-pump (access rule in WSP)	Pumping is not permitted: • from in-channel pools when the water level is lower than its full capacity • from natural off-river pools when the water level is lower than its full capacity or at an agreed pool draw down level • from pump sites when there is no visible flow These rules apply unless there is a commence to pump access rule that specifies a higher flow rate that licence holders can begin pumping.
Cold water pollution	The artificial lowering of water temperature that can extend hundreds of kilometres downstream of dams, due to releases of cold water from the dam. In older and deeper dams, water is typically released from the bottom of the dam where water temperatures can be significantly lower than surface readings. The effects of cold water pollution are harmful as it removes seasonal fish spawning cues, reduces availability of food, increases fish mortality and reduces the frequency and success of breeding events.
Constraints	The physical or operational constraints that effect the delivery of water from storages to extraction or diversion points. Constraints may include structures such as bridges that can be affected by higher flows, or the volume of water that can be carried through the river channel, or scheduling of downstream

	water deliveries from storage, or land uses in and around wetlands and floodplains.
Consumptive water	Water that is removed from available supplies without return to a water resource system (such as water removed from a river for agriculture). Consumptive water deliveries may contribute or support environmental water requirements prior to the point of extraction.
Cultural water-dependent asset	A place that has social, spiritual and cultural value based on its cultural significance to Aboriginal people and is related to the water resource.
Cultural water-dependent value	An object, plant, animal, spiritual connection or use that is dependent on water and has value based on its cultural significance to Aboriginal people.
Discharge	The amount of water moving through a river system, most commonly expressed in megalitres per day (ML/d).
Dissolved Organic Carbon (DOC)	A measure of the amount of carbon from organic matter that is soluble in water. DOC is transported by water from floodplains to river systems and is a basic building block available to bacteria and algae that microscopic animals feed on, that are in turn consumed by fish larvae, small bodied fish species, yabbies and shrimp. DOC is essential for building the primary food webs in rivers, wetlands and floodplains, ultimately generating a food source for large bodied fish like Murray cod and golden perch and predators such as waterbirds.
Ecological asset	The physical features that make up an ecosystem and meet one or more of the assessment indicators for any of the five criteria specified in Schedule 8 of the Basin Plan.
Ecological function	The resources and services that sustain human, plant and animal communities and are provided by the processes and interactions occurring within and between ecosystems. Identified ecosystem functions must also meet one or more of the assessment indicators for any of the four criteria specified in Schedule 9 of the Basin Plan.
Ecological objectives	Objective for the protection and/or restoration of an environmental asset or ecosystem function. Objectives are set for all priority environmental assets and priority ecosystem functions, and have regard to the outcomes described in the Basin-wide environmental watering strategy.
Ecological target	Level of measured performance that must be met to achieve the defined objective. The targets in this long-term water plan are SMART (Specific/Measurable/Achievable/Realistic/Time-bound) and are able to demonstrate progress towards the objectives and the outcomes described in the Basin-wide environmental watering strategy.
Ecological value	An object, plant or animal which has value based on its ecological significance.
Ecosystem	A biological community of interacting organisms and their physical environment. It includes all the living things in that community, interacting with their non-living environment (weather, earth, sun, soil, climate and atmosphere) and with each other.
Environmental water	Water for the environment. It serves a multitude of benefits to not only the environment, but to communities, industry and society. It includes water held in reservoirs (held environmental water) or protected from extraction from waterways (planned environmental water) for meeting the water requirements of water-dependent ecosystems.
Environmental water requirement (EWR)	An environmental water requirement (EWR, singular) describes the characteristics of a flow event (e.g. magnitude, duration, timing, frequency, and maximum dry period) within a particular flow category (e.g. small fresh), that are required for that event to achieve a specified ecological objective or set of objectives (e.g. to support fish spawning and in-channel vegetation). There may be multiple EWRs defined within a flow category, and numerous EWRs across multiple flow categories within a planning unit. Achievement of

	each of the EWRs will be required to achieve the full set of ecological objectives for a planning unit.
Floodplain harvesting	The collection, extraction or impoundment of water flowing across floodplains. NSW is currently bringing floodplain harvesting extraction under regulation and licencing framework and to be included under Water Sharing Plans.
Flow category	The type of flow in a river defined by its magnitude (e.g. bankfull). See Table 7 and Table 8 for more details.
Flow regime	The pattern of flows in a waterway over time that will influence the response and persistence of plants, animals and their ecosystems.
Freshes	Temporary in-channel increased flow in response to rainfall or release from water storages.
Groundwater	Water that is located below the earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater is recharged from, and eventually flows to, the surface naturally.
Held environmental water (HEW)	Water available under a water access licence or right, a water delivery right, or an irrigation right for the purposes of achieving environmental outcomes (including water that is specified in a water access right to be for environmental use).
Hydrograph	A graph showing the rate of flow and/or water level over time at a specific point in a river. The rate of flow is typically expressed in megalitres per day (ML/d).
Hydrological connectivity	The link of natural aquatic environments.
Hydrology	The occurrence, distribution and movement of water.
Hypoxic Blackwater	Occurs when dissolved oxygen (DO) levels, as measured in milligrams per litre (mg/litre), fall below the level needed to sustain native fish and other water dependent species. Native fish begin to stress when DO levels fall below 4 mg/litre and fish mortality occurs when DO levels are less than 2 mg/litre. When bacteria that feed on dissolved organic carbon multiply rapidly, their rate of oxygen consumption can exceed the rate at which oxygen can be dissolved in the water, oxygen levels fall and a hypoxic (low oxygen) condition occurs.
Large fresh (LF)	High-magnitude flow pulse that remains in-channel, connects most in channel habitats, provides partial longitudinal connectivity by drowning out of some low-level weirs and other in channel barriers and may engage flood runners and inundate low-lying wetlands.
Lateral connectivity	The flow linking rivers channels and the floodplain
Long Term Water Plan (LTWP)	A requirement of the Basin Plan that gives effect to the Basin-Wide Watering Strategy for each river system and will guide the management of water over the longer term. DPIE is responsible for the development of nine plans for river catchments across NSW, with objectives for five, 10 and 20-year timeframes.
Longitudinal connectivity	The consistent downstream flow along the length of a river.
LTA frequency	Minimum long-term average target frequency.
Mitchell landscapes	A classification of ecosystems established through multivariate mapping information, including rainfall, temperature, topography, geology, soil and vegetation.
Overbank flow (OB)	Flows that spill over the riverbank or extend to floodplain surface flows.

Pindari stimulus flow	Planned environmental water made under the *NSW Border Rivers Regulated River 2009 Water Sharing Plan* that is triggered by inflows into Pindari Dam of above 1,200 ML/day between 1 April to 31 August. If triggered 4,000 ML is set aside in Pindari Dam at the start of each water year, with a carry over capped to a maximum account balance of 8,000ML, for a 'stimulus flow' released between 1 August and 1 December.
Planned environmental water (PEW)	Water that is committed by the Basin Plan, a water resource plan, a water sharing plan, or a plan made under state water management law to achieve environmental outcomes.
Planning Unit	A spatial division of a water resource plan area based on water requirements or a sub-catchment boundary.
Population structure	The range of age and size classes within a species population. A population with a range of age and size, with a good number of sexually mature individuals, demonstrates regular recruitment and is healthy.
Priority environmental asset	A place of particular ecological significance that is water dependent, meets one or more of the assessment indicators for any of the five criteria specified in Schedule 8 in the Basin Plan, and can be managed with environmental water. This includes planned and held environmental water.
Priority ecological function	Ecological functions that can be managed with environmental water.
Recruitment	Successful development and growth of offspring; so that they can contribute to the next generation.
Registered cultural asset	A cultural water-dependent asset that is registered in the Aboriginal Heritage Information Management System (AHIMS).
Regulated river	A river that is gazetted under the *NSW Water Management Act 2000.* Flow is largely controlled by major dams, water storages and weirs. River regulation increases reliability of water supplies in most years but alters the natural flow regime required by water-dependent environmental assets and values.
Riffle	A rocky or shallow part of a river where river flow is rapid and broken.
Riparian	The part of the landscape adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within them.
Risk management strategy	A plan of management to overcome risks to achieving environmental outcomes.
Small fresh (SF)	Low-magnitude in-channel flow pulse that can inundate low lying benches, connect sections of a channel or river and trigger animal movement.
Supplementary access	A category of water entitlement where water is made available to licence holder accounts during periods of high river flows that cannot be controlled by river operations (i.e. supplementary event).
Supplementary event	An uncontrolled flow (such as a tributary flow below a regulating structure) that is accessible for extraction under supplementary water access licences, as announced by the Minister for a set time period.
Surface water	Water that exists above the ground in rivers, streams creeks, lakes and reservoirs. Although separate from groundwater, they are interrelated and over extraction of either will impact on the other.
Sustainable diversion limit (SDL)	The grossed-up amount of water that can be extracted from Murray–Darling Basin rivers for human uses while leaving enough water in the system to achieve environmental outcomes.
Stimulus flow	A planned environmental water rule in the Water Sharing Plan for the NSW Border Rivers Regulated River Water Source 2009 that aims to provide a flow

	pulse in the Severn River downstream of Pindari Dam. See section 4.5 for more details.
Unregulated river	A waterway where flow is mostly uncontrolled by dams, weirs or other structures.
Very low flow (VLF)	Small flow that joins river pools, thus providing partial or complete connectivity in a reach. Can improve DO saturation and reduce stratification in pools.
Water quality management plan (WQMP)	A document prepared by state authorities, as part of the Water Resource Plan, that is accredited by the Commonwealth under the Basin Plan. It aims to provide a framework to protect, enhance and restore water quality.
Water resource plan (WRP)	A policy package prepared by state authorities and accredited by the Commonwealth under the Basin Plan. It describes how water will be managed and shared between users in an area and meet Basin Plan outcomes.
Water resource plan area (WRPA)	Catchment-based divisions of the Murray–Darling Basin defined by a water resource plan.
Water sharing plan (WSP)	A plan made under the NSW *Water Management Act 2000* that sets out specific rules for sharing and trading water between the various water users and the environment in a specified water management area. A water sharing plan will be a component of a water resource plan.
Water-dependent	An ecosystem or species that depends on periodic or sustained inundation, waterlogging or significant inputs of water for natural functioning and survival.

Summary

Rivers, creeks, wetlands and floodplains play a vital role in sustaining healthy communities and economies. They provide productivity and connections across the landscape for people, plants and animals with benefits that extend well beyond the river bank and floodplains.

Over the past 200 years, many rivers, wetlands and floodplains in New South Wales (NSW) have had their natural flow regimes disrupted because of dams, weirs, floodplain development, and water regulation and extraction. In the case of the NSW Border Rivers, the frequency, duration and timing of cease-to-flow periods, low flows and small freshes have experienced the greatest alteration.

The NSW Border Rivers Long Term Water Plan (LTWP) is an important step to describing the flow regimes that are required to maintain or improve environmental outcomes in the NSW Border Rivers. The Plan identifies water management strategies for maintaining and improving the long-term health of the NSW Border Rivers riverine and floodplain environmental assets and the ecological functions they perform. This includes detailed descriptions of ecologically important river flows and risks to water for the environment.

Importantly, the LTWP does not prescribe how environmental water should be managed in the future but looks at management of all water to promote environmental outcomes in the catchment. The LTWP will help water managers make decisions about where, when and how water can be used to achieve agreed long-term ecological objectives. This recognises that the Murray-Darling Basin Plan (Basin Plan) (MDBA 2012a) specifically requires environmental water managers to act adaptively by making timely decisions based on the best-available knowledge, and from monitoring and evaluating the outcomes from water use.

Background to Long Term Water Plans

The Basin Plan (Chapter 8, part 4) establishes a framework for managing environmental water at the Basin and catchment-scale. The framework is designed to ensure environmental water managers work collaboratively to prioritise water use to meet the long-term needs of native fish, water-dependent native vegetation and waterbirds and co-ordinate water use across multiple catchments to achieve Basin-scale outcomes.

The *Basin-wide Environmental Watering Strategy* (BWS) (MDBA 2014) and LTWPs are central features of this framework. The BWS establishes long-term environmental outcomes and targets for the Basin and its catchments. LTWPs, which apply to catchment-scale water resource plan areas (WRPAs), must contribute to the achievement of the BWS by identifying:

- priority environmental assets and functions in a WRPA
- ecological objectives and ecological targets for those assets and functions
- environmental water requirements (EWRs) needed to meet those targets and achieve the objectives.

Water resource plans (WRP's) must have regard to LTWPs.

The NSW Border Rivers Long Term Water Plan

The NSW Border Rivers LTWP is one of nine plans being developed by the Department of Planning, Industry and Environment, Biodiversity and Conservation Division (DPIE–BC) to cover the NSW portion of the Murray-Darling Basin. Development of the LTWP has involved six main steps:

1. undertaking a comprehensive **stocktake** of water dependent native fish, birds and plant species and the river processes that underpin a healthy river system across the catchment to identify priority environmental assets and priority ecosystem functions.

2. determining specific and quantifiable **objectives and targets** for the priority assets and functions in the NSW Border Rivers catchment.
3. determining the **environmental water requirements** (including volume, frequency, timing and duration) needed to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions.
4. identifying the **risks and constraints** to meeting the long-term water requirements of priority environmental assets and ecosystem functions.
5. identifying potential **management strategies** to meet environmental water requirements.
6. identifying **complementary investments** to address **risks and constraints** to meeting the long-term water requirements of priority environmental assets and ecosystem functions.

This LTWP presents this information in seven chapters in two parts, with accompanying appendices.

Environmental values of the NSW Border Rivers catchment

The NSW Border Rivers catchment supports a range of water-dependent ecosystems, including instream aquatic habitats, riparian forests, and floodplain watercourses, woodlands and wetlands. Notably, the Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon complex are nationally recognised in the Directory of Important Wetlands (Environment Australia 2001). These ecosystems benefit many water-dependent species, including state and federally listed threatened ecological communities, threatened, endangered and migratory waterbirds, and threatened native fish species, by providing habitat and food resources.

The ecological condition of the NSW Border Rivers water-dependent environmental assets is largely driven by flows that connect the instream benches, cut-off channels, anabranches, floodplains and wetlands. Flows that provide these connections support organic carbon transfer and nutrient cycling, trigger movement and breeding of native fish and waterbirds, and directly impact vegetation condition and habitat availability.

Information to support this LTWP was sourced from local, traditional and scientific sources collected in partnership with water managers, natural resource managers and environmental water holders. Information about the NSW Border Rivers environmental values closely aligns with material in the NSW Department of Planning, Industry and Environment’s *NSW Border Rivers Surface Water Resource Plan Risk Assessment* (NSW DPIE-Water 2019a).

Water for the environment

The NSW Border Rivers LTWP contains ecological objectives and targets for priority environmental assets and ecosystem functions in the NSW Border Rivers catchment. Priorities are defined by the Basin Plan as those assets and functions that can be managed with environmental water. The objectives and targets have been identified for native fish, native vegetation, waterbirds and ecosystem functions. As noted in the BWS, each of these themes is a good indicator of river and wetland health and is responsive to flow.

The objectives express the current understanding of environmental outcomes that might be expected from implementation of the Basin Plan in the rivers, wetlands, floodplains, and watercourses of the NSW Border Rivers. The targets for each ecological objective provide a transparent means of evaluating progress towards their achievement and the long-term success of management strategies.

Table 1 Summary of the environmental outcomes sought in the NSW Border Rivers

Broad outcomes	Overarching objectives	Example uses of water for the environment to achieve LTWP outcomes and objectives
Maintain the diversity and improve the population of native fish in the catchment	Increase native fish distribution and abundance, and ensure stable population structures	• Ongoing use of the stimulus flow to boost productivity and, if possible promote spawning • In dry times, replenish refuge waterholes for native fish
Maintain the extent and improve the health of water dependent native vegetation and wetlands	Maintain and improve the viability and extent of river red gum, black box and coolibah communities, lignum shrublands and non-woody wetland vegetation	• Limit any reduction in flood size, frequency and changes to flow paths
To maintain the diversity of waterbird species and increase their numbers across the catchment	Restoration of habitat for waterbirds to contribute to recovery of waterbird populations across the Murray-Darling Basin	• Maintain connection and disconnection of anabranches • Coordinate consumptive flows and held environmental water releases to meet EWRs at higher flow categories
Improve connections along rivers and between rivers and their floodplains for improved river system health	Improve ecosystem functioning to provide healthy ecosystems capable of supporting native biota	• Maintain connection and disconnection of anabranches • Coordinate consumptive flows and held environmental water releases to meet EWRs at higher flow categories

Management strategies and complementary investments

There are complementary measures that may be required to ensure the LTWPs objectives and targets are achieved (see Chapter 7). These include addressing cold water pollution caused by water releases from Pindari and Glenlyon Dams, addressing major barriers to fish movement, providing incentives to landholders to conserve riparian, wetland and floodplain vegetation and screening irrigation pumps to protect fish.

Currently, many in-channel environmental watering requirements (EWRs) are being met by consumptive flows. There is potential to achieve additional EWRs from cooperative and coordinated river operations. It will be necessary to coordinate the use of held environmental water with planned environmental water and consumptive flows to maximise environmental efficiency and enable the best possible achievement of EWRs.

In addition, in the Border Rivers there is planned environmental water committed through intergovernmental agreement with Queensland and the Border Rivers Commission (NSW DPI 2008). This includes a flow target at Mungindi of 100ML/d between 1 September and 31 March. Coordination among water managers is required to ensure that this flow target is not met by held environmental water to avoid held water substituting for the planned environmental water.

Monitoring and evaluation of the Long Term Water Plan

Over the 20-year duration of this LTWP, NSW and Commonwealth agencies will, where possible and funded, undertake monitoring of the health of rivers, wetlands and floodplains within the NSW Border Rivers to:

- monitor and demonstrate progress towards the objectives and targets identified in the LTWP
- inform and support the management of environmental water
- provide early information to test the assumptions and conditions that underpin the plan.

Review and update of the LTWP

As knowledge and evidence of ecological processes in the Border Rivers improves, it may be necessary to review and update the LTWP. To ensure the information in this LTWP remains relevant and up-to-date, this plan will be reviewed and updated no later than five years after it is first published. Additional reviews may also be triggered by:

- accreditation or amendment to the WSP or WRP for the NSW Border Rivers catchment
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit (SDL) adjustment
- new information arising from evaluating responses to environmental watering
- new knowledge about the water-dependent cultural values and assets of the catchment
- new knowledge about the ecology of the catchment that is relevant to environmental watering
- improved understanding of the effects of climate change and its impacts on the catchment, EWRs and water management
- changes to the river operating environment or the removal of constraints that affect watering strategies
- material changes to river and wetland health, not considered within this LTWP.

PART A: NSW Border Rivers Catchment

1. Introduction

The Border Rivers catchment straddles NSW and QLD. It has a total area of approximately 49,500 square kilometres, with 24,500 square kilometres in NSW (Green et al. 2012). The NSW Border Rivers catchment stretches east to west between the western slopes of the Great Dividing Range and the township of Mungindi. Major townships in the region include Inverell, Glen Innes, Tenterfield and the cross-border communities of Goondiwindi and Mungindi.

Water storages in the Border River catchment include Glenlyon Dam on Pikes Creek (QLD), Coolmunda Dam on Macintyre Brook (QLD) and Pindari Dam on the Severn River (NSW). Major tributaries include Tenterfield Creek in NSW and the QLD Severn River, which merge to become the Dumaresq River. The NSW Severn River joins the Macintyre River below Pindari Dam, which links to the Dumaresq River upstream of Goondiwindi. A map of the catchment is shown in Figure 4.

Downstream, the catchment is characterised by numerous anabranches and distributary channels including the Boomi River. The Macintyre River continues its cross-country journey, meeting the Weir River and becoming the Barwon River, north east of Mungindi.

Characterised by its many waterholes, billabongs and wetlands, the NSW Border Rivers support the iconic Murray cod and 15 other species of native fish including the threatened purple-spotted gudgeon, silver perch and eel-tailed catfish have been recorded in the catchment (NSW DPI 2015a).

The various wetlands and waterholes also support internationally and nationally significant waterbirds including brolgas, bar-tailed godwit, black-necked stork and magpie geese. The aquatic community of the NSW Border Rivers forms part of the endangered ecological community (EEC) known as the *Aquatic ecological community in the natural drainage system of the lowland catchment of the Darling River*.

Remnant native vegetation in the tablelands to the east of the catchment includes New England grassy woodlands and Northern Tableland dry sclerophyll forests. The vegetation communities on the slopes of the middle catchment are remnants of large expanses of forest and woodland, with grassy white-box woodlands, kurrajong, cypress pine, Blakely’s red gum, yellow box and silver ironbark. In these areas of less disturbed vegetation, there are significant cultural heritage sites.

To the west on the floodplains, extensive areas have been cleared for agriculture. Remnants of coolibah floodplain woodlands remain, with occasional myall woodlands, and whitewood and belah woodlands with lignum and mimosa. The western plains once supported significant areas of Mitchell and plains grass communities, however these are now greatly reduced.

Threatened Ecological Communities (TECs) found in the catchment include *McKies Stringybark Blackbutt Open Forest, New England Peppermint Woodland, White Box Yellow Box Blakely’s Red Gum Woodland, Coolibah-Black Box Woodlands, Carbeen Open Forest, Myall Woodland and Inland Grey Box Woodland.*

Traditional owners have longstanding and continuing ties to country and hold the many billabongs along the rivers in this catchment in high regard. Of particular importance is the Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon complex, with Boobera Lagoon having special cultural significance. Aboriginal nations and communities in the region include the Kamilaroi, Kambuwal, Githabul, Bigambul, Kwiambul and Ngarabal groups (NSW DPI 2017a). River flows in the NSW Border Rivers, like many Murray-Darling Basin catchments, have been altered by headwater dams, weirs, river and creek modifications, and large-scale irrigation development of the floodplain. With the development of large-scale irrigation industries, patterns and total volumes of flows, as well as the regularity of small to moderate-sized events, have reduced. Plans and rules that specify how water is to be shared between users and the environment have been developed. The condition of the catchment's riverine and floodplain ecosystems, and the plants and animals they support, has declined considerably because of development.

1.1 Water sharing arrangements

Water resources are managed under two NSW Water Sharing Plans (WSPs) in the NSW Border Rivers. These WSPs determine how water is shared between the environment and consumptive users, and how river systems are managed.

The Water Sharing Plan for the NSW Border Rivers Regulated River Water Source 2009 (WSP 2009) applies to all regulated river sections in the NSW Border Rivers Water Management Area. This includes the upper limit of Pindari Dam including all tributaries downstream to the junction of the Severn River with the Macintyre River, the Macintyre River from its junction with the Severn River to the junction of the Barwon River, the Barwon River downstream to Mungindi Weir and the Dumaresq River from the junction of Pike Creek to the junction of the Macintyre River.

Water for the environment in the regulated WSP is classified in two ways:

- planned environmental water – water that is committed by management plans for fundamental ecosystem health or other specified environmental purposes, either generally or at specified times or in specified circumstances, and that cannot, to the extent committed, be taken or used for any other purpose, and
- adaptive environmental water – water that is committed by the conditions of access licences for specified environmental purposes, either generally or at specified times or in specified circumstances.

The Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012 (WSP 2012) applies to rivers and streams that do not have regulating structures such as dams, that can control the natural flow of water. This WSP determines how natural flows are shared between the environment and consumptive uses. It does this by imposing licence volumes and conditions, with one of the key ones being restrictions on pumping access when flows are low. This includes cease to pump rules that require users to stop taking water when flow declines below a set level. When the 2012 WSP commenced, surface water licences in all unregulated water sources were made subject to cease to pump rules (excluding licences held by town water suppliers, local water utilities, licensed stock and domestic users, and licences used for food safety and essential dairy care).

In addition to these two WSPs, flows in Border Rivers are also subject to conditions set by the Border Rivers Commission and NSW-QLD Border Rivers Intergovernmental Agreement 2008 (NSW DPI 2008).

The Dumaresq-Barwon Border Rivers Commission (the BRC) was constituted under the provisions of the New South Wales-Queensland Border Rivers Agreement made in 1946 (*NSW-QLD Border Rivers Act 1947*). The Commission was established by the NSW and QLD Governments to operate and maintain jointly "owned" water infrastructure and implement agreed water sharing arrangements in the region.

The NSW-QLD Border Rivers Intergovernmental Agreement 2008 was established to give direction for the sustainable management and sharing of water in the Border Rivers catchment including:

- environmental flow management on those streams that are shared between the states

- formalising water sharing between the states and between users and the environment
- formalising water access arrangements
- provision of adequate flows to the Darling Basin downstream of Mungindi, and
- interstate trading of water entitlements.

The NSW Government has developed the NSW Border Rivers Long Term Water Plan (LTWP) with the aim of informing watering requirements and other measures aimed at protecting and improving the health of the NSW Border Rivers riverine and floodplain ecosystems. It also recognises the NSW Border Rivers connection and contribution to the environmental health of the Barwon-Darling system.

Figure 2 Upper Macintyre River.
Photo: M. Miles

1.2 Approach to developing the NSW Border Rivers Long Term Water Plan

The NSW Border Rivers LTWP applies to the NSW Border Rivers surface water resource plan area (WRPA) and is one of nine catchment-based plans covering the NSW portion of the Murray-Darling Basin. The LTWP has been developed to be consistent with the requirements of the Basin Plan (MDBA 2012a).

The NSW Border Rivers LTWP is the product of best available information and engagement with water managers, natural resource managers, environmental water holders and community members. It draws together local, traditional and scientific knowledge to identify the catchment's priority environmental assets and ecosystem functions to guide the management of water to protect and restore condition over the long-term.

Development of the NSW Border Rivers LTWP has involved six main steps:

1. undertaking a comprehensive **stocktake** of water dependent native fish, birds and plant species and the river processes that underpin a healthy river system across the catchment to identify priority environmental assets and priority ecosystem functions.
2. determining specific and quantifiable **objectives and targets** for the priority assets and functions in the NSW Border Rivers catchment.
3. determining the **environmental water requirements** (including volume, frequency, timing and duration) needed to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions.
4. identifying the **risks and constraints** to meeting the long-term water requirements of priority environmental assets and ecosystem functions.
5. identifying potential **management strategies** to meet environmental water requirements.
6. identifying **complementary investments** to address **risks and constraints** to meeting the long-term water requirements of priority environmental assets and ecosystem functions.

1.3 Implementing the Long Term Water Plan

Implementation of the LTWP requires strong partnerships and coordination between all land managers and water users. The LTWP provides the foundation to support future coordination efforts by:

- informing and guiding annual and longer-term water management deliberations and planning by the Department of Planning, Industry and Environment – Biodiversity and Conservation Division (DPIE-BC) and the Commonwealth Environmental Water Office (CEWO)
- informing planning processes that influence river and wetland health outcomes, including development of WSPs and WRPs
- identifying opportunities for more strategic river operations and strengthening collaboration between holders of environmental water
- helping target investment priorities for complementary actions that will effectively contribute to progressing the outcomes sought by this LTWP
- building broad community understanding of river and wetland health issues.

1.4 The Long Term Water Plan document structure

The NSW Border Rivers LTWP is presented in seven chapters in total with accompanying appendices. It is divided into Part A (catchment scale information) and Part B (planning unit scale details and refinements).

Part A: The whole NSW Border Rivers catchment

- **Chapter 1** explains the background and purpose of the LTWP.
- **Chapters 2** and **3** identify the NSW Border Rivers water-dependent environmental assets and ecosystem functions, and articulate the environmental outcomes that are expected from implementation of the LTWP through ecological objectives and targets.
- **Chapter 4** describes the environmental water requirements (EWRs) needed to achieve the ecological objectives over the next five, 10 and 20 years.
- **Chapter 5** describes the risks and constraints that may limit water managers' capacity to achieve the environmental water requirements and their associated ecological

objectives in the NSW Border Rivers. This chapter also outlines potential management strategies.

- **Chapter 6** identifies the possible ways to use held and planned environmental water, and other system flows, that support flow regimes to meet the environmental water requirements of the Border Rivers NSW environmental assets under different water resource availability scenarios.
- **Chapter 7** outlines the workplan going forward to progress towards the objectives. This includes potential cooperative arrangements between government agencies.

Part B: NSW Border Rivers planning units

- **Chapter 8** introduces Part B of the LTWP and the planning unit scale specifics provided in this section.
- **Chapter 9** presents the detail of the LTWP at a finer scale of management areas and planning units. This includes a summary of the priority environmental assets and values the planning unit supports, specific environmental water requirements with flow rates attributed to specific gauges, and an evaluation of the impact of water resource development on local hydrology.
- **Appendix A** details the ecological objectives relevant to each planning unit.
- **Appendix B** provides further details on the relevance of Resource Availability Scenarios to water management decision-making.
- **Appendix C** collates asset data across the planning units.

Figure 3 Lemon Tree Flat, Severn River.
Photo: N. Foster.

1.5 Planning units

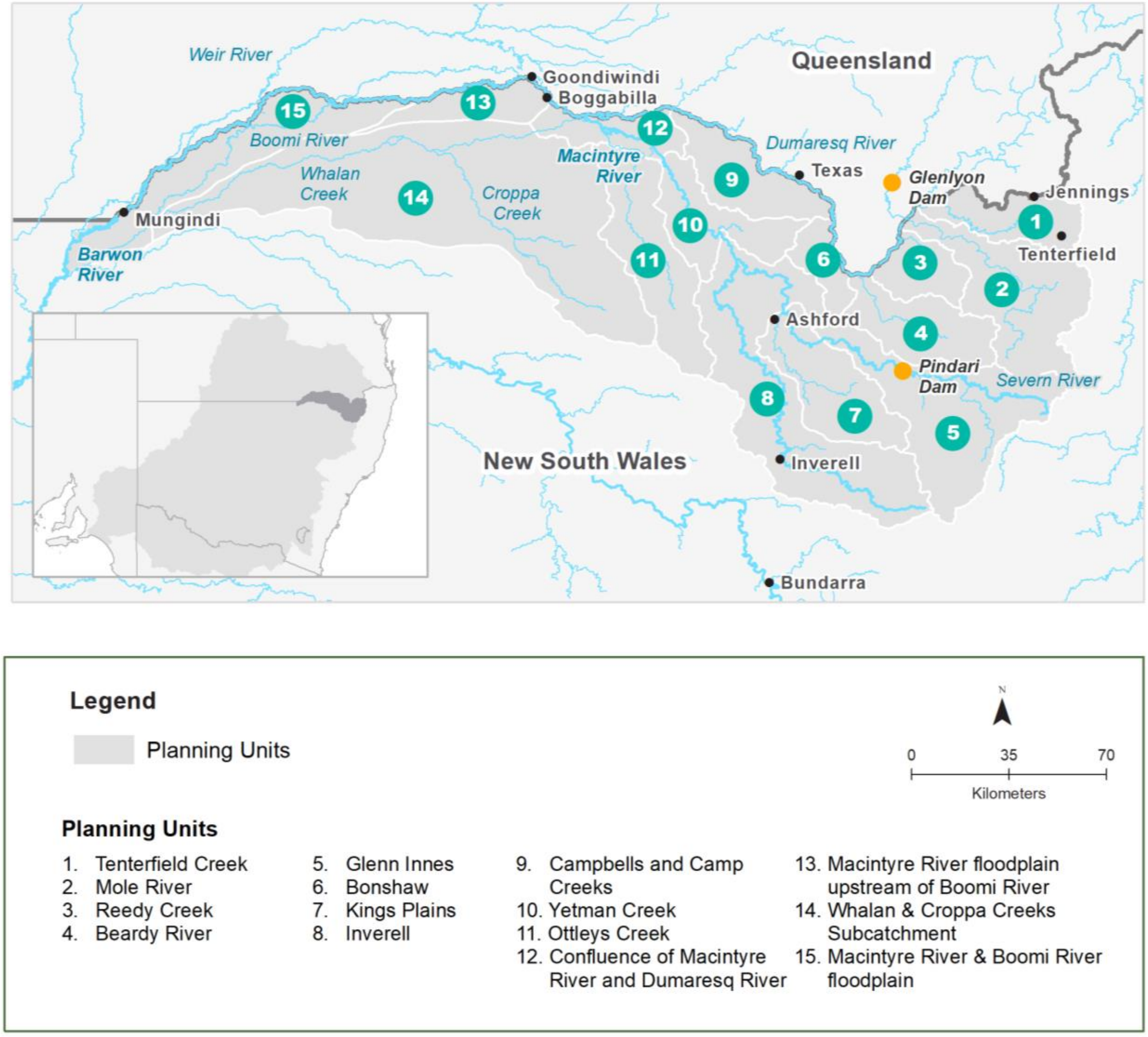


Figure 4 NSW Border Rivers showing the location of planning units in the LTWP

The planning units (PU) shown in Figure 4 are referred to in most chapters. The planning units in the NSW Border Rivers were derived from water sources in the 2012 Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources. A few adjustments were made for the purpose of the LTWP to reflect various features of river operations and the landscape. The end result is planning units that are relatively uniform within, with boundaries that recognise ecologically relevant differences to other planning units.

- Campbells Creek and Camp Creek water sources have been merged as there is only one gauge within this section on which to set EWRs.
- the Ottleys Creek water source has been split to recognise the aquatic differences between the Macintyre and Dumaresq rivers in the lower northern part from the more ephemeral nature of Ottleys Creek. Mitchell landscapes (Mitchell 2002) were used to identify a relevant boundary.
- a number of new planning units were created downstream of the junction between the Macintyre and Dumaresq rivers.

- Planning unit 14 – Whalan Creek & Croppa Creek sub-catchment distinguishes the unregulated and ephemeral Croppa and Whalan Creeks from the Macintyre and Boomi rivers. The trade boundary in the unregulated WSP was adopted.
- The division created above Terrewah on the Macintyre River to form planning units 13 – Macintyre River floodplain u/s of Boomi River and 15 – Macintyre River and Boomi River floodplain, recognises the change in the geomorphology of the river channel that occurs in this section of river. Mitchell landscapes were again used to identify a relevant boundary.

Figure 5 Dumaresq River from Bonshaw Weir.
Photo: L. Cameron and J. St Vincent-Welch.

2. Environmental assets of the NSW Border Rivers

The NSW Border Rivers supports a variety of water-dependent ecosystems, including instream aquatic habitats, riparian forests, and floodplain woodlands and wetlands. These ecosystems are located throughout the catchment and each has its own water requirements depending on the plants, animals and ecosystem functions they contain.

2.1 Priority environmental assets in the NSW Border Rivers

In addition to the assets identified in the Basin-wide Environmental Water Strategy (BWS), Schedule 8 of the Basin Plan outlines criteria for identifying water-dependent ecosystems that should be recognised as environmental assets in the Murray-Darling Basin. The criteria are designed to identify water-dependent ecosystems that are internationally important, natural or near-natural, provide vital habitat for native water-dependent biota, and/or can support threatened species, threatened ecological communities or significant biodiversity.

The water-dependent ecosystems in NSW Border Rivers were assessed against the Schedule 8 criteria. Significant Aboriginal cultural water-dependent sites, such as Aboriginal ceremony and dreaming sites, fish traps, scar trees, and waterholes that are registered in the Aboriginal Heritage Information Management System (AHIMS) were also included as water-dependent assets in the LTWP. Results of the assessment are presented Figure 6.

Priority environmental assets in LTWPs are the assets that have been identified using Schedule 8 criteria that can be managed through NSW’s planned environmental water (PEW), NSW’s and CEWO’s held environmental water (HEW), and/or through implementation of the Water Sharing Plan rules. Priority environmental assets may be, for example, a reach of river channel and its floodplain features at a geographic location, or a wetland complex or anabranch.

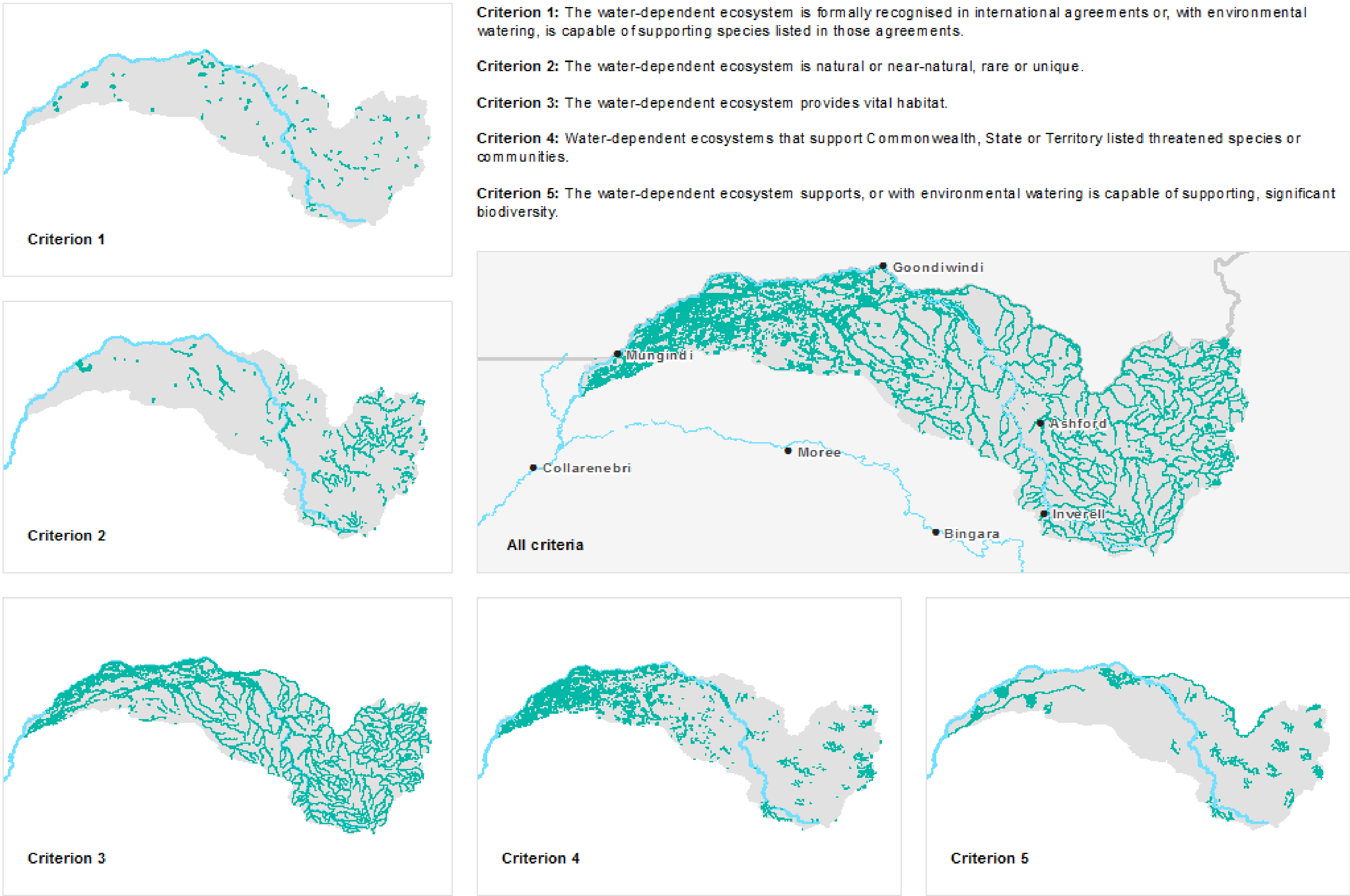


Figure 6 Five criteria for identification of environmental assets applied to NSW Border Rivers

3. Ecological objectives and targets

Ecological objectives and targets have been established for priority environmental assets and values in the NSW Border Rivers (sections 3.1–3.4). Consistent with the Basin-wide Watering Strategy (BWS) (MDBA 2014), the objectives are grouped into four themes: native fish, native vegetation, waterbirds and ecosystem functions. The water requirements of indicator species, or functional groups of species or ecosystem functions within each theme are also representative of those needed by other water-dependent species such as frogs and turtles. Achievement of the objectives will also contribute to the landscape and Basin-scale environmental outcomes sought by the BWS and benefit other water-dependent species.

The five, 10 and 20-year targets for each ecological objective provide a transparent means of evaluating progress towards their achievement and the long-term success of the LTWP's management strategies and their implementation. If met, the targets will indicate that the environment is responding positively to water management. Failure to meet targets should trigger re-assessment of the related flow regime and whether the LTWP is being implemented as intended to determine if changes are needed. It is important to note that the 20-year targets in the LTWP assume the relaxation or removal of constraints to allow more flexibility in water delivery.

The ecological objectives for the NSW Border Rivers as they relate to individual planning units are listed in Appendix A.

3.1 Native fish values and objectives

The fish community of the NSW Border Rivers includes up to 16 native species recorded or expected to occur (including flat-headed gudgeon) and up to five alien species (NSW DPI 2015a). In general, the NSW Border Rivers fish community is rated in moderate condition with some rivers such as the Dumaresq, mid-lower Macintyre, Boomi and Upper Barwon, and Whalan Creek rated as good. Other waterways—Tenterfield Creek, Deepwater River, upstream reaches of the Severn River, upper Macintyre and some tributaries of Whalan Creek—are rated as being in poor condition (see Figure 7).

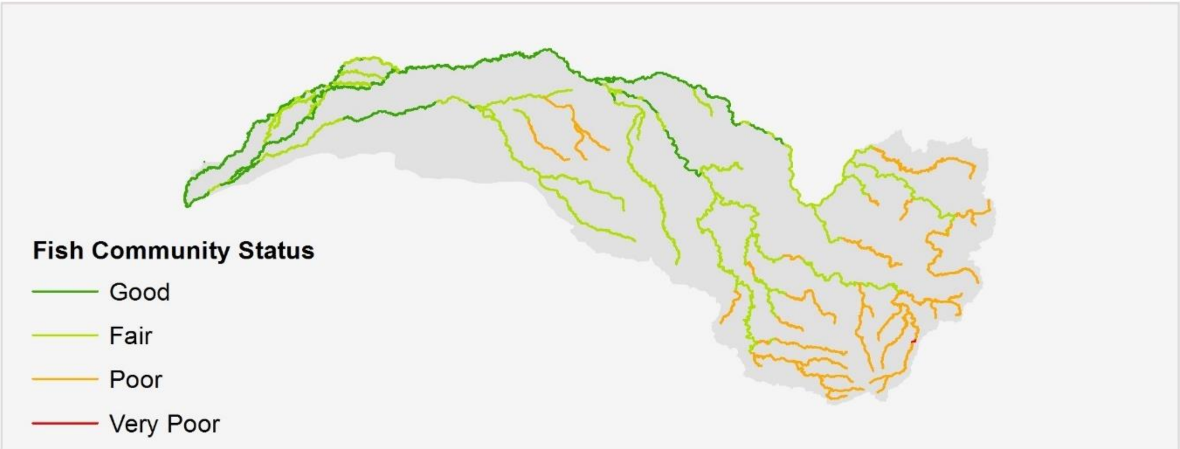


Figure 7 The current status of fish communities in NSW Border Rivers (NSW DPI 2016b).

Priority drought refuge sites are located along the Severn and Dumaresq Rivers with these sites known to support purple-spotted gudgeons, mountain galaxias, river blackfish, silver perch, olive perchlet, freshwater catfish, Murray cod, and unspecked hardyhead (McNeil, Gehrig & Cheshire 2013). In addition, the BWS (MDBA 2014) has identified three key rivers in the Border Rivers as important environmental assets for native fish:

- Barwon-Darling River (Menindee to Mungindi)—values include 'key movement corridor', 'high biodiversity', 'key site of hydrodynamic diversity', 'threatened species' and 'dry spell/drought refuge'
- Macintyre River – Mungindi to Severn in NSW—values include 'key movement corridor', 'high biodiversity', 'key site of hydrodynamic diversity', 'threatened species' and 'dry spell/drought refuge'
- Severn River within Sundown National Park—values include ‘high biodiversity’, ‘key site of hydrodynamic diversity’, 'threatened species' and 'dry spell/drought refuge'.

Other important assets in the Border Rivers include large areas of aquatic habitat—large woody debris and fallen timber on bench platforms and inset floodplain areas—along the Macintyre, Weir, Boomi and Barwon river reaches downstream of Goondiwindi (Boys 2007; MDBA 2012b). The Dumaresq River supports large aggregations of aquatic macrophytes providing considerable habitat for native fish (DoE 2016). Below Pindari Dam, the NSW Severn River sustains high fish diversity and provides good quality refuges for native fish (DoE 2016).

Four of the NSW Border Rivers native fish species are listed as vulnerable, threatened or endangered in NSW Murray-Darling Basin waters under the *Fisheries Management Act 1994* (FM Act). These include the purple-spotted gudgeon, freshwater catfish, olive perchlet and silver perch, with the indicative distribution of these species shown in Figure 9 (for detail on the method used, see NSW DPI 2016a). In addition, the Darling River snail is listed as critically endangered. Parts of the NSW Border Rivers and its associated aquatic biota, including parts of the Macintyre River, Severn River and the Dumaresq River have also been listed under the FM Act as part of the Lower Darling EEC.

Figure 8 Purple-spotted gudgeon and freshwater catfish. Photos: G. Schmida

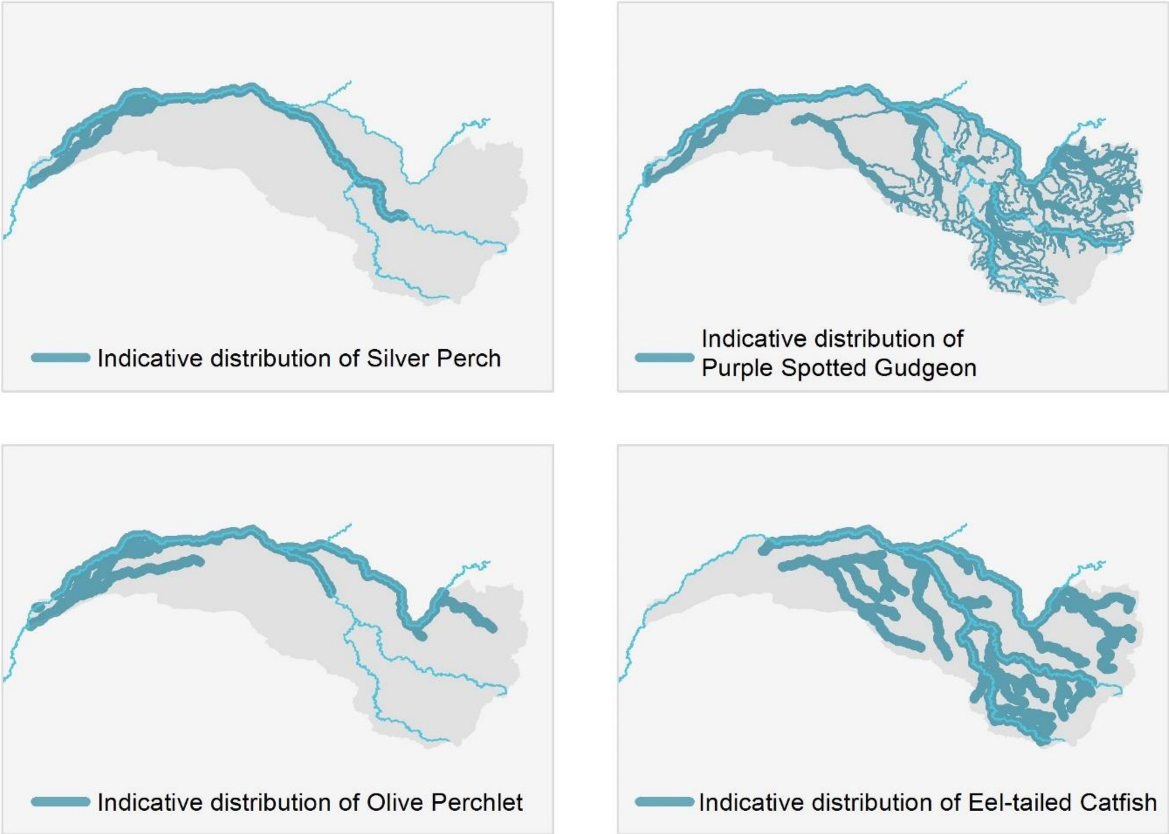


Figure 9 Maps of indicative distribution of four key native fish species in the NSW Border Rivers (NSW DPI 2016b).

Table 2 Native fish (NF) ecological objectives and targets

Ecological objectives		Target fish species	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
NF1	No loss of native fish species	All recorded fish species	All known species detected annually		
				Fish community status improved by one category compared to 2014 assessment	
NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species	Australian smelt, carp gudgeon, western carp gudgeon, bony herring, Murray-Darling rainbowfish, unspecked hardyhead	Increased distribution and abundance of short to moderate-lived species compared to 2014 assessment No more than one year without detection of immature fish (short-lived) No more than two years without detection of immature fish (moderate-lived species)		
NF3	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species	Olive perchlet[1]			
NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	Golden perch, silver perch, spangled perch	Juvenile and adult fish detected annually No more than two consecutive years without recruitment in moderate-lived species No more than four consecutive years without recruitment in long-lived species		
			Minimum of 1 significant recruitment event in 5 years	Minimum of 2 significant recruitment events in 10 years	Minimum of 4 significant recruitment events in 20 years

[1] Purple-spotted gudgeon and olive perchlet may be considered either floodplain specialist or riverine specialist depending on geographical location.

Ecological objectives		Target fish species	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	Murray cod, river blackfish, freshwater catfish, purple-spotted gudgeon[1]	Juvenile and adult fish detected annually No more than two consecutive years without recruitment in moderate-lived species No more than four consecutive years without recruitment in long-lived species		
			Minimum of 1 significant recruitment event in 5 years	Minimum of 2 significant recruitment events in 10 years	Minimum of 4 significant recruitment events in 20 years
NF6	A 25% increase in abundance of mature (harvestable sized) golden perch and Murray cod	Golden perch, Murray cod	Length-frequency distributions include size classes of legal take size for golden perch and Murray cod 25% increase in abundance of mature golden perch and Murray cod		
NF7	Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas (within historical range)	Olive perchlet[1]	Adults detected annually in specified planning units No more than 1 year without detection of immature fish in specified planning units (short-lived)		
				Increased distribution and abundance in specified planning units	Increased distribution and abundance in specified planning units
NF8	Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range)	Freshwater catfish, purple-spotted gudgeon[1]	Adults detected annually in specified planning units No more than 2 years without detection of immature fish in specified planning units (moderate-lived species) No more than 4 years without detection of immature fish in specified planning units (long-lived species)		
				Increased distribution and abundance in specified planning units	Increased distribution and abundance in specified planning units

3.2 Native vegetation values and objectives

The NSW Border Rivers catchment supports a range of water-dependant vegetation communities. River red gum is found throughout the catchment in areas closely fringing the main river channels. The total area of river red gum is approximately 30,000 hectares (NSW OEH 2015). Black box and coolibah are generally limited to the lower floodplain. Black box (approximately 400 hectares) occurs in the Macintyre River and Boomi River floodplain planning unit while more extensive areas of coolibah (600,000 hectares in total) occur throughout the lower part of the catchment from the confluence of the Dumaresq and Macintyre Rivers to Mungindi and in the Whalan and Croppa Creek subcatchments. Small areas of lignum shrublands (approximately 4000 hectares in total) also occur in the lower part of the catchment and Whalan and Croppa creek subcatchments (Figure 10).

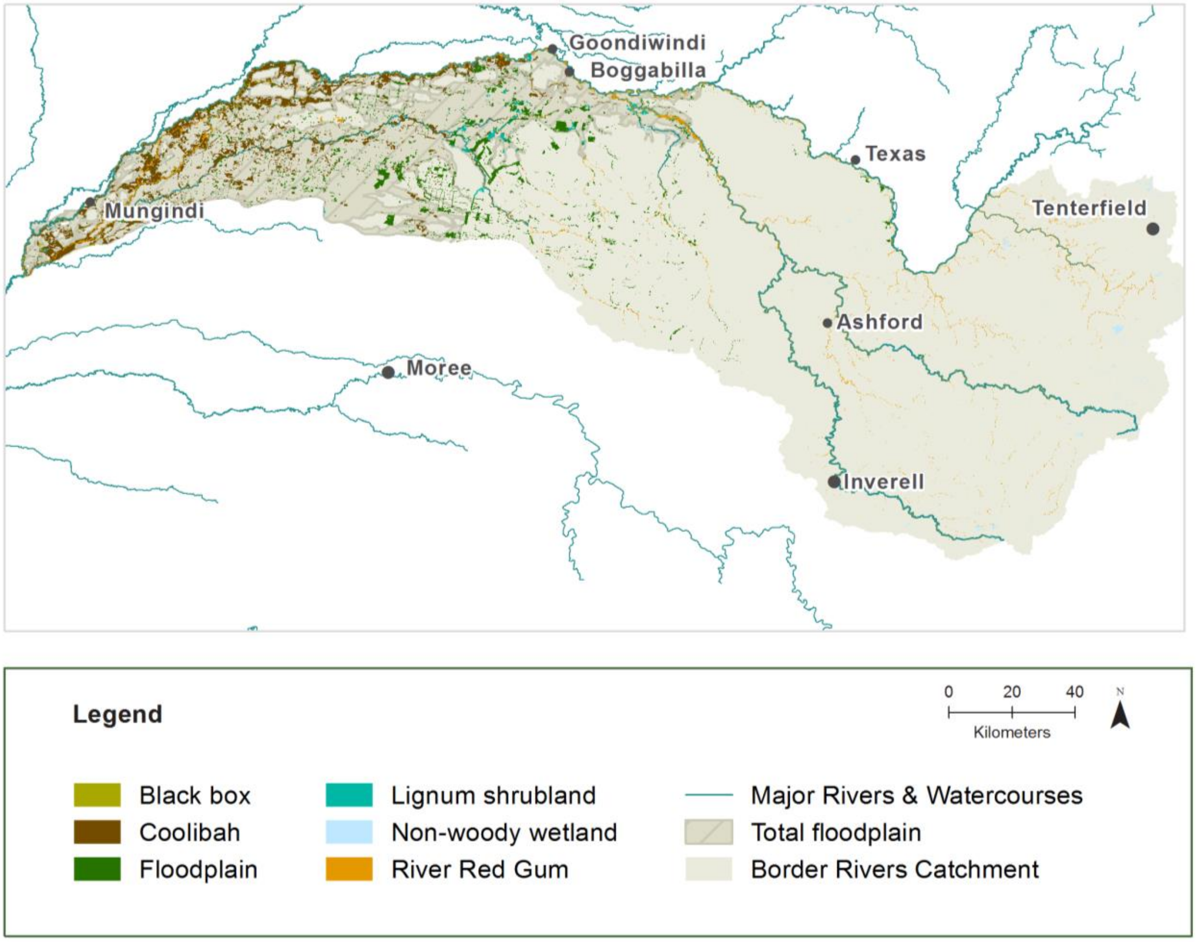


Figure 10 Map of native vegetation assets in the NSW Border Rivers (compiled by DPIE in 2016 based on NSW OEH 2015)

The availability of water across the landscape affects plant germination, survival and reproduction, and ultimately influences the position of species in the landscape (Casanova 2015). The native vegetation species and communities identified by the BWS have been grouped into objectives, that reflect similar watering requirements and the variable extent of flooding that spans laterally from the riparian zone through to the outer floodplain. In the NSW Border Rivers, river red gum is predominantly found in riparian zones and requires more frequent watering. Coolibah and black box remnants can be found on the floodplain and require less frequent surface water to maintain condition and extent (Roberts & Marston

2011; Casanova 2015). Across these patches of remnant vegetation, there is also a gradient of vegetation condition, as related to the frequency of inundation across landscape components, with vegetation closer to the river channels having more frequent access to water and generally being in better condition. Flooding is often required for recruitment Roberts & Marston 2011; Casanova 2015).

It may not be possible to increase the extent of woody vegetation due to agricultural land development. The objectives and targets of this plan aim to maintain the current extent. This requires native vegetation of good condition to limit tree mortality and may require recruitment to replace any losses. Objectives and targets for within channel vegetation, lignum shrublands and non-woody wetland recognise the ongoing need for vegetative growth and regular seed setting to ensure ongoing population viability of these short-lived species (Roberts & Marston 2011; Casanova 2015).

Figure 11 Macintyre River at Holdfast.
Photo: N. Foster.

Table 3 Native vegetation (NV) ecological objectives and targets

<table>
<tr><th colspan="2" rowspan="2">Ecological objectives</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td>NV1</td><td>Maintain the extent and viability of non-woody vegetation communities occurring within channels</td><td colspan="3">Increase the cover of non-woody, inundation-dependent vegetation within or closely fringing river channels following inundation events</td></tr>
<tr><td>NV2</td><td>Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains</td><td colspan="3">Over a 5-year rolling period, water couch and marsh club-rush to flower and set seed at least 2 years in 5
Maintain the total area of non-woody wetland vegetation communities occurring on actively managed floodplains and floodplains influenced by planned environmental water[2]</td></tr>
<tr><td rowspan="2">NV3</td><td rowspan="2">Maintain the extent and improve the condition of river red gum communities closely fringing river channels</td><td colspan="3">Maintain the 2016 mapped extent[3] of river red gum woodland communities closely fringing river channels</td></tr>
<tr><td colspan="2">Over a 5-year rolling period:
• maintain the extent and proportion of river red gum communities closely fringing river channels that are in moderate or good condition[4]
• no further decline in the condition of river red gum communities closely fringing river channels that are in poor or degraded condition</td><td>Over a 5-year rolling period:
• increase the proportion of river red gum communities closely fringing river channels that are in moderate or good condition
• improve the condition score of river red gum communities closely fringing river channels that are in poor, degraded or severely degraded condition by at least one condition score</td></tr>
</table>

[2] Unregulated areas where river flows and off-channel pools are protected by the Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012

[3] Extent based on compiled native vegetation plant community type (PCT) mapping. Map compiled by DPIE from best available PCT mapping as at 2016 (State vegetation type map for the Border Rivers, Gwydir and Namoi region, NSW OEH 2015)

[4] Condition score according to the MDBA Stand Condition tool (Cunningham et al. 2009)

<table>
<tr><th colspan="3" rowspan="2">Ecological objectives</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td>NV4c</td><td rowspan="3">Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains</td><td>Black box woodland</td><td colspan="2" rowspan="2">Over a 5-year rolling period:
• maintain the extent and proportion of woodlands and shrublands in moderate or good condition
• no further decline in the condition of woodlands and shrublands in poor or degraded condition
• increase the abundance of woodland seedlings and saplings in degraded communities on the actively managed floodplain</td><td rowspan="2">Over a 5-year rolling period:
• increase the proportion of woodlands and shrublands in moderate or good condition
• improve the condition score of woodlands and shrublands in poor, degraded or severely degraded condition by at least one condition score
Support successful recruitment of trees in the long-term by increasing in the abundance of young adult trees (10–30 cm DBH) compared to the previous 10-year period</td></tr>
<tr><td>NV4d</td><td>Coolibah woodland</td></tr>
<tr><td>NV4e</td><td>Lignum shrublands</td><td colspan="2">Maintain the 2016 extent[3] of lignum shrubland and coolibah woodland communities</td><td>Increase the total area of lignum shrublands and coolibah woodlands by 10% occurring within the actively managed floodplain</td></tr>
</table>

3.3 Waterbird values and objectives

Waterbirds are useful indicators of the health of water-dependent ecosystems (Amat & Green 2010). In the 30 years to 2012, annual waterbird surveys revealed a 72% decline in average waterbird abundance in the Murray-Darling Basin (MDBA 2014). This is a critical observation because waterbirds are an important indicator of wetland health as their abundance and diversity are related to the total area of wetland available, the health of wetland vegetation and the abundance of food resources e.g. microcrustacea, fish and aquatic vegetation (Kingsford 1999). Wetlands in good condition with vegetation in good health, a variety of habitats and varying water depths tend to support the greatest diversity of waterbird species and highest waterbird abundance (Kingsford & Norman 2002).

Waterbirds are a group of highly mobile species and can respond to flows over large spatial scales (Kingsford & Norman 2002; Amat & Green 2010). Improvements in waterbird populations across the Murray-Darling Basin is one of the main ecological objectives of the Basin Plan. With more water available for the environment through the Basin Plan, increases in frequency, duration and extent of inundation of wetland areas are expected to provide more habitat for waterbirds and other water-dependent species (MDBA 2014).

Sixty one waterbird species have been recorded in the NSW Border Rivers (ALA 2017; NSW Bionet 2017; Porter et al. 2016), including six threatened species and eight species protected under international agreements (Table 4). Overall there is limited waterbird monitoring in the NSW Border Rivers.

Table 4 Waterbird species in the NSW Border Rivers listed as threatened or protected under international agreements

Functional waterbird groups	Species and status[5]
Ducks	blue-billed duck (V), freckled duck (V)
Herbivores	magpie goose (V)
Large waders	black-necked stork (E), brolga (V)
Piscivores	Caspian tern (J), white-winged black tern (C, J, K)
Shorebirds	bar-tailed godwit (C, J, K, CE, V), common greenshank (C, J, K), Latham's snipe (J, K), marsh sandpiper (C, J, K), pectoral sandpiper (J, K), sharp-tailed sandpiper (C, J, K)

More than 100 waterbird species have been recorded in the NSW portion of the MDB (MDBA 2014) and these species can be split into functional groups that reflect differences in their habitat requirements. The five waterbird functional groups described by Bino et al. (2014) and used in the BWS are: ducks and grebes, herbivores, piscivores (fish-eating waterbirds), large waders, and shorebirds (or small waders). Knowledge of the water requirements of different waterbird species informs watering strategies and can be used to evaluate whether these strategies have met the timing, duration and frequency requirements for different waterbird groups. These functional groups are reflected in the objectives and targets in this LTWP. In addition, the objectives recognise the differences between colonial and non-colonial waterbirds. Colonial waterbirds gather in large numbers when their breeding and feeding habitats are inundated. There are no known colonial waterbird

[5] V = listed as vulnerable on NSW threatened species list, CE = critically endangered in EPBC Act or NSW Biodiversity Act, E = endangered in EPBC Act or NSW Biodiversity Act, C = CAMBA listed, J = JAMBA listed, K = RoKAMBA listed

breeding sites in the NSW Border Rivers and consequently objective WB4 is not included in this LTWP.

The total number of waterbird species and total number of individuals can change rapidly in response to flows, specifically increases in total wetland area and the diversity of wetland habitats inundated. When inundated, floodplain habitats can provide feeding and breeding habitat for a range of waterbird species. Waterbird species richness is greatest when there are varying water depths across a range of wetland types (Taft et al. 2002). This is because there is a mosaic of wetland types with varying water depths this can provide deeper wetlands for fish-eating waterbirds and diving ducks, and vegetated shallower wetlands that provide feeding habitat for dabbling ducks and large waders. Emergent aquatic vegetation on the edge of waterbodies also provides habitat for cryptic crakes, rails and bitterns. As wetlands dry, exposed mudflats can form providing feeding habitat for resident and migratory shorebird species.

Table 5 Waterbird (WB) ecological objectives[6] for NSW Border Rivers.

Ecological objectives		Targets		
		5 years (2024)	10 years (2029)	20 years[7] (2039)
WB1	Maintain the number and type of waterbird species	Maintain a 5-year rolling average of 6[8] or more waterbird species in the NSW Border Rivers		
			Identify at least 52 waterbird species in the NSW Border Rivers in a 10-year period	Identify at least 59 waterbird species in the NSW Border Rivers in a 20-year period
WB2	Increase total waterbird abundance across all functional groups	Total abundance of the 5 functional groups maintained in the NSW Border Rivers compared to the 5 years 2012–16 period		
WB3	Increase opportunities for non-colonial waterbird breeding	Total abundance of non-colonial waterbirds in the waterbird area maintained compared to the five-year 2012–16 baseline period		
WB5	Maintain the extent and improve condition of waterbird habitats	Maintain or increase extent and improve condition of waterbird foraging and breeding locations in the waterbird area (to be evaluated under targets set for native vegetation)		

3.4 Ecosystem function objectives

The NSW Border Rivers catchment is comprised of streams and rivers, anabranches with semi-permanent lagoons and wetlands, and floodplain features (NSW DPI 2015a). Within

[6] Objective WB4 relates to colonial waterbird breeding and is irrelevant for the NSW Border Rivers LTWP.

[7] 20-year targets will be further refined following additional data collection.

[8] This value is low and represents an absolute minimum target. There is limited waterbird survey coverage for NSW Border Rivers and the BWS does not identify any waterbird assets in this valley.

these broad habitat types, niche habitats such as deep channels, pools and riffles, gravel beds, instream benches, snags, aquatic vegetation and riparian vegetation are available to the catchment's aquatic species. Flows that connect within and between these niche habitats can enable biological, geochemical and physical processes that provide ecosystem function, as needed to support healthy ecosystems (Bunn & Arthington 2002).

Ecosystem functions include the maintenance of vital habitats such as refugia during drought, the transportation of nutrients and organic matter to provide food and resources, the movement of sediment for the maintenance of riparian channels, movement of water dependent species, and maintenance of water quality suitable for the persistence of flora and fauna (see Schedule 9, Basin Plan, 2012).

Ecosystem functions have been grouped into objectives based on the broad processes involved. Collectively, the objectives require variable flows, with periods of low flows alongside a range of higher flows to maintain ecosystem functions such as in-channel complexity (e.g. benches) (Boulton et al. 2000; Thoms & Sheldon 2002).

The anabranches in the Border Rivers are known to make a significant contribution to ecosystem health within the catchment, and also more broadly to the Murray-Darling Basin (McGinness 2007). Flows required to maintain these habitats, and contribute to the health of the catchment and basin, are considered under the broader objectives of quality instream habitat, instream and floodplain productivity and sediment, carbon and nutrient exchange.

Drought refugia

Refugia can occur within the main river channels, as instream pools, or in off-channel habitat where water persists after disconnection from the channel, such as in the anabranches, or where maintained by groundwater inflows such as in Boobera Lagoon (Reid, Delong & Thoms 2012). The refugia can contain different types of habitat, such as logs, wet undercut banks, riffles, sub-surface stream sediments and riparian vegetation. The range of habitat available can inform assessment of the quality of the refugia.

Refugia is critical to the survival of many aquatic species during dry spells and drought, and act as source populations for subsequent recolonisation and population growth (Adams & Warren 2005; Arthington et al. 2010). In the Border Rivers, establishing and maintaining off channel drought refugia occurs during higher connective flows that occur in wetter years. Water quality of pools is also considered under this objective.

Quality instream habitat (geomorphic processes)

Processes grouped in this objective include water quality, flow variability, appropriate wetting and drying cycles, geomorphic processes that create and maintain diverse physical habitat, large woody debris and rates of rise and fall that can influence bank erosion. The physical form of instream habitats, including the location of riparian and instream vegetation, channel shape and bed sediment, is influenced by river flow (Bunn & Arthington 2002). For example, fresh and bankfull flows with sufficient velocity are required to maintain pool depth and riffles by scouring out bed material and initiating material transportation downstream (Davie & Mitrovic 2014). Changes to the rates of rise and fall of river levels can also impact on the quality of instream habitat.

Movement and dispersal opportunities for aquatic biota

Longitudinal and lateral connectivity allows organisms to move and disperse between environments. It can be essential for maintaining population viability (Amtstaetter, O'Connor & Pickworth 2016) by allowing individuals to move to different habitat types for breeding and conditioning, and recolonisation following disturbances like flood and drought. Flow pulses can promote dispersal of early life stages for a range of species from the breeding site and promote genetic diversity among catchments (Humphries & King 2004).

Instream and floodplain productivity

The supply of organic material underpins all river food webs by providing the food energy needed to drive life. The sources of organic material, the timing of its delivery and how long it remains in a section of river depends on the flow regime and the nature of the riparian vegetation. Instream productivity can be gained by wetting higher surfaces and higher velocity flows that scour and break down filamentous algae (Davie & Mitrovic 2014).

In the Border Rivers the extent of productivity gained from the wetting and drying cycles of the anabranches differs to that of the floodplain (McGinness 2007). It is known that regular drying and wetting of the anabranches can maintain a base level of productivity between overbank flow events that provide greater levels of productivity. River flow management can be used to increase carbon and nutrient sources in-channel by increasing the frequency of anabranch connection and floodplain inundation (McGinness 2007).

Groundwater-dependent biota

While this LTWP is primarily focused on the management of surface water, there are interactions with groundwater and groundwater-dependent ecosystems. Recharge to groundwater is considered under this objective.

Sediment, carbon and nutrient exchange

This objective addresses the processes of sediment delivery to downstream reaches and the mobilisation of carbon and nutrients to and from anabranches, floodplains and wetlands. The flows, and processes, required to meet this objective overlap with those required for instream and floodplain productivity and quality instream habitat.

Inter-catchment flow contributions

Connectivity between key planning units (PUs) and between the NSW Border Rivers catchment and the Barwon River during critical spawning periods will support native fish outcomes and contribute to improved outcomes in the NSW Border Rivers and Barwon-Darling catchments. Hydrological connectivity is required at a PU-scale throughout the catchment, as contributing to end of system flows. End of system flows requires assessment of flows at both Mungindi and Presbury gauges due to inflows from the Boomi River.

Figure 12 Barwon River at Mungindi.
Photo: E.Wilson

Table 6 Priority ecosystem function (EF) ecological objectives and targets

Ecological objectives		Description and key contributing processes	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
EF1	Provide and protect a diversity of refugia across the landscape	Water depth and quality in pools (in-channel), core wetlands and lakes Condition of vegetation in core wetlands and riparian zones	Maintain dissolved oxygen and salinity levels in key refuge pools at ecologically tolerable levels		
EF2	Create quality instream, floodplain and wetland habitat	Regulation of dissolved oxygen, salinity and water temperature Flow variability and hydrodynamic diversity Provision of diverse wetted areas Appropriate wetting and drying cycles Geomorphic (erosion/deposition) processes that create and maintain diverse physical habitats Appropriate rates of fall to avoid excessive bank erosion Control of woody-vegetation encroachment into river channels and wetlands	Rates of rise and fall do not exceed the 5th and 95th percentiles (respectively) of natural rates during regulated water deliveries		

<table>
<tr><th colspan="3" rowspan="2">Ecological objectives</th><th rowspan="2">Description and key contributing processes</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td rowspan="2">EF3</td><td rowspan="2">Provide movement and dispersal opportunities within, and between, catchments for water-dependent biota to complete lifecycles and disperse into new habitats</td><td>a. within catchments</td><td rowspan="2">Dispersal of eggs, larvae, propagules and seeds downstream and into off-channel habitats
Migration to fulfil life-history requirements
Foraging of aquatic species recolonisation following disturbance</td><td colspan="3" rowspan="2">Protect or improve frequency of events that allow fish passage in target planning units/gauges
Annual detection of species and life stages representative of the whole fish community through key fish passages in specified planning units
Increase in passage of key moderate to long-lived riverine and moderate to long-lived flow pulse specialists through key fish passages in the Border Rivers compared to passage rates detected in 2014–2019
Protect or improve the number of events that enable movement of fish between catchments within 12 months of major breeding events and dry spells</td></tr>
<tr><td>b. between catchments</td></tr>
<tr><td rowspan="2">EF4</td><td colspan="2" rowspan="2">Support instream and floodplain productivity</td><td rowspan="2">Aquatic primary productivity (algae, macrophytes, biofilms, phytoplankton)
Terrestrial primary productivity (vegetation)
Aquatic secondary productivity (zooplankton, macroinvertebrates, fish larvae, adult fish)
Decomposition of organic matter</td><td colspan="3">Maintain soil nitrogen, phosphorus and carbon levels at long-term natural levels
Maintain/Improve the abundance and distribution of decapod crustaceans</td></tr>
<tr><td colspan="2">No decline in key native fish species condition metrics (e.g. weight:length ratio)</td><td>Improve key native fish species metrics (e.g. weight:length ratio)</td></tr>
</table>

Ecological objectives		Description and key contributing processes	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
EF5	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	Sediment delivery to downstream reaches and to/from anabranches, floodplains and wetlands Mobilisation of carbon and nutrients from in-channel surfaces (e.g. benches/banks), floodplains and wetlands and transport to downstream reaches and off-channel habitats Dilution of carbon and nutrients that have returned to rivers	Maintain nutrient and carbon (DOC) pulses at multiple locations along a channel during freshes, bankfull and overbank events Maintain extent and condition of floodplain vegetation Maintain soil nitrogen, phosphorus and carbon levels at long-term natural levels		
EF6	Support groundwater conditions to sustain groundwater-dependent biota	Groundwater recharge and discharge Dilution of saline/acidic groundwater Salt export from the Murray-Darling Basin	Maintain the 2016 mapped extent of groundwater-dependent vegetation communities Maintain groundwater levels within the natural range of variability over the long-term		
EF7	Increase the contribution of flows into the Murray and Barwon-Darling from tributaries	Provision of end of system flows to support ecological objectives in downstream catchments	No reduction in rolling 5-year average flows at each end of planning unit gauge and end of catchment gauge. No increase in the long term average number of days of cease to flow conditions.		

4. Environmental water requirements

Flow and inundation regimes drive the ecological characteristics of rivers and floodplain wetlands (Poff and Zimmermann 2010). A flow regime represents the sequence of flow events over time, and it is this sequence of different flow magnitudes that produce flooding and drying patterns. Flow regimes govern river channel and wetland formation, their configuration and connectivity with the floodplain. Flow regimes prompt key ecological processes such as nutrient cycling and energy flow, breeding and migration, and dispersal of plants and animals.

The sequence of flows over time can be considered as a series of discrete events. These events can be placed into different flow categories (e.g. baseflows, freshes, bankfull, overbank and wetland flows) according to the magnitude of flow discharge or height within a watercourse, and the types of outcomes associated with the events (e.g. inundation of specific features such as channel benches, riparian zones or the floodplain).

Each flow category can provide for a range of ecological functions. For example, a small fresh might inundate river benches that provide access to food for native fish and support in-channel vegetation. Similarly, an overbank flow may support carbon exchange between the river and its floodplain and improve river red gum condition. Flow categories describe the height or level of a flow within a river channel or its extent across a floodplain (Figure 13 and Table 6). Flow rates for flow categories at sites across the NSW Border Rivers catchment are shown in Table 9.

An environmental water requirement (EWR) is the flow or inundation regime that a species, or community, needs to ensure its survival and persistence. It can also be the flow regime needed to meet the water requirements of a range of species in a defined geographic area. EWRs are based on knowledge of a species' biological and ecological needs, such as what it needs to feed, breed, disperse and migrate.

Meeting the full life-history needs of an aquatic organism (plant or animal) typically requires a combination of several different flow categories over time. For example, a native fish species may require a 'small fresh' as a 10-day pulse in late winter to cue spawning, followed by a relatively stable flow for 2–4 weeks in early spring to support nesting. Once the fish reaches maturity (1–3 years) it may require a 'bankfull' fast-flowing river in combination with 'overbank' flows to trigger dispersal and migration.

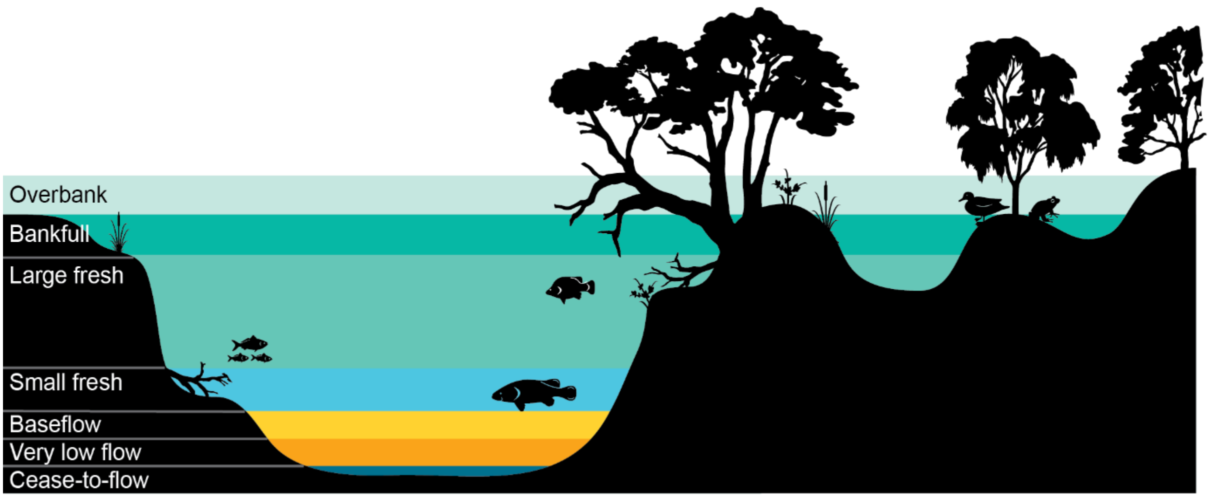


Figure 13 A simplified conceptual model of the role of each flow category

Table 7 Description of the role provided by each flow category shown in Figure 13

Flow category	Description
Overbank / Wetland inundation flow (OB / WL)	Broad scale lateral connectivity with floodplain and wetlands. Supports nutrient, carbon and sediment cycling between floodplain and channel. Promotes large-scale productivity.
Bankfull flow (BK)	Inundates all in-channel habitats and connects many low-lying wetlands. Partial or full longitudinal connectivity. Drown out of most in-channel barriers (e.g. weirs).
Large fresh (pulse) (LF)	Inundates benches, snags and inundation-tolerant vegetation higher in the channel. Supports productivity and transfer of nutrients, carbon and sediment. Provides fast-flowing habitat. May connect wetlands and anabranches with low commence-to-flow thresholds. Drown out of some smaller in-channel barriers.
Anabranch connection (AC)	Begins to wet off-channel habitat and provides connectivity along anabranches. It can also commence to fill low lying wetlands at flows below bankfull.
Small fresh (pulse) (SF)	Improves longitudinal connectivity. Inundates lower banks, bars, snags and in-channel vegetation. Trigger for aquatic animal movement and breeding. Flushes pools. May stimulate productivity/food webs.
Baseflow (BF)	Provides connectivity between pools and riffles and along channels. Provides sufficient depth for fish movement along reaches.
Very low flow (VF)	Minimum flow in a channel that prevents a cease-to-flow. Provides hydrological connectivity between some pools.
Cease-to-flow (CF)	Partial or total drying of the channel. Stream contracts to a series of disconnected pools. No surface flows.

4.1 Developing environmental watering requirements to support ecological objectives

Development of EWRs for LTWPs draws on the best available information from water managers, ecologists, scientific publications and analysis of gauged and modelled flows. The process started with an assessment of the water requirements of individual species, then of guilds or functional groups. Where water requirements (flow category, duration, timing, etc.) overlapped between species or groups, the individual requirements were combined to provide a single EWR that supported the relevant group of environmental objectives.

At the planning unit scale, EWRs are informed by an understanding of the channel morphology and hydrology. This included an analysis of channel cross-sections, floodplain inundation data, observed flow data, modelled flow data and operational experience.

Each EWR is expressed as a flow category that has been assigned a flow rate or volume, an ideal timing, duration and frequency, and a maximum inter-event period based on the suite of plants, animals and functions it supports (see Table 8 for full description of EWR terms). Complete EWRs for each planning unit in the NSW Border Rivers, including flow rates and total volumes, can be found in Part B.

A summary of flow rates for flow categories at sites in the NSW Border Rivers are shown in Table 9. The timing, duration and frequency components of EWRs, grouped by flow category, for all biota and functions in the NSW Border Rivers catchment and the objectives they support, are presented in Table 10. Many of these details are consistent across the NSW Border Rivers, while some details, such as the duration of a specific EWR may be tailored to planning units. Planning unit-specific EWRs are presented in Part B. Important flow regime characteristics to meet life-history needs and each of the LTWP objectives are described in Table 11.

Table 8 Definition of terms and guide for interpreting environmental water requirements

Term	Explanation
EWR code	Each EWR is given a specific code that abbreviates the EWR name (e.g. SF1 for small fresh 1). This code is used to link ecological objectives and EWRs.
Ecological objectives	The LTWP ecological objectives supported by the EWR. Includes reference to codes of all LTWP Objectives supported (e.g. NF1 = Objective 1 for Native Fish), and a short description of key objectives and life stages being targeted (e.g. spawning or recruitment). Bold text indicates the primary objectives of each EWR. See Tables 2-6 for full objectives.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the respective EWR and associated ecological objective(s). To assess the achievement of the EWR, flow recorded at this gauge should be used.
Flow rate or flow volume	The flow rate (typically ML/d) or flow volume (typically GL over a defined period of time) that is required to achieve the relevant ecological objective(s) for the EWR. Most EWRs are defined using a flow rate, whilst flow volumes are used for EWRs that represent flows into some large wetland systems.
Timing	The required timing (or season, typically expressed as a range of months within the year) for a flow event to achieve the specified ecological objective(s) of the EWR. In some cases, a preferred timing is provided, along with a note that the event may occur at 'anytime'. This indicates that ecological objectives may be achieved outside the preferred timing window, but perhaps with sub-optimal outcomes. In these instances, for the purposes of managing and delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times and still achieve ecological objectives.
Duration	The duration for which flows must be above the specified flow rate for the flow event to achieve the specified ecological objective(s) of the EWR. Typically, this is expressed as a minimum duration. Longer durations will often be desirable and deliver better ecological outcomes. Some species may suffer from extended durations of inundation, and where relevant a maximum duration may also be specified. Flows may persist on floodplains and within wetland systems after a flow event has past. Where relevant a second duration may also be specified, representing the duration for which water should be retained within floodplain and wetland systems.
Frequency	The frequency at which the flow event should occur to achieve the ecological objective(s) associated with the EWR. Frequency is expressed as the number of years that the event should occur within a 10-year period. In most instances, more frequent events will deliver better outcomes, and maximum frequencies may also be specified, where relevant. Clustering of events over successive years can occur in response to climate patterns. Clustering can be ecologically desirable for the recovery and recruitment of native fish, vegetation and waterbirds populations, however

	extended dry periods between clustered events can be detrimental. Achieving ecological objectives will require a pattern of events over time that achieves both the frequency and maximum inter-flow period, and the two must be considered together when evaluating outcomes or managing systems. Where a range of frequencies is indicated (e.g. 3-5 years in 10), the range reflects factors including the natural variability in population requirements, uncertainty in the knowledge base, and variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences at the lower end of the range, and population improvement and recovery during wet climate sequences at the upper end of the range). The lower end of the frequency range (when applied over the long term) may not be sufficient to maintain populations and is unlikely to achieve any recovery or improvement targets. As such, when evaluating EWR achievement over the long-term through statistical analysis of modelled or observed flow records, DPIE-BC recommend that the average of the frequency range is used as the minimum long-term target frequency.
Long Term Average (LTA) frequency	Minimum long-term average target frequency.
Maximum inter-flow or inter-event period	The maximum time between flow events before a significant decline in the condition, survival or viability of a particular population is likely to occur, as relevant to the ecological objective(s) associated with the EWR. This period should not be exceeded wherever possible. Annual planning of environmental water should consider placing priority on EWRs that are approaching (or have exceeded) the maximum inter-event period, for those EWRs that can be achieved or supported using environmental water or management.
Additional requirements and comments	Other conditions that should occur to assist ecological objectives to be met – for example rates of rise and fall in flows. Also comments regarding limitations on delivering environmental flows and achieving the EWR.

4.2 Flow category thresholds

The flow rates that define each flow category (baseflows, small freshes etc.) and associated EWRs will vary between catchments and river reaches. Table 9 presents the range of flow rates for each flow category at representative gauge sites in the NSW Border Rivers catchment (Figure 15). The environmental outcomes associated with each flow category are expected to begin occurring at the bottom end of the flow ranges. Greater and sometimes substantially increased outcomes are likely to occur (e.g. for wetland connecting large freshes and overbank flows) as flows increase in size. While the flow rates for each flow category are expressed as ranges in Table 9, flow rates for the EWRs presented in Part B are expressed as minimum flow rates (i.e. the bottom end of the range) in most cases, meaning that an EWR may also be met by higher flows in other categories.

Figure 14 Dumaresq River upstream of Riverton.
Photo: L. Cameron and J. St Vincent Welch.

Table 9 Flow threshold estimates (ML/day) for flow categories in planning units in the NSW Border Rivers catchment[9].

Planning unit	Gauge	Low flows			Freshes			Overbank[10]	
		Cease-to-flow	Very low	Baseflow	Small	Large	Bankfull and Anabranch connection[11]	Small	Large
TENTERFIELD CREEK									
Tenterfield creek at Clifton	416003	<2	N/A	2-20	20-450	450-10000	3100-10000	>10000	N/A
MOLE RIVER									
Mole R at Donaldson	416032	<5	<45	45-170	170-550	550-16000	7100-16000	>16000	N/A
REEDY CREEK									
Dumaresq R Roseneath	416011	<1	<10	10-160	160-6250	6250-19000	19000-66600	>66600	N/A
BEARDY RIVER									
Beardy R at Haystack	416008	<1	N/A	1-50	50-700	700-15200	4700- 15200	>15200	N/A
GLEN INNES									
Severn R at Strathbogie	416039	<2	<20	20-110	110-560	560-10000	3840-10000	>10000	N/A
BONSHAW									
Dumaresq R U/S Bonshaw	416007	<5	<40	40 -150	150-600	600-15000	10000- 15000	>15000	N/A

[9] See definitions table for explanations.

[10] These EWRs also include ideal total event volumes. These values are yet to be determined.

[11] Anabranch connection only applies to some planning units.

Planning unit	Gauge	Low flows			Freshes			Overbank[10]	
		Cease-to-flow	Very low	Baseflow	Small	Large	Bankfull and Anabranch connection[11]	Small	Large
KINGS PLAIN									
Severn R at Ashford	416006	<5	<40	40-170	170-1520	1520-20000	8210-20000	>20000	N/A
INVERELL									
Macintyre River at Ridgelands	416031	<20	<130	130- 435	435-2600	2600-30000	12000-30000	>30000	N/A
CAMPBELLS CREEK & CAMP CREEK									
Dumaresq R at Glenarbon	416040	<10	<80	80-150	150-1300	1300-8500	8500-25000	>25000	N/A
YETMAN									
Macintyre at Holdfast	416012	<10	<260	260-400	400-3000	3000-10000	10000-45000	>45000	N/A
CONFLUENCE OF MACINTYRE RIVER AND DUMARESQ RIVER									
Macintyre at Boggabilla	416002	<25	<230	230-840	840-3100	3100-21400	10900 - 21400	>21400	>60000
OTTLEYS CREEK									
Ottleys Creek at Coolatai	416020	<55	N/A	N/A	N/A	N/A	400	N/A	N/A
WHALAN & CROPPA CREEKS									
Whalan at Euraba	416072	<150	N/A	N/A	N/A	N/A	850	2000	N/A
Macintyre at Goondiwindi*	416201A	<10000	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Planning unit	Gauge	Low flows			Freshes			Overbank[10]	
		Cease-to-flow	Very low	Baseflow	Small	Large	Bankfull and Anabranch connection[11]	Small	Large
MACINTYRE RIVER FLOODPLAIN UPSTREAM OF BOOMI									
Macintyre at Goondiwindi*	416201A	<10	<120	120-260	260-1300	1300-27000	7000-27000	>27000	>56000
Macintyre River at Terrewah	416047	<5	<40	40-110	110-1300	1300-7900	3300-7900	>7900[12]	>11400[12]
MACINTYRE RIVER AND BOOMI RIVER FLOODPLAIN									
Macintyre u/s Boomi	416043	<5	<60	60-100	100-650	650-2510	1200-2510	N/A[12]	N/A[12]
Boomi R at Boomi Weir offtake	416037	<5	N/A	5-20	20-750	750-3250	1100-3250	N/A[12]	N/A[12]
Macintyre at Kanowna	416048	<5	<40	40-90	90-900	900-4900	2500-4900	N/A[12]	N/A[12]
Barwon River at Mungindi*	416001	<1	45-160	160-540	540-3000	3000-7900	7900-9500	>10000	>19000

* Primary gauges. Other gauges in these planning units provide for EWR tracking in sections along lengthy stretches of river. Achievement of EWRs for the whole planning unit is determined by the flows at the primary gauge.

[12] Overbank events for these planning units are best measured at the Macintyre at Goondiwindi gauge (416201A) due to gauging limitations.

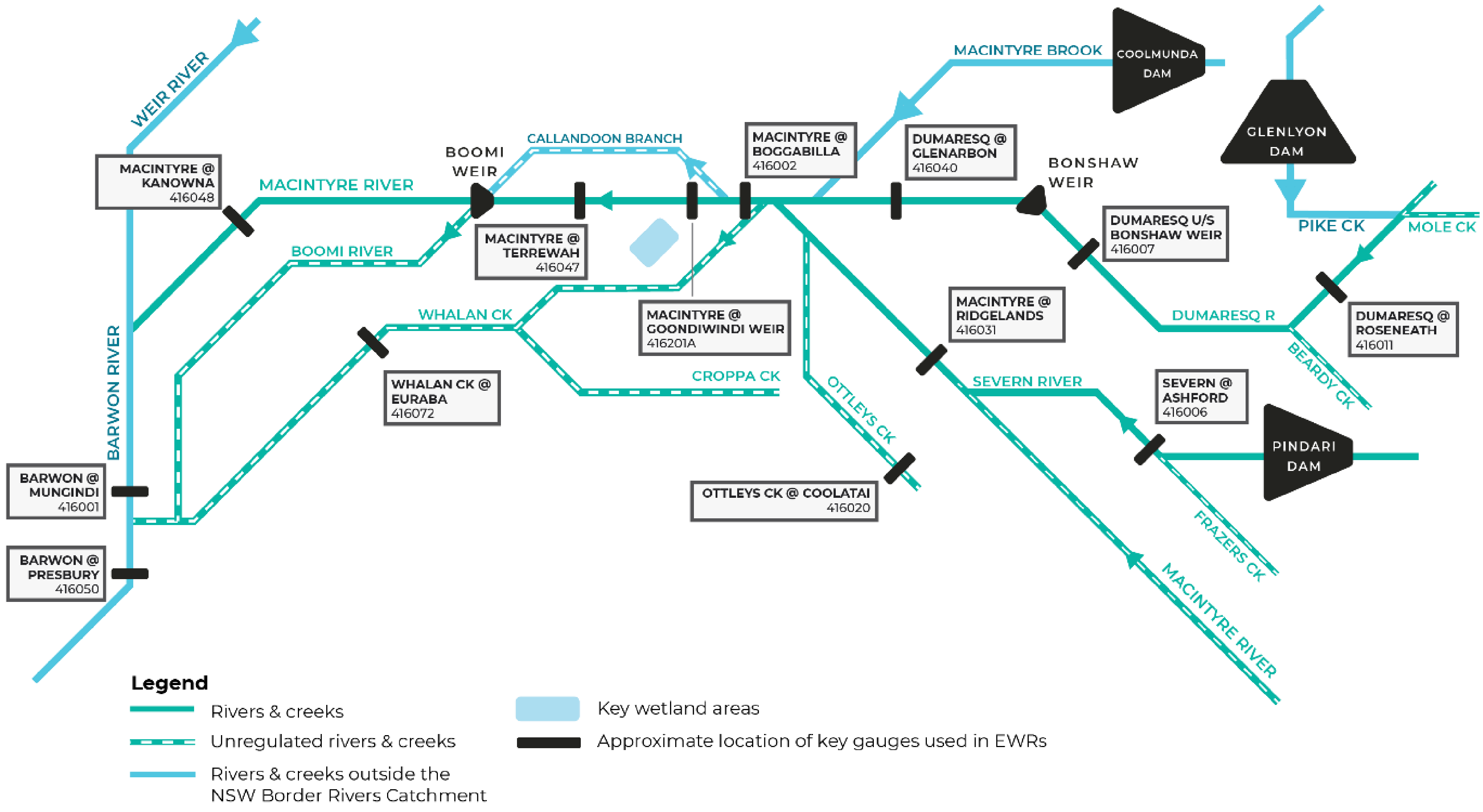


Figure 15 **Schematic diagram showing river gauge locations on the main watercourses in the NSW Border Rivers**

4.3 Catchment-scale environmental water requirements

Table 10 Catchment scale environmental water requirements and the ecological objectives they support

Flow category and EWR code[13]		Ecological objectives[13]	Timing[13]	Duration[13]	Frequency (*LTA frequency*)[13]	Maximum inter-event period[13]
Cease-to-flow	CF	Native fish: NF1 – Survival (all species) Waterbirds: WB1 – Survival (all species) Ecosystem functions: EF1, 2 – refuge habitat		No more than natural[14]		
			Median number of days above cease to flow in each water year 5th percentile of days above cease to flow in each water year (in very dry years)			
Very low flow	VL	Native fish: NF1– Survival and condition (all species) Waterbirds: WB1 – Survival (all species) Ecosystem functions: EF1, 2 – refuge habitat	Median number of days above very low flow in each water year 5th percentile of days above very low flow in each water year (in very dry years)			
Baseflow	BF1	Native fish: NF1, 2, 3, 4, 5, 6, 7, 8 – Survival, condition & movement (all species) Waterbirds: WB1 – Survival (all species) Ecosystem functions: EF1, 2, 3a – refuge habitat, within catchment dispersal	Median number of days above baseflow in each water year 5th percentile of days above baseflow in each water year (in very dry years) 95th percentile deficiency volume (below baseflow) in each water year			

[13] See Table 8 for definitions of terms and explanatory text for EWRs

[14] Determined by the 95th percentile of historical observed cease to flow event duration.

Flow category and EWR code[13]		Ecological objectives[13]	Timing[13]	Duration[13]	Frequency (*LTA frequency*)[13]	Maximum inter-event period[13]
	BF2	Native fish: NF1, 2, 3, 5, 6, 8 – Recruitment (riverine specialists, generalists) Waterbirds: WB1 Native vegetation: NV1 – in-channel non-woody vegetation Ecosystem functions: EF1	Sep to Mar	For duration of timing window	5-10 years in 10 (*75%*)	No more than natural[15]
	BF3	Native fish: NF1, 2, 3, 5, 7, 8 – Spawning & recruitment (riverine specialists, generalists) Waterbirds: WB1, 2, 5 Native vegetation: NV1– in-channel non-woody vegetation Ecosystem functions: EF2	Sep to Apr	10[16] days minimum	Annual	2 years
Small fresh	SF1	Native fish: NF1, 6, 8 – Dispersal/condition (all species) Native vegetation: NV1 – in-channel non-woody vegetation Ecosystem functions: EF3a, 3b, 4 – within and between catchment biotic dispersal	Oct to Apr (but can occur anytime)	10 days minimum	Annual	1 year
	SF2	Native fish: NF2, 3, 5 – spawning and recruitment (generalists, river and floodplain specialists)	Oct to Apr[17]	14 days minimum	5-10 years in 10 (*75%*)	2 years

[15] Determined by the average of historical observed and modelled without development 95th percentile spell duration.

[16] Longer durations are required for fish recruitment, with longer durations also beneficial for establishment of some in-channel vegetation species.

[17] September to December for Murray cod.

Flow category and EWR code[13]		Ecological objectives[13]	Timing[13]	Duration[13]	Frequency (*LTA frequency*)[13]	Maximum inter-event period[13]
Large fresh	LF1	Native fish: NF1, 6, 9 – dispersal & condition (all species); recruitment (flow pulse specialists) Native vegetation: NV3 – fringing river red gum Ecosystem functions: EF1, 2, 3a, 4, 6 – channel maintenance; nutrient, sediment & carbon transport; productivity	Jul to Sep (but can occur anytime)	5 days minimum	5-10 years in 10 (*75%*)	2 years
	LF2	Native fish: NF2, 4 – spawning (flow pulse specialists)	Oct to Apr	5 days minimum	3-5 in 10 years (*42%*)	4 years
	LF3	Native fish: NF1, 3, 7 – spawning & dispersal (floodplain specialists) Native vegetation: NV1, 2— non-woody vegetation in & fringing anabranches and low-lying wetlands	Oct to Apr	10 days minimum	5-10 years in 10 (*75%*)	4 years
Bankfull	BK1	Native fish: NF6, 9 – dispersal & condition (flow pulse specialists) Waterbirds: WB1, 2, 5 – condition, breeding, habitat Native vegetation: NV1, 2, 3 – non-woody vegetation in-channel, wetlands, & anabranches; fringing river red gum Ecosystem functions: EF2, 3a, 3b, 4, 5, 6 – nutrient, sediment & carbon transfer; biotic dispersal; productivity	Any time	3 days minimum	5-10 years in 10 (*75%*)	4 years
	BK2	Native fish: NF3 – spawning (floodplain specialists Waterbirds: WB1, 3 – condition, breeding, habitat Native vegetation: NV1, 2, 4e – non-woody vegetation in-channel, wetlands & anabranches; lignum	Oct to Apr	No less than natural	1-2 events per year 10 years in 10 (*100%*)	4 years

Flow category and EWR code[13]	Ecological objectives[13]	Timing[13]	Duration[13]	Frequency (*LTA frequency*)[13]	Maximum inter-event period[13]
BK3	Native fish: NF1, 3, 7 – dispersal & condition (all species); spawning (floodplain specialists) Waterbirds: WB1, 2, 5 – condition, breeding, habitat Native vegetation: NV2 – non-woody vegetation in wetlands & anabranches Ecosystem functions: EF1, 2 – off-channel refuge habitat	Oct to Apr	10 days minimum	5-10 years in 10 (*75%*)	4 years
Anabranch connection AC1	Native fish: NF1 – condition & dispersal (all species) Waterbirds: WB1, 2, 3 – condition, breeding & habitat Native vegetation: NV1, 2, 4e – non-woody vegetation & lignum in anabranches & low-lying wetlands Ecosystem functions: EF1, 4, 5 – lateral connectivity with wetland & anabranch habitats; nutrient, carbon & sediment transfer; productivity	Median number of days above commence to flow threshold in each water year 5th percentile of days above commence to flow threshold in each water year (in very dry years)			No more than natural[18]
AC2	Native fish: NF1 – condition & dispersal (all species) Native vegetation: NV1, 2 – non-woody vegetation in anabranches & low-lying wetlands Ecosystem functions: EF2, 4, 5 lateral connectivity with wetland & anabranch habitats; nutrient, carbon & sediment transfer; productivity	Any time	No less than natural[19]	No less than natural	7 years

[18] Determined as the average of historical observed and modelled without development 95th percentile spell duration

[19] Determined as the average of the median number of consecutive days above commence to flow in historical observed data and modelled without development.

Flow category and EWR code[13]		Ecological objectives[13]	Timing[13]	Duration[13]	Frequency (*LTA frequency*)[13]	Maximum inter-event period[13]
Small overbank	OB1	Native fish: NF1, 9 – condition & dispersal (all species); recruitment (flow pulse specialists) Waterbirds: WB1, 3, 5 – condition, breeding & habitat Native vegetation: NV2, 3, 4c, 4e – non-woody vegetation in wetlands & anabranches; river red gum; black box & lignum Ecosystem functions: EF2, 4, 5, 7 – lateral connectivity with floodplain habitats, nutrient, carbon & sediment transfer; productivity; longitudinal connectivity & contribution of flow to Barwon-Darling system	Any time	3 days minimum	3 years in 10 (*30%*)	4 years
Large overbank	OB2	Waterbirds: WB1, 3, 5 – condition, breeding & habitat Native vegetation: NV2, 3, 4c 4d, 4e – non-woody vegetation in wetlands & anabranches; river red gum; black box; coolibah and lignum Ecosystem functions: EF2, 4, 5, 6, 7 – lateral connectivity with floodplain habitats; nutrient, carbon & sediment transfer; productivity; groundwater recharge; longitudinal connectivity & contribution of flow to Barwon-Darling system	Any time	No less than natural	1-1.4 in 10 years (*12%*)	No more than natural

Table 11 Important flow regime characteristics to deliver ecological objectives

Ecological objective	Important flow regime characteristics[20]
NATIVE FISH OBJECTIVES[21]	
NF1: No loss of native fish species	• Cease-to-flow: No increase in the frequency or duration of cease to flow periods is required to minimise the loss of refuge pools, beyond levels of ecosystem tolerance. • Very low flows (VF): in dry times may maintain or minimise loss of pools, as critical for fish survival and maintenance. A very low flow can provide some hydrological connection. A flow depth of 10 to 30 cm above cease to flow is considered a low flow for the purposes of stable low flow spawning fish (Kerr & Prior 2018). • Baseflows (BF1): are required for the survival and maintenance of native fish condition as these flows maintain adequate water quality (dissolved oxygen, salinity and temperature) in refuge pools and sufficient flow depth to allow fish movement [at least 0.3 m above cease-to-flow for small and moderate bodied fish (Gippel 2013; O'Conner et al. 2015). In wide channels, habitat mapping and/or local knowledge is used to determine the appropriate flow rate. • A baseflow (BF2) preferably between September and March with an annual or biannual frequency and maximum interflow period of two years enhances recruitment outcomes of river specialist and generalist fish. • A baseflow (BF3) is beneficial for stable low flow spawning fish. These species require less than 10 cm fluctuation of a low flow for 7 to 21 days, with up to 60 days for recruitment (Kerr & Prior 2018). Spawning and recruitment flows for riverine specialists require a minimum of 24 days flow (NSW DPI 2018). • Small freshes (SF1): (at least 0.5 m above cease-to-flow) supports movement and dispersal opportunities for large bodied fish (Fairfull & Witheridge 2003; Gippel 2013; O'Conner et al. 2015). • A large fresh (LF1): an annual large fresh that wets higher in-channel surfaces (ideally between July and September) and ideally for at least five days, releases carbon and nutrients and provides for fish condition. Rate of release peaks in the first day (Southwell 2008) and in anabranches the dissolved organic carbon rises with rising flow (McGinness & Arthur 2011). The large fresh should trigger some primary productivity that will provide food resources and hence improve fish condition prior to the spring/summer spawning season. Flow velocities of >0.3 m/s are ideal to trigger fish movement. In upland valley confined settings, flows are naturally faster passing events and a shorter duration event is relevant (Poff et al. 1997). • An anabranch connection (AC2): can fill deep pools in the anabranches providing a higher variability of habitat types. These pools can persist for several years (Reid, Delong & Thoms 2012) and provide some drought refuge.

[20] See Table 8 for definitions of terms and explanatory text for EWRs.

[21] Important flow regime characteristics for all native fish objectives are based on NSW DPI 2015a and Ellis et al. 2018.

Ecological objective	Important flow regime characteristics[20]
	• A bankfull (BK3) that inundates low lying off channel habitat for 10 days supports the spawning and recruitment of floodplain specialists. The ideal timing is October to April with a maximum interflow period of 4 years. • A small overbank (OB1): and floodplain wetland inundating flows, ideally from August to February, for at least three days and occurring two to three years in 10 years (with a maximum inter-event period of five years) is also required to support condition and movement/dispersal outcomes of all native fish groups. Larger flows that inundate off-stream habitat can also promote growth and recruitment through increased floodplain productivity and habitat availability. To achieve productivity, overland flows need to return to the main channels (Baldwin et al. 2016). Larger flows that connect low-lying billabongs provide important habitat to support strong survivorship and growth of juveniles. • Hydrological connection: Total flow diversion is the most important threatening process. Australian studies on the percentage of flows required to maintain a low risk of environmental degradation report that between two-thirds to 80–92% of natural mean annual flow is required (Arthington & Pusey 2003).
NF2: Increase the distribution and abundance of **short to moderate-lived generalist** native fish species	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for generalists are listed below. Regular (ideally annual) spawning and recruitment events for the persistence of short lived species. • A baseflow (BF2), preferably between September and March with an annual or biannual frequency and maximum interflow period of two years enhances recruitment outcomes of river specialist and generalist fish. • Baseflow (BF3) is required for stable low flow spawning fish require less than 10 cm fluctuation of a low flow for 7 to 21 days for, with up to 60 days for recruitment (Kerr & Prior 2018). Spawning and recruitment flows for riverine specialists require a minimum of 24 days flow (NSW DPI 2018). • Although spawning often occurs independent of flow events, spawning is enhanced by small freshes (SF2) during the warmer months of October to April. At a minimum, events should occur five to 10 years in 10 years with a minimum event duration of 14 days for egg development and hatching. Providing multiple freshes during the spawning season provides flexibility in species response and opportunities for multiple spawning events. A slow recession is beneficial for recruitment. • Large freshes (LF2) occurring two to three weeks after spawning will enhance recruitment of larvae and juveniles by aiding dispersal and access to habitat and suitable prey. Larger flows that inundate off-stream habitat (such as anabranch connecting flows) can also promote growth and recruitment (i.e. increased productivity and habitat availability).
NF3: Increase the distribution and abundance of **short to moderate-lived floodplain specialist** native fish species	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for floodplain specialists, specifically the olive perchlet. The flow category that off channel habitat, or in-channel low velocity niches are inundated varies with the ecological features found at a planning unit scale. The most ideal habitat is off-channel as this provides a more stable velocity and water height for spawning. In planning units where this habitat is not available, or where this habitat can be accessed at lower flows, lower flow categories are applied to the EWR to support this objective.

Ecological objective	Important flow regime characteristics[20]
	• Small fresh, large fresh, bankfull and anabranch inundating flows (BF3, SF3, LF3, BK3): during the warmer months of October to April provide low velocity spawning habitat and productivity benefits to support fish growth. These flows should inundate habitats for at least 10 days to allow for egg development and occur at least five years in 10, with a maximum inter-event period of four years. This period will depend on the persistence of off-channel habitats and time between reconnection to mainstem waterways. Flows should be of a long enough duration to support isolated populations. Water temperatures should be above 22°C. The flow category required to connect with off-channel and other low velocity habitat varies with the landscape features in each planning unit. • Recruitment is enhanced by subsequent flows events that boost productivity (large fresh, bankfull, anabranch connecting or overbank flows) 2–4 weeks after spawning flows. Most floodplain specialist species require spawning and recruitment every one to two years for population survival. • Stable low flow spawning fish can also respond to long periods of stable low flows maintain partial wetting of in-channel vegetation. A baseflow (BF3) for a minimum of 7 days, with 21 days considered more ideal, between September and March at least every second year can be beneficial to the survival of these species (Kerr & Prior 2018).
NF4: Improve native fish population structure for **moderate to long-lived flow pulse specialist** native fish species	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for flow pulse specialists include: • Spawning of flow pulse specialists is triggered by a rapid rise or fall in flow (relative to natural rates) between spring and summer when temperatures are greater than 17°C. In lowland systems, spawning responses are enhanced by substantial flow rises of at least 2 m to cover in-stream features and high flow velocities of greater than 0.3 m/s. • A large fresh (LF2): between October to April for a minimum of five days and a rapid rate of rise should meet these spawning requirements. This is needed three to five years in 10 with a maximum inter-event period of four years. A rapid rise with temperatures greater than 17ºC, ideally 2-3 weeks before SF2 will enhance spawning outcomes. Rate of fall no faster than 5th percentile of natural. Integrity of flow events need to be maintained over long distances (10s to 100s of km) to maximise the capacity for in-stream spawning, downstream dispersal by drifting eggs and larvae and movements by adults and juveniles.
NF5: Improve native fish population structure for **moderate to long-lived riverine specialist** native fish species	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for riverine specialists include: • A baseflow (BF2), preferably between September and March with an annual or biannual frequency and maximum interflow period of two years enhances recruitment outcomes of river specialist and generalist fish. • Baseflow (BF3) is required for stable low flow spawning fish require less than 10 cm fluctuation of a low flow for 7 to 21 days for, with up to 60 days for recruitment (Kerr & Prior 2018). Spawning and recruitment flows for riverine specialists require a minimum of 24 days flow (NSW DPI 2018). • Spawning of riverine specialists usually occurs annually, independent of flow events. However, spawning may be enhanced by a small freshes (SF2) between October and April to promote ecosystem productivity and inundate additional spawning habitat.

Ecological objective	Important flow regime characteristics[20]
	Event duration should be a minimum of 14 days with an average frequency of five to 10 years in 10 and maximum inter-event period of two years. Water temperatures should be >20°C. River blackfish may spawn in lower water temperatures of >16°C and Murray cod in >18°C. Murray cod have a narrower spawning window of September to December. • Small freshes (SF2) are required for nesting species (e.g. Murray cod and freshwater catfish). Preventing rapid drops water levels (that exceed natural rates of fall) during, and for a minimum of 14 days after, spawning is important for preventing fish nests from drying. • Recruitment is enhanced by an immediately following secondary flow pulse (large fresh, bankfull or overbank) for dispersal and access to nursery habitat in low-lying wetland and billabong habitats. • Overall, riverine specialists prefer hydraulically complex flowing streams containing submerged structure (snags and benches) that provides cover and spawning habitat. Flow variability through the delivery of small and large freshes, bankfull and overbank flows enhance the availability of diverse habitat, enhances growth and condition of larvae and juveniles and provides connectivity for dispersal between habitats.
NF6: A 25% increase in abundance of mature (harvestable sized) Golden perch and Murray cod	The flow requirement of golden perch (flow pulse specialist) and Murray cod (riverine specialist) are outlined above under NF4 and NF5, respectively. An increase in mature (harvestable size) fish will be particularly dependant on recruitment success and supporting improved population structure. Baseflows (BF) support the maintenance of populations, while recruitment for both species benefits from fresh events and larger flows that boost productivity (bankfull, anabranch connection overbank and in some cases, large freshes). Small and large freshes provide dispersal opportunities and access to sheltered and productive nursery habitat.
NF7: Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas (within historical range)	These floodplain specialist fish spawn in low velocity habitats such as off channel wetlands, billabongs, at stable low flows or edge habitat in-channel. The flow category most relevant for this objective varies with the landscape and habitat features of each planning unit. • Baseflow (BF3) is required for stable low flow spawning fish require less than 10 cm fluctuation of a low flow for 7 to 21 days for, with up to 60 days for recruitment (Kerr & Prior 2018). Spawning and recruitment flows for riverine specialists require a minimum of 24 days flow (NSW DPI 2018). • Small fresh, large fresh, bankfull and anabranch inundating flows (SF3, LF3, BK2): during the warmer months of October to April provide low velocity spawning habitat and productivity benefits to support fish growth. These flows should inundate habitats for at least 10 days to allow for egg development and occur at least five years in 10, with a maximum inter-event period of four years. This period will depend on the persistence of off-channel habitats and time between reconnection to mainstem waterways. Flows should be of a long enough duration to support isolated populations. Water temperatures should be above 22°C. The flow category required to connect with off-channel and other low velocity habitat varies with the landscape features in each planning unit. • Recruitment is enhanced by subsequent flows events that boost productivity (large fresh, bankfull, anabranch connecting or

Ecological objective	Important flow regime characteristics[20]
	overbank flows) 2–4 weeks after spawning flows. Most floodplain specialist species require spawning and recruitment every one to two years for population survival.
NF8: Increase the prevalence and/or expand the population of key **moderate to long-lived riverine specialist** native fish species into new areas (within historical range)	Flow requirements of riverine specialists are outlined for NF5. A small fresh or greater is required to enable movement and increased distribution of these species. This can occur any time of the year for a minimum duration of 10 days.
NF9: Increase the prevalence and/or expand the population of key **moderate to long-lived flow pulse specialists** native fish species into new areas (within historical range)	Flow requirements of riverine specialists are outlined for NF4. Expanding populations into new areas will be particularly dependant on dispersal flows, particularly large freshes (LF1), bankfull (BK1) and overbank flows (OB1, OB2).
NATIVE VEGETATION OBJECTIVES[22]	
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within and closely fringing channels	Non-woody, inundation tolerant plants occurring on the channel bed, banks, bars and benches require regular wetting and drying to complete life cycles. Variable size and duration of flows including baseflows, variable size freshes and bankfull flows throughout the year will promote diverse communities. Regular inundation will also encourage a dominance of native species over exotic species, as the latter tend to be less tolerant of inundation (Catford et al. 2011). Increased cover of non-woody, inundation tolerant vegetation on banks is likely to stabilise bank material and therefore reduce the risk of excessive bank erosion. • Baseflow (BF3): It is known that the same stable low flows that support stable low flow spawning fish, also support in channel vegetation. Aquatic plants establish beds and increase in species richness at flows of up to 0.3 m/s, and then decline as velocity further increases (Kerr & Prior 2018). Ideal season is late winter and spring (Kerr & Prior 2018). • Small freshes in summer and autumn are important for replenishing soil moisture in river banks to ensure survival and maintenance. • Bankfull: Inundation of banks during late winter and early spring by freshes and bankfull flows is required to replenish soil moisture to promote growth during spring. Prolonged submergence of some amphibious species (e.g. especially if there are continuous high flows during the irrigation season) may have detrimental impacts on survival. • Anabranch connection (AC1): Hydrological connection increases the diversity of plant species, with shallower, higher connectivity billabongs have more diverse niche habitats, such as muddy margins and greater recruitment (Reid, Reid & Thoms 2015).

[22] Important flow regime characteristics for all native vegetation objectives are based on Cassanova 2015, Roberts & Marston 2011, and Rogers & Ralph 2011.

Ecological objective	Important flow regime characteristics[20]
	• Anabranch connection (AC2): The natural pattern of connection with distinct wet and dry phases creates a mosaic of habitat and benefits wetland vegetation. This is particularly important for shallower off-channel habitats with greater vegetation diversity (Reid, Reid & Thoms 2015). The duration of connection and disconnection are also important factors in the movement of organic carbon and nutrients (McGinness 2007; McGinness & Arthur 2011). • Hydrological connection: Total flow diversion is the most important threatening process. Australian studies on the percentage of flows required to maintain a low risk of environmental degradation report that between two-thirds to 80–92% of natural mean annual flow is required (Arthington & Pusey 2003).
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	A flow that inundates lignum at least every 18 months is ideal for high condition shrubs that are capable of supporting bird breeding (Thoms et al. 2007). Long periods of inundation, of between 3 to 7 months from late summer is preferable and may also support breeding of waterbirds (Brandis & Bino 2016). In between floods, drying is required for soil aeration and to preserve crack habitat (Casanova 2015). A flow that inundates lignum every 3 to 5 years will sustain shrubs in a lesser condition (Casanova 2015). After 7 years condition drops and regular (annual) watering is required for several years to regain condition (Casanova 2015). Overall it requires greater volumes of water to restore condition as opposed to a maintenance regime. Flood sequences, with multiple higher flow events within shorter timeframes provide sufficient wetting longer term (Leigh et al. 2010). In Border Rivers, non-woody vegetation is also found in wetlands and billabongs located along the anabranches. A larger flow event will provide greater connection to wetlands and billabongs in anabranches (Reid, Reid & Thoms 2015). • Anabranch connections (AC1): will support non-woody wetland vegetation instream and in some low-lying wetlands with low commence to flow thresholds. The pattern of connective flows influences the structure of wetland plant communities, with impacts to diversity and abundance (Reid, Reid & Thoms 2015). The required duration and frequency varies widely by species. Highly water-dependant, amphibious species such as water couch, spike-rush, and cumbungi require inundation for five to eight months, eight to 10 years in 10. The maximum period between events is two years. • Anabranch connection or bankfull flows and above: To support non-woody, inundation tolerant vegetation habitat should be inundated for two to eight months. Hydrological connection increases the diversity of plant species, with shallower, higher connectivity billabongs have more diverse niche habitats, such as muddy margins and greater recruitment (Reid, Reid & Thoms 2015). Small but frequent anabranch connections events (e.g. AC1) will be important for maintaining the extent and viability of these species. • Larger overbank flows (OB2) will support amphibious damp species such as floodplain herbs, grasses and sedges that require less frequent (three to ten years in ten) and shorter duration (two to four months) inundation.
NV3: Maintain the extent and maintain or improve the condition of river red gum communities closely fringing river channels	• Large freshes and bankfull (BK1): River red gum fringing river channels will be supported by this range of flows which inundate the upper channel and can wet the root zone of fringing riparian vegetation. Flows that recharge alluvial aquifers and soil moisture in

Ecological objective		Important flow regime characteristics[20]
		the riparian zone are also important for maintaining deep rooted vegetation between inundation events. • Overbank (OB1): A small overbank that inundates river red gum to a depth of 20 to30 cm for 4 to 6 weeks is required for recruitment (Casanova 2015). The most beneficial timing is between August and December to coincide with flowering. The maximum interflow spell is 7 years with a frequency of every 3 years preferable (Casanova 2015). Longer spells lead to loss in condition (Casanova 2015). A follow up flood or local rainfall to supply soil moisture in the following spring or early summer will assist survival of seedlings (Roberts & Marston 2011). • Overbank (OB2): Vigorous growth of river red gum woodlands requires flooding every 2 to 4 years, with inundation persisting for 2 to 4 months. This longer duration of inundation is more likely to occur on larger events, or when small overbanks are clustered (i.e. more than one event in a short period) as in (BK2) in low lying areas. • Hydrological connection: Total flow diversion is the most important threatening process. Australian studies on the percentage of flows required to maintain a low risk of environmental degradation report that between two-thirds to 80–92% of natural mean annual flow is required (Arthington & Pusey 2003).
NV4: Maintain the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains	NV4b: River red gum woodland	Maintaining the condition of river red gum woodlands on the floodplain requires overbank flows that inundate vegetation for between two and seven months during September to February. • Overbank (OB1): For river red gum communities located on lower parts of the floodplain, inundation needs to occur every 2 to 4 years with a maximum period between events of four years. • Overbank (OB2): Maintenance of river red gum communities located higher on the floodplain requires larger overbank events, but these can occur less frequently; a little more than once in 10 years, with a maximum inter-event period that is no more than natural. It is likely that river red gum persisting further from the main channel may be supported by rainfall and groundwater.
	NV4c: Black box woodland and NV4d: Coolibah woodland	• Overbank (OB2): floods are required to create conditions for germination and maintain condition or coolibah and black box, with recruitment following flood recession (Casanova 2015). Flood duration of 4 weeks is ideal, unless seedlings are less than 2 months of age (Casanova 2015). Recession of floodwaters from September to February is considered most favourable for germination, with a follow up flood or local rainfall increasing survival of seedlings. Ideal frequency is 1 in 3 to 7 years, with a critical spell duration of 10 years (Casanova 2015).

Ecological objective		Important flow regime characteristics[20]
	NV4e: Lignum shrubland	The condition of lignum is strongly related to flood frequency and duration of inundation. Once condition is lost, it requires additional flows to restore. The flow category required to inundate lignum depends on its location in the landscape with low lying areas inundated at bankfull and higher areas requiring overbank flows to connect. • Bankfull (BK2): Regeneration requires more frequent inundation (ideally annual), for one to 12 months between August and March (September to February for vegetative expansion). • Overbank (OB1) flows can inundate wetlands to maintain lignum shrublands and coolibah wetland woodland. Inundation is required for three to seven months at a frequency of five to 10 years in 10 and a maximum period between events of five years (OB1). • Anabranch connection (AC1): maintaining past inundation patterns of billabongs and wetlands located along the anabranches will ensure the continued survival of lignum in these parts of the landscape.
WATERBIRD OBJECTIVES[23]		
WB1: Maintain the number and type of waterbird species		A variety of foraging habitat including deep pools, muddy edges and riparian vegetation is maintained by a range of flows from very low flow and above. Dry spells no greater than experienced historically are required to support refugia during drought. Breeding requires inundation of lignum, reeds and cumbungi and forested wetlands with tree hollows at least every 1-2 years. Ideal duration is between 2 and 6 months, pending on the species. Small overbank events in summer are ideal, with opportunistic breeding in autumn and spring. • Baseflows (BF1-3) that create muddy edges may be favourable for shorebirds. • Bankfull (BK1): Riparian and low-lying wetland vegetation condition is needed for foraging and breeding habitat. This requires bankfull or greater flows, as defined in the native vegetation objectives. At these flow rates, the inundation of anabranches may create deep pools that can serve as refugia in drier times. • Anabranch connection (AC1): Regular connection of off channel habitat creates a complex mosaic of semi-permanent and permanent waterholes. These billabongs can retain water for several years providing drought refuge for waterbirds and other fauna during extended periods of low flow (Reid, Delong & Thoms 2012). High connectivity billabongs below Goondiwindi have commence to flow thresholds of 7,000ML/d at Goondiwindi, with these flows having an ARI of 1 year, while low connectivity billabongs may require overbank flows of up to 60,000 ML/d (Reid, Reid & Thoms 2015). • Overbank (OB1): A flood will increase foraging and breeding area, with longer duration providing greater benefit to vegetation, waterbird condition and potential for breeding. These floods are required at least every 5 years (Brandis & Bino 2016). Overbank and wetland inundating flows, preferably in spring–summer, that inundate a mosaic of floodplain habitats including non-woody

[23] Important flow regime characteristics for all waterbird objectives are based on Brandis 2010, Brandis & Bino 2016, Rogers & Ralph 2011, and Spencer 2017.

Ecological objective	Important flow regime characteristics[20]
	floodplain vegetation, open shallow waterbodies and deep lakes and lagoons will provide feeding habitat for a range of waterbird species including open water foragers, herbivores, emergent vegetation dependent species, large waders, wetland generalists and small waders (including migratory shorebird species). Where there is gradual drawdown of habitats over late summer–autumn this can extend feeding habitat available for migratory and resident shorebird species (small waders). • Overbank (OB2): A larger flood will increase foraging and breeding area, with longer duration providing greater benefit to vegetation, waterbird condition and potential for breeding (Brandis & Bino 2016). • Hydrological connection: Total flow diversion is the most important threatening process. Australian studies on the percentage of flows required to maintain a low risk of environmental degradation report that between two-thirds to 80–92% of natural mean annual flow is required (Arthington & Pusey 2003).
WB2: Increase total waterbird abundance across all functional groups	As in WB1, provide seasonal (spring–summer) flooding with gradual drawdown over summer into autumn to provide feeding habitat for waterbird species and maintain the condition of waterbird breeding and feeding habitats (WB5). • Anabranch connection (AC1): Regular connection of off channel habitat creates a complex mosaic of semi-permanent and permanent waterholes. These billabongs can retain water for several years providing drought refuge for waterbirds and other fauna during extended periods of low flow (Reid, Delong & Thoms 2012). High connectivity billabongs below Goondiwindi have commence to flow thresholds of 7,000ML/d at Goondiwindi, with these flows having an ARI of 1 year, while low connectivity billabongs may require overbank flows of up to 60,000 ML/d (Reid, Reid & Thoms 2015). • Overbank flows (OB1-2) at the same time as neighbouring catchments to provide benefits to waterbird populations by providing habitat across a larger area of the Murray-Darling Basin. Follow-up overbank and wetland inundating flows (OB1-2, AC1-2) in years following large breeding events in the other catchments may also promote the survival of juvenile birds and contribute to increased waterbird populations. Increasing total waterbird abundance will also rely on maintaining (and in some cases) improving the condition of key native vegetation types that provide breeding and foraging habitats (see WB5). In the Border Rivers these include river red gum, river cooba, common reed, lignum and cumbungi. Overbank and wetland inundating flows are critical to maintaining the extent and condition of these breeding habitats (see WB5 for more details).
WB3: Increase opportunities for non-colonial waterbird breeding	• Anabranch connection (AC1): Breeding habitat includes lignum, reeds and cumbungi, and sometimes flood-dependent trees standing in water. Flows that connect the anabranches may create deep pools and provide appropriate conditions. • Overbank (OB1-2): A larger flood will increase foraging and breeding area, with longer duration providing greater benefit to vegetation, waterbird condition and potential for breeding (Brandis & Bino 2016).

Ecological objective	Important flow regime characteristics[20]
WB5: Maintain the extent and improve condition of waterbird habitats	Riparian and low-lying wetland vegetation condition is needed for foraging and breeding habitat. This requires bankfull flows, as defined in the native vegetation objectives. Waterbirds depend on a wide variety of breeding and foraging habitats, which are maintained through a range of anabranch connecting (AC1-2), bankfull (BK1-2) and overbank flows (OB1–2). Important habitat include sites that provide nesting habitat consisting of river red gum, river cooba, belah, lignum and/or cumbungi. Flows of sufficient duration are needed to maintain the extent and condition of these vegetation communities across the catchment. This ensures that sites are in event-ready condition when large overbank events (OB1-2) initiate large scale colonial waterbird breeding events occur across the wider Murray-Darling Basin. Anabranch connecting (AC1-2) and overbank flows (OB1-2) will also support a broader range of foraging habitats in the Border Rivers, including spike-rush sedgelands, marsh grasslands, lignum shrublands, open lagoons and lakes. The required duration and frequency of overbank flows to support these vegetation types are outlined under the native vegetation objectives.
PRIORITY ECOSYSTEM FUNCTIONS OBJECTIVES[24]	
EF1: Provide and protect a diversity of refugia across the landscape.	• Cease-to-flow periods of durations that are not longer than the persistence of water of sufficient volume and quality in key larger river pool refuges is vital for survival of native plants and animals. No increase in the duration or frequency of cease-to-flow periods of less than 10ML/d at Mungindi (CEWO 2018), as compared to historical. Small flows can replenish pools while a larger event may be required to end an extended dry period. Further work is required to identify higher habitat variability and quality refuge pools (NSW DPI 2015b; NSW DPI 2018). • Very low flows (VF) can maintain the volume of in-channel pools as refugia for native fish and other biota, minimising the loss of pools. These flows are unlikely to improve water quality. • Baseflow (BF1-2): the flow rate used to replenish pools needs to be of sufficient velocity and for sufficient duration to de-stratify the pools. In lowland areas (e.g. below Goondiwindi) a flow above 0.3 - 0.5 m/s for 12 days de-stratifies pools and minimises risk of blue-green algae outbreaks. Algal blooms are more likely in October to March and if thermal stratification persists more than 5 days (Mitrovic et al 2003). Baseflows are required every year for most of the year (no less than natural) and are especially important during dry times. Water quality (e.g. dissolved oxygen, temperature and salinity) may inform timing and urgency of response. • Large fresh (LF1): When restarting flows after a cease-to-flow event, larger magnitude flows (e.g. large fresh or above) may be required to dilute poor water quality, and minimise the risk of

[24] Important flow regime characteristics for all priority ecosystem function objectives are based on Alluvium 2010.

Ecological objective	Important flow regime characteristics[20]
	ecological disturbances (such as fish kills) as water from the bottom of pools is mixed through the water column. • Large fresh (LF1): In cobble dominated riffle sections higher velocities of approximately 1.2 m/s scour and reduce filamentous algae (Davie & Mitrovic 2014). • Anabranch connection (AC1): Regular connection of off channel habitat creates a complex mosaic of semi-permanent and permanent waterholes. These billabongs can retain water for several years providing drought refuge for waterbirds and other fauna during extended periods of low flow (Reid, Delong & Thoms 2012). High connectivity billabongs below Goondiwindi have commence to flow thresholds of 7,000ML/d at Goondiwindi, with these flows having an ARI of 1 year, while low connectivity billabongs may require overbank flows of up to 60,000 ML/d (Reid, Reid & Thoms 2015). • Hydrological connection: Total flow diversion is the most important threatening process. Australian studies on the percentage of flows required to maintain a low risk of environmental degradation report that between two-thirds to 80–92% of natural mean annual flow is required (Arthington & Pusey 2003).
EF2: Create quality instream and floodplain and wetland habitat	The full range of in-channel and overbank flows are required to maintain quality instream and floodplain habitat. Variable in-channel flows (baseflows – bankfull flows) will provide a diversity of physical and hydraulic habitats. With increasing magnitude of flows, greater areas of the channel are inundated (e.g. benches, bars, snags & banks at different elevations in the channel). Baseflows and small freshes provide areas of slackwater (slow flowing) habitat, while large freshes provide deeper and faster flowing habitats. Small and large freshes are important for flushing fine sediment from pools, de-stratifying pools and maintaining geomorphic features such as benches and bars. Bankfull flows are important for geomorphic maintenance of all channel features. To protect banks from excessive erosion it is important to maintain rates of fall that do not exceed natural rates of fall for all regulated deliveries. Slow rates of fall allow water to drain from the bank slowly, preventing mass failure of the banks. Maintaining slow rates of fall is particularly important when flows are in the lower third of the channel, to protect the 'toe' of the bank, which supports the rest of the bank above. Rapid draw down can cause excessive bank slumping more likely in areas with higher pumping capacities. In addition, rapidly rising river levels when banks are dry can lead to bank slumping and erosion. This is particularly relevant in the regulated water source, prioritised to higher fragility reaches. Operation of weirs may also result in damaging rates of rise and fall if water is quickly released at the end of the irrigation season. Bank notching can be avoided by varying flows (avoiding holding flows constant for too many consecutive days) and targeting different peak heights for freshes. • Baseflows (BF1,3) are required to promote growth of in-channel vegetation, creating quality habitat. • Large fresh (LF): Higher velocities will scour, move sediment and maintain geomorphology of the channels. Flows greater than 80% of channel capacity for a minimum duration of 3 days with gradual rates of fall contributes to channel conservation (Gippel 2002). A bankfull flow between the Macintyre distributaries (particularly Boomi River and Whalan Creek) and Presbury on the Barwon-

Ecological objective	Important flow regime characteristics[20]
	Darling is required to maintain connection between Border Rivers and Barwon-Darling. These velocity and volume flows occur more than once a year in some landscapes (Gippel 2002). • Anabranch connecting (AC1-2) and overbank flows (OB1–2) are required to provide essential floodplain and wetland habitat for native fish, waterbirds and other aquatic fauna.
EF3: Provide movement and dispersal opportunities within and between catchments for water dependent biota to complete lifecycles and disperse into new habitats.	Providing longitudinal connectivity is critical for migration, recolonisation following disturbance events, allowing species to cross shallow areas, and dispersal of larvae to downstream habitats. In-channel flows of adequate depth and duration (baseflows and freshes) are important to allow for the movement of aquatic and riparian fauna and flora along rivers and creeks. For example, flows of at least 0.3 m are needed to allow medium sized native fish to move along a channel. The achievement of native fish objectives requires productivity flows for fish condition and movement of fish. A small fresh or greater is required to enable movement and increased distribution. • A small fresh or greater at each of floodplain gauge and Mungindi is required for dispersal of fish into the NSW Border Rivers. A flow within one year of an LF2 in the Barwon-Darling is ideal. • Large fresh (LF): Upstream dispersal of fish requires drown out of physical barriers, such as dams and weirs. In the lower Macintyre there are known barriers at Boggabilla Weir (7,610 ML/d) and Goondiwindi Weir (4,330 ML/d) (NSW DPI 2018). These drown outs occur within the large fresh flow range. • Bankfull (BK): Drown out of physical barriers is particularly important following major breeding events and to reconnect populations after dry times. The largest two barriers are thought to be Cunningham Weir at 44,500 ML/d and Glenarbon Weir at 26,200 ML/d both in planning unit Campbells and Camp creeks. Further upstream on the Dumaresq River, Bonshaw Weir has an estimated drown out of 19,300 ML/d (NSW DPI 2018). These three drown outs are within bankfull flows.
EF4: Support instream and floodplain productivity	No increase in the cease-to-flow duration or frequency at Mungindi, Presbury and Goondiwindi gauges to support downstream productivity. • Small fresh (SF), large freshes (LF1–3) bankfull (BK1) may drive significant pulses of productivity that can maintain ecosystem function in between overbank events. Carbon and nutrients are released when benches and higher level in channel surfaces are wet after a dry period. The rate of release peaks quickly (in the first day), and then tapers (Southwell 2008). Flows that target high level surfaces provide particularly significant contribution to river productivity between flood events (McGinness 2007). • Anabranch connecting flows (AC1) provide a significant pulse in productivity in-between overbank events. Productivity from the complex arrangement of anabranches in Border Rivers can sustain ecosystem functions between flood events (McGinness 2007). Productivity requires pulse connections, as opposed to continuous flows. Dry periods allow for organic matter to build up that can then release organic carbon when connected. Increased time between connections also increases the risk of blackwater (deoxygenated water) when flows reconnect (McGinness & Arthur 2011). • Overbank flows (OB1–2) that inundate the floodplain are the most critical flow categories for supporting large scale productivity, which in turns drives aquatic food webs both on the floodplain and in-stream. Primary productivity includes growth of algae, macrophyte,

Ecological objective	Important flow regime characteristics[20]
	biofilms and phytoplankton, which in turn drives secondary productivity (zooplankton, macroinvertebrates, fish larvae etc.).
EF5: Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands.	Freshes and bankfull flows are important for mobilising organic matter and sediment from in-channel surfaces (e.g. leaf litter that has accumulated on bars, benches and banks during low flows). This material is transported downstream or deposited in other parts of the channel where it is utilised, in the case of nutrients and carbon, to drive primary productivity, or in the case of sediment, for channel maintenance (e.g. to replenish banks and benches). • Anabranch connection (AC1): Cycles of connection and disconnection create off channel billabong refuges and lentic habitats (Mallen-Cooper & Zampatti 2018). No increase in the duration of anabranch cease-to-flow periods, as defined by the ratio of time below commence to flow thresholds to time above commence to flow thresholds, is required to maintain natural wetting and drying cycles, and associated nutrient processes. In turn, this may impact on plant diversity (Reid, Reid & Thoms 2015). Productivity requires pulse connections, as opposed to continuous flows. Dry periods allow for organic matter to build up that can then release organic carbon when connected. Increased time between connections also increases the risk of blackwater (deoxygenated water) when flows reconnect (McGinness & Arthur 2011). • Overbank flows (OB1–2) are essential for transferring nutrients and carbon from the floodplain to the channel. A larger overbank flood and above will provide greater connection between anabranches, billabongs, the floodplain and river, with increased nutrient transfer. A flushing flow at least every 8 to 10 years is expected to minimise build-up of organic carbon on the floodplains and limit the risk of blackwater events (McGinness 2007).
EF6: Support groundwater conditions to sustain groundwater dependent biota.	• Recharge to groundwater is more likely at higher flows when downwards pressure is greater. Large freshes (LF1–3), bankfull flows (BK1-2) and overbank (OB1–2) will contribute to recharging shallow groundwater aquifers in areas where there is a surface-groundwater connection. This recharge can reduce the salinity of shallow aquifers and raise water tables, providing critical soil moisture for deep-rooted vegetation in the riparian zone and on low-lying floodplains. • Overbank (OB2): A large overbank flood or greater is allows recharge of groundwater-dependent ecosystems that are further from the river, and this may contribute to persistence of deep rooted woody vegetation such as coolibah and black box.
EF7: Increase the contribution of flows into the Murray-Darling from tributaries That is, into the Barwon-Darling from the Border Rivers catchment.	• Hydrological connection: Total flow diversion is the most important threatening process. Australian studies on the percentage of flows required to maintain a low risk of environmental degradation report that between two-thirds to 80–92% of natural mean annual flow is required (Arthington & Pusey 2003). Hydrological connection occurs at very low flows and above (Mallen-Cooper & Zampatti 2015). The Intergovernmental Agreement (NSW DPI 2008), Basin Plan and BWS all include considerations for long term flow. The BWS is seeking to keep baseflows at least 60% of the natural level and an overall 10% increase of flows in the Barwon-Darling. Specific targets for Border Rivers include a 10 to 20% increase in freshes and bankfull events. To increase contribution of flows to the Barwon-Darling requires no loss in flows at Mungindi and Presbury gauges (end of system), Terrewah and Kanowna (inflows from QLD), and no loss in flows at end of PU gauges (contributing flows). Minimum volumes for hydrological connection is calculated at 60%

Ecological objective	Important flow regime characteristics[20]
	of average annual flow pre-development (averaged modelled and observed). Future monitoring of hydrological connection may require assessment of a 5 year rolling average to account for climatic variation. • Flows from the Border Rivers are to provide movement & dispersal opportunities between catchments (see EF3) will also contribute to important EWRs in the Barwon-Darling WRPA. • Protecting overbank flows (OB1, 2) will also provide important flows & transfer nutrients & carbon from floodplains in the Border Rivers to the Barwon River.

4.4 Changes to the flow regime

Dams were built in the Border Rivers catchment in the 1960s and 1970s for flood mitigation and irrigation water supply to the plains. Since that time, river flows in the catchment have been highly regulated.

The major water storages are located in the headwaters of each of the major rivers and include Pindari Dam (312,000 ML capacity with 166 GL/y long-term average annual inflows (LTAA)) located on the Severn River, the Glenlyon Dam (261,000 ML capacity with 72 GL/y long-term average annual inflows) on Pike Creek which connects to the Dumaresq River, and Coolmunda Dam (69,000 ML capacity with 62 GL/y LTAA inflows) on the headwaters of the Macintyre Brook River for Macintyre Brook water users. System inflows are mainly regulated by Glenlyon and Pindari Dams. Flows from these dams are regulated to Mungindi which is the downstream boundary of the Border Rivers region (Green et al. 2012).

Glenlyon Dam on the Pike Creek, in the upper Dumaresq catchment, regulates 88% of inflows, and Pindari Dam on the Severn River (New South Wales) regulates 70% of inflows.

CSIRO (2008) calculated that for Border Rivers the average long-term water availability (under historical climate conditions) is around 1,208 GL/y of which under development conditions then around 34% is extracted (around 411 GL/y). This is high compared with other catchments in the Basin. In the NSW Border Rivers, in the regulated water source, the long-term average annual extraction (LTAAE) under Baseline Diversion Limits (BDL) is estimated at 207.6 GL/y (NSW DPI 2017c). Groundwater extraction from some areas is up to 75% of inflows (e.g. Dumaresq River area) and is affecting stream flows (CSIRO 2007). While these are the long-term average annual figures, the actual level of extractions and systems flows is highly variable from year to year, depending on volumes held in dams and then the natural flows in the system. In very high flows and/or flood years, the volumes extracted as a percentage of flows can be lower, while in other years the percentage can be higher, for example if most flows are deliveries for irrigation from water storages dams.

There are also 15 main channel weirs constructed to assist in providing water for irrigation, urban, stock and domestic purposes, as well as numerous small weirs on tributaries and anabranch channels. This includes weirs at Bonshaw, Goondiwindi, Mungindi and Boggabilla. Boggabilla Weir located 20 kilometres upstream of Goondiwindi was constructed in 1991 and is the largest of the main channel weirs. This is the main regulating structure for the lower sections of the Macintyre River, controlling flows during the main irrigation season from October to March.

Regulation of the river has had the greatest impact on the lowland region of the Border Rivers system, due to reduced flows and changes in the patterns and sizes of flows, with extractions, including floodplain harvesting reducing flows progressively towards the end of the catchment. Dams and weirs have also changed the timing and size of flows. Baseflows and small fresh sized flows have increased in size and frequency in areas downstream of major dams and upstream of the major extraction points, while larger freshes and bankfull events have decreased in frequency. Timing of flows has shifted to the main periods of irrigation releases from October to February. Natural downstream flows are also reduced due to extraction under supplementary access licences or rules, and for overbank events from floodplain harvesting.

A shift towards using unregulated rivers for irrigation and water harvesting, including harvesting of on-farm overland flow, occurred in the 1990s with on-farm storage increasing. Across the region, on-farm ring tanks that pump floodwaters from a nearby watercourse account for 40% of constructed storage capacity in the region (MDBC 2007). In the QLD Border Rivers, the storage capacity of weirs and private dams is estimated at 15 GL for weirs, 459 GL for ring tanks and 119 GL for hillside dams (MDBC 2007). In the NSW Border Rivers, the storage capacity of farm dams is estimated at 211 GL (NSW DPI 2017c).

There have been several studies investigating changes to parts of the flow regime.

- CSIRO (2007) found that water resource development has resulted in a decrease in the average frequency of 20,000 ML/d flows at Goondiwindi by 16 percent and has reduced the volume of individual events on average by around 8 percent.
- Thoms, Southwell and McGinness (2005) reported that water resource development and river operation practices had decreased the average frequency of inundation of a number of billabongs on the Macintyre River floodplain by between 12 and 17 percent.
- Davies et al. (2012) for the Sustainable Rivers Audit found that hydrological condition at the Border Rivers audit sites declines from the upland zone upstream of regulation and diversion, through the slopes zone downstream of the storages, to the lowland zone. By the time most flows enter the Barwon-Darling downstream of Mungindi, the gross volume of annual flow and high flow events at the lowland zone are generally rated as ‘poor’ to ‘very poor’ condition.
- Gippel (2006) also undertook a comparison of flows under current (baseline) arrangements and natural (without-development) conditions. The analysis was based on flows predicted by IQQM (Integrated Quantity and Quality Model) for an 80-year period between 1922 and 2002 and indicated that based on modelled flows at Mungindi, there has been a significant change in bankfull flows in the Lower Border Rivers system as a result of water resource development.
- MDBA (2012b) analysis of modelled flow data for 1895- 2009 at Goondiwindi and Mungindi showed that when compared with flow patterns at Goondiwindi, a significant alteration of flows under baseline (current) conditions is apparent for predicted flows at Mungindi when compared to pre-development conditions. The impact of development on flows at Mungindi has been to reduce average daily flows throughout the year, with a less defined seasonal peak.

Planning units and gauges located upstream of major water storages, or in tributaries, can be impacted by unregulated licences and other factors that can impact on inflows. Planning units downstream of major water storages and weirs can also be impacted by the operation of such infrastructure and water delivery patterns. Further analysis of the observed flow data is required to determine if the EWRs are being impacted by insufficient flow volumes, duration of flow events, seasonality of flow events or some other factor.

4.5 Planned and held environmental water in Border Rivers

The following describes the planned and held environmental water arrangements as per the existing Water Sharing Plans (WSPs). Any currently proposed revisions to these plans, such as changes to the long-term average annual extraction, are not reflected in the below details. Once these changes to the WSP are confirmed, this section of the LTWP will require updating, along with any subsequent changes to the risks, constraints and/or potential management strategies.

Water resources in the NSW Border Rivers catchment are managed under two WSPs:

- Water Sharing Plan for the NSW Border Rivers Regulated River Water Source 2009, and the
- Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012.

Planned environmental water

Planned environmental water (PEW) is committed by the WSP for fundamental ecosystem health or other specified environmental purposes. This applies generally, or at specified times, or in specified circumstances. This water is not able to be taken or used for any other purpose. The following rules in the regulated WSP define the PEW within that plan.

Long term average annual extraction

Long term average annual extraction in NSW Border Rivers is limited to 194,500 ML/y, with the model indicating a long term average annual extraction volume of 399,400 ML/y to be shared between NSW and QLD. By limiting the long term average extraction in NSW Border Rivers to 194,500 ML/y, the WSP attempts to ensure that approximately 60% of the long term average annual flow at Mungindi (estimated to be 565,560 megalitres per year) will be preserved and will contribute to the maintenance of basic ecosystem health.

There are approximately 398 surface water licences and 33 groundwater property account holders in both the NSW WSPs. There is approximately 30,805 ML of surface water entitlement (unregulated river access licence) and 17,435 ML of groundwater entitlement (aquifer access and aquifer access (high security)).

In NSW, this is comprised of an estimated 8000 ML/y of basic landholder right stock and domestic, 1205 ML/y domestic and stock alluvial, 620ML/y low water use alluvial, 1233 unit shares of high security alluvial, 21,000 unit shares of A class general security, 244,000 unit shares of B class general security, 120,000 unit shares of supplementary and up to 10,000 ML/y of Boomi River replenishment flow.

The majority of licences are used for irrigation, with a significant proportion also used for town water supply. There has been an embargo on granting new surface water licences in both the unregulated and regulated systems of the NSW Border Rivers since 1998. Alluvial aquifers were embargoed in 2008.

Continuous low flow rule

The continuous low flow rule is aimed at providing riparian flow, connectivity of downstream pools and riffles and curtail problems associated with extended flow recession (WSP 2009). A minimum daily release of 10 ML/d is made from Pindari Dam, except when a greater volume is released to meet basic landholder rights and licenced extractions.

Translucency rule

This rule refers to the immediate release of specified inflows into the dam, intended to provide some reflection of the natural flows downstream of the dam to the point of the next significant inflow (from Frazers Creek near Ashford). It requires that:

- from September to May inflows into Pindari Dam are released, up to a limit of 50ML/d unless a greater volume is released to meet basic landholder rights and licenced extractions
- from July to August inflows into Pindari Dam are released, up to a limit of 200ML/d, unless a greater volume is released to meet basic landholder rights and licenced extractions

Stimulus flow rule

The stimulus flow rule is intended to provide a flow in the river that mirrors a naturally occurring hydrograph, add benefit to any translucency environmental health releases, provide targeted pre-season cues to fish breeding, and regularly wet and inundate the interconnected riparian areas primarily in the river downstream of Pindari Dam to the confluence with Frazers Creek, after which the flow is no longer protected from extraction. This rule requires that at the start of each water year, 4000 ML is set aside in Pindari Dam. To trigger release of the stimulus flow, an inflow to Pindari Dam of greater than 1200ML/d is required between 1 April and 31 August. The release can only occur between 1 August and 1 December. Water set aside but not released can be carried over to the next water year to a maximum of 8000 ML. The timing, rate, volume and duration of the stimulus flow released is determined by DPIE-BC, in collaboration with other stakeholders such as DPIE-Water, DPIF and CEWO.

Mungindi flow rule

This flow rule is also outlined in the Intergovernmental Agreement (NSW DPI 2008). Each year, between 1 September and 31 March, take of uncontrolled stream flow is not permitted if, after taking into account stream losses, the uncontrolled stream flow would result in a flow in the Barwon River at Mungindi of 100 ML/day or less (WSP 2009).

Cease to pump rules

Water for the environment is protected in unregulated water sources through licence volumes and conditions, such as access restrictions on days when flows are low. This is achieved by establishing cease to pump rules that require users to stop taking water when flow declines below a set level. Currently, in rivers and creeks, users must cease to pump when there is no visible flow at the pump site. In pools, pumping is not permitted when the water level is lower than its full capacity.

Held environmental water

Held environmental water is the water that is committed by the conditions of access licences for specified environmental purposes. In the WSP it is termed ‘adaptive environmental water’. Currently NSW does not have any environmental water holdings in the NSW Border Rivers, while the Commonwealth Environmental Water Holder holds 38,933 ML of entitlements across the NSW and QLD Border Rivers, with a long term average annual yield of 14,506 ML. The Northern Basin Review recommended further water recovery in QLD Border Rivers and NSW Border Rivers to reach total reductions of 29 GL in QLD and 7 GL in NSW. Full recovery of these volumes has the potential to significantly contribute to achievement of NSW Border Rivers EWRs.

5. Risks, constraints and strategies

The Border Rivers LTWP is focused on managing water, where possible, to maximise ecological outcomes in a heavily modified landscape. There are a number of factors that could potentially impact how the plan is implemented, or how the environment responds to management under this plan. These are either risks to river and wetland health, or constraints on our capacity to manage water in the most appropriate and effective way.

The DPIE-Water Risk Assessment for the NSW Border Rivers (NSW DPIE 2019a) was undertaken to inform water resource planning in the NSW Border Rivers. It identifies risks to areas of conservation value based on the degree of hydrological change, and several areas at high risk of insufficient water. This chapter complements that risk assessment and addresses the specific risks and constraints that may affect the implementation of the LTWP.

This chapter focuses on risks to meeting the EWRs of priority environmental assets and functions in the NSW Border Rivers catchment (Table 12). It also outlines the risks and constraints that affect our capacity to achieve the ecological objectives of this LTWP (Table 13). This risk assessment has assisted with identifying investment opportunities for improving the likelihood that EWRs can be achieved in the short and long-term (Table 22).

Figure 16 Boomi Regulator.
Photo: E Wilson

5.1 Risks and constraints to meeting EWRs

Table 12 Risks and constraints to meeting environmental water requirements in the NSW Border Rivers and strategies for managing them

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
Insufficient water for the environment	There is a relatively small volume of HEW. There is a small volume of PEW associated with the Pindari Stimulus Flow. This is only protected within the Kings Plain planning unit.	Many EWRs cannot be met with existing planned and held environmental water. Any further development of water storages is likely to further exacerbate this current shortage of water. Associated objectives are unlikely to be achieved.	No reduction in planned environmental water, explore options for additional water recovery and protect natural inflows from unregulated tributaries.	DPIE-BC, DPIE-Water and CEWO
	Flows in NSW Border Rivers are influenced by rainfall, flows and extraction in QLD.	Increased take from unregulated rivers in QLD, such as the Weir River and Boomi River will reduce flows in the lower floodplain area of NSW Border Rivers. Flows in anabranches and ephemeral streams in the floodplain are at risk. Inflows from QLD are managed under the 2008 NSW-QLD Border Rivers Intergovernmental agreement and NSW-QLD Border Rivers Act 1947. The current business plan for the Border Rivers Commission is to shift responsibilities to each state's respective water infrastructure managers. Mechanisms for compliance and accountability remain unclear.	Ensure transparent public reporting of flows and extraction in both QLD and NSW	Border Rivers Commission, NRAR
	The most recently available General Purpose Water Accounting Report for NSW Border Rivers identifies 855 GL of unaccounted difference between inflows and extraction in the catchment in 2016-17 (Burrell et al. 2018).	The unaccounted difference between inflows and extraction is after system 'losses' such as rewetting and evaporation are accounted for. The volume in 2016-17 is approximately 10 times higher than the previous year. The unaccounted difference represents less planned environmental	Refer to the Natural Resources Access Regulator (NRAR) water compliance policy and strategy	NRAR

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
		water (water not extracted under licence) and less water available for downstream catchments.		
	Inadequate commence and cease to pump rules in unregulated water sources can place pools at risk and limit the volume that tributaries are able to provide to downstream environments.	There is potential for direct impact on ecosystem functions objectives, and also fish objectives including those pertaining to purple-spotted gudgeon and other threatened species.	Investigate extent of impact and explore options such as changes to rules, improved metering and trade out of high risk areas.	DPIE-BC & DPIE-Water
Take of environmental water delivery	The likelihood of water loss is related to the pressure for consumptive water and a perceived lack of monitoring and/or enforcement of water extraction conditions.	This may prevent flows from reaching the flow thresholds and event duration required by environmental water requirements, and subsequently prevent objectives from being achieved.	Refer to the Natural Resources Access Regulator (NRAR) water compliance policy and strategy	NRAR
Knowledge gaps and uncertainties	There are significant knowledge gaps in the Border Rivers. These include: • relationship between ground and surface water; • location of high quality habitat drought refugia; • location and watering needs of cultural assets; • ongoing fish tagging to monitor movement of species and populations; and • confirmation of flow requirements of stable low flow spawning fish.	As regionally specific knowledge is gained, revision to the objectives and EWRs will be required.	As funding permits, undertake research activities such as habitat mapping and monitoring of LTWP outcomes.	DPIE-BC, DPIF
Floodplain structures and barriers	Construction (e.g. levees, diversion channels, sediment blockage of culverts) has caused barriers to delivering water to wetland and	Changes to overland flows that redirect water away from environmental assets may limit achievement of native vegetation, waterbird and functions objectives	Implement the Border Rivers Floodplain Management Plan and if funding permits, undertake remedial work	DPIE-Water, DPIE-BC

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
	floodplain areas. These will be identified by the hotspots project.	associated with overbank environmental water requirements.		
Instream barriers and structures	The largest three barriers are thought to be Cunningham Weir with a drown out of 44,500 ML/d, Glenarbon Weir with a drown out of 26,200 ML/d and Bonshaw Weir with a drown out of 19,300 ML/d. Upstream fish movement is limited by these structures and sections are only connected during bankfull flows.	This directly limits the dispersal of fish across the whole of the Border Rivers after major breeding events and dry spells. Remediation to add suitable fish ways would enable this objective to be achieved at lower flow rates.	Refer to NSW DPI-F Fish for the Future: Action in the Northern Basin-NSW proposal for Northern Basin Toolkit. Seek funding to remove barriers.	DPIF
			Remove priority illegal barriers	NRAR
Take of environmental water delivery	The likelihood of water loss is related to the pressure for consumptive water and a perceived lack of monitoring and/or enforcement of water extraction conditions.	This may prevent flows from reaching the flow thresholds and event duration required by environmental water requirements, and subsequently prevent objectives from being achieved.	Refer to the Natural Resources Access Regulator (NRAR) water compliance policy and strategy	NRAR
Insufficient channel capacity	In some catchments there is insufficient channel capacity for both environmental water and consumptive water delivery. Given that the volume of environmental water held in Border Rivers is minimal, it is unlikely that this constraint is present.	Considered unlikely. Further investigation is needed to determine if this constraint is relevant and its potential impacts.	Investigate extent of risk and explore options for addressing.	DPIE-BC
Insufficient release rates from storages	The maximum daily release from storages may not be sufficient to create events that peak in higher flow categories, such as large fresh and bankfull flows.	This would prevent achievement of certain EWRs.	Coordinate dam releases with unregulated tributary flows to promote higher peaking events.	DPIE-BC & CEWO
			Ensure no further development of unregulated tributaries, including no further construction of dams	DPIE-Water & WaterNSW

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
Unsympathetic river operations	In drier times block releases are used to deliver consumptive water. These blocks can cause unnatural rates of rise and fall, short pulses in flow that do not meet durations required for EWRs, or extended periods of steady flow that lack the cues for ecological responses such as spawning. The extent to which block releases are limiting the achievement of EWRs or causing negative environmental impacts requires further investigation.	There is potential for direct impacts on ecosystem functions objectives and the durations of EWRs.	Investigate extent of risk and explore options for increasing environmental effectiveness of consumptive water releases.	DPIE-BC & WaterNSW
	Inappropriate rate and timing of release can mean that river levels rise and fall rapidly.	This directly impacts on achievement of some ecosystem functions objectives.		

5.2 Non-flow related risks and constraints to meeting LTWP objectives

The risks and constraints to meeting the ecological objectives include external factors that could potentially impact on achieving the targets outlined in this plan. These may be water related, such as cold water pollution downstream of major water storages (NSW DPI 2015a); or consequences of inappropriate land use practices, such as the reduction of groundcover over large areas in upper catchments and the clearing of native vegetation. While managing these risks and constraints is outside the scope of this LTWP, they have been included to draw attention to their influence on river and wetland health, and to highlight the importance of linking this LTWP with natural resource management.

Table 13 Risks and constraints to meeting ecological objectives in the Border River catchment

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
Unsuitable water quality	Water quality affects the ecology and survival of aquatic organisms. Unfavourable water quality can be caused by natural processes, such as during hypoxic blackwater events after dry or low-flow periods. This occurs from the build-up of organic material in channels and on floodplains and leads to low-dissolved oxygen levels and potential fish kills. Total nitrogen, total phosphorus, dissolved oxygen, pH and turbidity have been assessed at 12 monitoring stations, with a medium or high likelihood on at least one of these parameters reported at 5 stations. Salinity was rated as a high likelihood (only assessed at Mungindi). Blue-green algae likelihood is high at Pindari Dam, on the	Poor water quality may reduce ecosystem resilience to disturbances and reduce the extent of ecological response from watering. The ideal season of EWRs that pertain to fish spawning is the warmer months of spring-summer. The use of HEW may be limited to less ideal timings, such as autumn and winter, to minimise risk of fish kills associated with turnover of stratified pools in summer. Potential direct and indirect impacts on the objectives. Recovery may require increased frequency of environmental flows to encourage species recruitment and a return to stable populations.	Implement recommendations detailed in the *Water Quality Management Plan and the Incident response guide* (NSW DPIE-Water 2019b and 2019c) to promote prevention of water quality incidents. Monitor water quality and if thresholds of ecological tolerance.	DPIE-BC DPIE-Water

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
	Severn River downstream of Pindari and the Macintyre River at Boggabilla. Glenlyon Dam is also prone to blue-green algae.			
Poor condition of water dependent ecosystems	There are non-water related factors impacting on the condition of water dependent ecosystems. This includes land management practices, native vegetation clearing, invasive species and erosion.	Poor condition of ecosystems may reduce ecosystem resilience to disturbances and reduce the extent of ecological response from watering. A higher frequency of environmental watering and reduced spell duration between events may be required to enable recovery.	Encourage improvement in land management	LLS with landholders
			Implement the Local Land Services Act 2016 and Biodiversity Conservation Act 2016	DPIE-BC, LLS, BCT, DPIE-Water
Altered hydrograph due to climate change	Increased extremes of temperature and rainfall may increase the flashiness of flows and reduce the persistence of water in inundated areas. Longer and more frequent cease to flow periods, coupled with increased dry sequences may put pressure on maximum interflow periods and increase demand for environmental water.	It may become more difficult to meet the minimum durations of environmental water requirements, particularly in unregulated streams. Frequencies of EWRs in moderate and wet conditions may need to increase to enhance ecosystem recovery and sufficient resilience for dry times.	No further construction of regulating structures on unregulated tributaries. Revision of pumping rules may be required.	DPIE-Water
			Monitor changes and adjust use of HEW and PEW in response	DPIE-BC
Knowledge gaps and uncertainties	There are significant knowledge gaps in the Border Rivers. These include: • relationship between ground and surface water; • location of high quality habitat drought refugia;	As regionally specific knowledge is gained, revision to the objectives and EWRs will be required.	As funding permits, undertake research activities such as habitat mapping and monitoring of LTWP outcomes.	DPIE-BC DPIF

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
	• location and watering needs of cultural assets; • ongoing fish tagging to monitor movement of species and populations; and • confirmation of flow requirements of stable low flow spawning fish.			
Social willingness and adequacy of governance structures	Community acceptance and support for a healthy environment is important for the achievement of this LTWP. Establishment of a regional body to provide local knowledge is needed for regionally specific water management and ownership. Social understanding and acceptance of environmental water will also promote protection of environmental water.	A lack of social willingness for environmental protection may increase the need for compliance actions. Local knowledge may improve development of appropriate management strategies to achieve the EWRs and associated objectives.	Establish mechanism for gaining regional input to environmental water decisions to build knowledge and understanding and foster ownership.	DPIE-BC DPIE-Water
Floodplain structures and barriers	Construction (e.g. levees, diversion channels, sediment blockage of culverts) has caused barriers to delivering water to wetland and floodplain areas. These will be identified by the hotspots project.	Changes to overland flows that redirect water away from environmental assets may limit achievement of native vegetation, waterbird and functions objectives associated with overbank environmental water requirements.	Implement the Border Rivers Floodplain Management Plan and if funding permits, undertake remedial work	DPIE-Water, DPIE-EES
Fish entrainment	Native fish can be removed, injured or killed when sucked into irrigation pumps	This directly impacts on all the native fish objectives. Mortality or removal of native fish due to entrainment places additional pressure on successful spawning and recruitment events to maintain populations.	Refer to the Fisheries management plan for screens on pumps	DPIF DPIE-Water

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
Land management practices	Grazing practices can alter soil cover and damage native vegetation cover. Cropping practices can cause soil degradation and alter soil cover. Land degradation and erosion can impact the geomorphology of channels. Water runoff and water quality can also be impacted.	Potential impacts on the achievement of objectives, through indirect processes. Degradation of water quality and riparian zones may require increased frequency of environmental flows to enable to the system to compensate.	Encourage improvement in land management	LLS with landholders
Native vegetation clearing	Native vegetation clearing has direct impacts on vegetation objectives and the availability of waterbird habitat. Changes to riparian vegetation can impact on water quality, erosion rates and instream habitat.	Potential direct and indirect impacts on objectives. Native vegetation clearing may prevent achievement of native vegetation targets and objectives. Degradation of water quality and riparian zones may require increased frequency of environmental flows to enable to the system to compensate.	Implement the Local Land Services Act 2016 and Biodiversity Conservation Act 2016	DPIE-BC, LLS, BCT, DPE
Invasive species	Invasive plants and pest animal species may invade water course, make use of water features and impact on habitat quality. For example, azolla outbreaks in the Severn River may blanket the water surface, reduce dissolved oxygen and result in ecosystem damage.	Potential direct and indirect impacts on objectives. Recovery from in-channel invasive species may require increased environmental flows. Impacts of invasive species may directly affect species populations and achievement of targets and objectives.	Encourage improvement in land management	LLS with landholders
			Monitor introduction and spread of invasive species. Implement NSW Invasive Species Plan 2018-2021	LLS, DPIE-BC, DPIF and DPI
Biosecurity	Flows and water dependent biota can carry disease and toxins through the landscape. In cases such as the carp herpes this may be a positive outcome, in other cases this may cause	Potential direct and indirect impacts on objectives. Recovery from disease may require increased frequency of environmental flows to encourage species recruitment and a return to stable populations.	Implement NSW Biosecurity Act 2015 and NSW Biosecurity Strategy	LLS, DPIE-BC, DPIF and DPI

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Potential project partners
	significant loss of environmental values and assets.			
Cold water pollution	Cold water pollution was rated as high likelihood for downstream of Pindari Dam, Glenlyon Dam and Coolmunda Dam in the Risk Assessment for the NSW Border Rivers WRPA (NSW DPIE-Water 2019a). Cold water pollution from Pindari Dam extends to Boggabilla and Glenlyon Dam cold water pollution extends to the junction within Macintyre Brook (Lugg & Copeland 2014)	Cold water limits achievement of objectives related to fish spawning and recruitment, due to metabolic changes in native fish and absent spawning cues. Flow events of sufficient volume and duration may be achieved but ecological responses may be prevented due to water temperature.	Implement the NSW Cold Water Pollution Strategy	DPIE-Water WaterNSW
Dam stratification and destratification	Recent turnover (destratification) of Pindari Dam has resulted in large fish kills across all major fish guilds. At Glenlyon Dam, only minor fish kills of bony bream were reported.	This potentially impacts on all native fish objectives, creating additional pressure on successful fish spawning and recruitment to replace losses.	Monitor and explore opportunities for adaptive management of EWRs to encourage resilience.	DPIF, DPIE-BC & CEWO

5.3 Climatic change

Climate change is a key long-term risk to river, wetland and floodplain health. It will exacerbate the natural seasonal variability that exists in NSW, making it more difficult to manage our landscapes and ecosystems and the human activities that depend on them. The Murray–Darling Basin Sustainable Yields project investigated the potential impacts of climate change on water resources and flows to key environmental sites across the Basin, including the Border Rivers catchment (CSIRO 2007). The project predicts the following for the Border Rivers:

- a 9% reduction in average annual runoff to rivers in the catchment by 2030 (best estimate median)
- a 9% reduction in water availability and a 12% reduction in end-of-system flows by 2030
- a 26% increase in the average period between inundation events for the anabranches and billabongs of the Macintyre.

Best available climate change predictions for the New England and NSW North West indicate a significant change to climatic patterns in the future. According to the NARCLiM model[25] (scenario 2), the changes in Table 14 are predicted by 2030 and 2070.

There are uncertainties with these climate change predictions, and the predicted changes are unlikely to occur in isolation. Rather, the predicted changes will occur alongside other changes owing to water resource development, land use, and environmental water management. Accordingly, it is currently unclear what impacts these changes will have on the environmental assets of the NSW Border Rivers catchment.

Table 14 Potential climate-related risks in the New England and NSW North West.

<table>
<tr><th rowspan="2">Potential risk due to climate change</th><th rowspan="2" colspan="2">Description of risk</th><th colspan="2">NARCLiM projection (scenario 2)</th></tr>
<tr><th>2020–39</th><th>2060–79</th></tr>
<tr><td rowspan="4">Change in rainfall</td><td rowspan="4">By 2030 there will be little change in annual rainfall. Rainfall will increase across the region during autumn. Rainfall will decrease across the region during summer and winter.</td><td>Summer</td><td>-3.3%</td><td>+9.8%</td></tr>
<tr><td>Autumn</td><td>+14.9%</td><td>+16.8%</td></tr>
<tr><td>Winter</td><td>-7.6%</td><td>-0.7%</td></tr>
<tr><td>Spring</td><td>+2.6%</td><td>-0.7%</td></tr>
<tr><td rowspan="4">Change in average temperature</td><td rowspan="4">Mean temperatures are projected to rise by 0.7ºC by 2030. The increases are occurring across the region, with the greatest increase during summer and spring.</td><td>Summer</td><td>+0.89C</td><td>+2.28C</td></tr>
<tr><td>Autumn</td><td>+0.72C</td><td>+2.20C</td></tr>
<tr><td>Winter</td><td>+0.48C</td><td>+1.92C</td></tr>
<tr><td>Spring</td><td>+0.80C</td><td>+2.33C</td></tr>
<tr><td>Change in number of hot days (max. temp. >35C)</td><td>Hots days are projected to increase across the region by an average of 7 days per year by 2030. The greatest increases are seen in the west of the region around Moree with a projected 10–20 hot days per year.</td><td>Annual</td><td>+7.1</td><td>+23.4</td></tr>
</table>

[25] The NARCliM projections have been generated from four global climate models (GCMs) dynamically downscaled by three regional climate models (RCMs). http://climatechange.environment.nsw.gov.au/Climate-projections-for-NSW/About-NARCliM.

Potential risk due to climate change	Description of risk		NARCLiM projection (scenario 2)	
			2020–39	2060–79
Change in number of cold nights (min. temp. <2C)	Cold nights are projected to decrease by an average of 9 fewer days per year by 2030. The greatest decreases are seen around Glen Innes, which is projected to experience a 10–20 fewer cold nights per year.	Annual	-8.8	-26.1
Bushfires—changes in number of days a year FFDI>50[26]	Overall, severe fire weather is projected to increase (slightly) across the region by 2030. Increased severe fire weather is expected in the north-west part of the region during spring (the prescribed burning season) and summer (peak fire risk season).	Annual	+0.2	+0.9
Hillslope erosion	Changes are expected in soil erosion and rainfall erosivity. Soil organic carbon stocks are projected to decline to 2030.	Mean percent increase	10-20%	20-30%
Biodiversity	Species composition will likely be impacted by rising temperatures, increased fire frequency, changing fire regimes, storm damage and (potentially) drought.			

(a) Strategies for mitigating climate-related risks

Water Resource Plans and environmental water managers will need to adapt to changes in climate and flows when and if they occur. In striving to respond to the environmental demands of rivers, wetlands and floodplains, environmental water managers consider the range of priorities and strategies at their disposal on a 1–3 year timeframe. A changing climate that departs from historic records will be another important variable in this decision-making process.

[26] Forest Fire Danger Index (FFDI) is used in NSW to quantify fire weather. The FFDI combines observations of temperature, humidity and wind speed. Fire weather is classified as severe when the FFDI is above 50.

6. Water management under different water resource availability scenarios (RAS)

In addition to the longer-term climate related risks outlined above, environmental water managers consider antecedent conditions and seasonal predictions. Environmental water managers consider a range of factors when determining where and when discretionary water for the environment should be delivered. Some of these considerations include the current condition of the plants and animals, the recent history connectivity of river channels to their floodplain systems, rainfall history and predictions, and water availability (DECCW 2011). The EWRs, and specifically the maximum inter-event period, provide additional information to guide ecological demand and use of environmental water on a shorter-term basis.

Planning for the management of water-dependent environmental assets amid this variability means that plans must be adaptive. Watering activities need to range from building resilience and promoting ecological restoration by maximising environmental outcomes from flow events when water is abundant, to minimising losses or damage by maintaining drought refuges when resources become scarce. Ecological resilience can be gained through:

- maintaining healthy condition of water-dependent ecosystems, including species populations
- maintaining environmental flows within the boundaries of wetting and drying cycles
- maintaining spell durations within tolerance thresholds to prevent irreversible change
- protection of refugia during drought and other disturbances
- facilitating repopulation and/or recolonization following drought or other disturbances; and
- minimising human-induced threats (e.g. invasive species, habitat fragmentation).

This chapter sets out a framework to help inform annual water management decisions in river reaches which are regulated or affected by regulated water. This information is presented in terms of a water resource availability scenario (RAS) as proposed by MDBA (2012b). Each RAS is described below in two tables that include:

1. the broad priorities to guide management under the particular scenario
2. the potential management strategies for achieving these priorities
3. tables identifying the priority LTWP objectives for each scenario and target flow categories (marked with an X) (Table 19-22).

Some of the wording of the LTWP objectives has been adjusted to highlight the most relevant aspect of the objective under the scenario. For example, a LTWP objective that over 20 years seeks ‘improvement’ may only seek to ‘maintain’ under a dry scenario. Some of the objectives have been summarised or combined for better presentation. The full list of objectives can be found in Chapter 3. More information about RAS and how it is defined is outlined in Appendix B.

6.1.1 Water resource availability scenario: Very dry – Protect

In very dry conditions, the broad priority of water management is to protect and avoid irretrievable damage, such as the critical loss of species, communities and ecosystems. This may require preventing or minimising unnaturally prolonged dry periods and the maintenance of refuges. The priority objectives, and if relevant, refocused objectives for very dry conditions are shown in Table 15.

	Broad water management priorities	Key management strategies for consideration
Very Dry	Avoid critical loss of species, communities and ecosystems Maintain refuges Avoid irretrievable damage or catastrophic events Avoid unnaturally prolonged dry periods between flow events Support targeted longitudinal connectivity within catchment for functional processes and a range of flora and fauna Prevent two consecutive years of extreme dry to core wetland areas	Focus on limiting exceedance of maximum inter-flow periods through the following strategies: Provide very low flows to replenish in-channel pools with high habitat value, particularly during and after a hot summer. This may require alternative watering actions (e.g. pumping) to support anabranch/floodplain habitats to ensure no loss of species for floodplain specialists (e.g. to prevent wetlands with threatened fish species from drying out). Explore options to maximise environmental outcomes from weir replenishment flows. Explore options to maximise environmental outcomes from long block releases Review cease to pump rules in unregulated sections If a critical water shortage or similar critical incident restricts the use of water for the environment, then DPIE-BC as part of the Critical Water Advisory Panel, will work to minimise exceedances of maximum inter-flow periods for important areas.

Table 15 Priority LTWP objectives and flow categories in a very dry RAS

Priority LTWP objective	Flow categories								
	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels			X						
NV2: Maintain the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains					X	X			
NV3: Maintain the extent of river red gum communities closely fringing river channels						X			
NV4e: Maintain the extent of native woodland and shrubland communities on floodplains – Lignum shrublands						X			
WB1: Maintain the number and type of waterbird species	X	X	X			X			
NF1: No loss of native fish species			X		X				
EF1: Provide and protect a diversity of refugia across the landscape	X	X	X		X				X
EF2: Create quality instream, floodplain and wetland habitat	X	X	X			X			

6.1.2 Water resource availability scenario: Dry - Maintain

In dry conditions, the broad management priority is to maintain environmental assets and ecosystems functions. This may include seeking to provide flow connectivity and movement opportunities for aquatic biota, enabling species to move to more favourable habitats and refuges. In these conditions management remains focused to limiting exceedance of maximum inter-flow periods, as opposed to maintaining the long-term ideal frequency of events. EWRs aimed at spawning may be in high demand if the boundaries of species life cycles are being tested, but otherwise creation of spawning events may be deferred until conditions are more favourable for recruitment. Similarly, objectives that seek to maintain habitat or refugia and require higher flows for anabranch connection and bankfull may not be triggered as requiring action if these flows have occurred prior to dry conditions and the associated EWRs are within maximum inter-flow periods. The priority objectives, and if relevant, refocused objectives for dry conditions are shown in Table 16.

	Broad water management priorities	Key management strategies for consideration
Dry	Support the survival and viability of threatened species and communities Maintain refuges Maintain environmental assets and ecosystem functions Avoid unnaturally prolonged dry periods between flow events Support longitudinal connectivity for functional processes and a range of flora and fauna	Explore option for stimulus flow to provide a small fresh through the system Protect tributary inflows Review cease to pump rules in unregulated sections

Table 16 Priority objectives and flow categories in a dry RAS

Priority LTWP objective	Flow categories								
	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels		X	X						
NV2: Maintain the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains					X	X			
NV3: Maintain the extent and the condition of river red gum communities closely fringing river channels						X			
NV4e: Maintain the extent and maintain the condition of native woodland and shrubland communities on floodplains – lignum shrublands						X			
WB1: Maintain the number and type of waterbird species	X	X	X	X		X			X
WB2: Maintain total waterbird abundance across all functional groups	X	X	X	X		X			X

Priority LTWP objective	Flow categories								
	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
WB5: Maintain the extent and condition of waterbird habitats						X			X
NF1: No loss of native fish species			X	X					
NF2: Maintain the distribution and abundance of short to moderate-lived generalist native fish species				X					
NF3: Maintain the distribution and abundance of short to moderate-lived floodplain specialist native fish species				X	X				
NF4: Maintain native fish population structure for moderate to long-lived flow pulse specialist native fish species				X					
NF5: Maintain native fish population structure for moderate to long-lived riverine specialist native fish species				X					
NF7: Maintain the prevalence of key short to moderate-lived floodplain specialist native fish species in core population areas				X	X	X			
NF8: Maintain the prevalence of key moderate to long-lived riverine specialist native fish species in core population areas				X					
EF1: Provide and protect a diversity of refugia across the landscape	X		X	X					
EF2: Create quality instream, floodplain and wetland habitat	X		X				X		
EF3a: Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments					X				
EF4: Support instream and floodplain productivity	X			X			X		
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries		X	X	X	X	X			

6.1.3 Water resource availability scenario: Moderate - Recover

In moderate conditions, the broad management priority is to promote recovery of environmental assets and ecosystems functions. This includes enabling growth, reproduction and small-scale recruitment for a diverse range of flora and fauna. If moderate conditions are following a dry period, activation of low lying off-channel habitat such as anabranches may be required to increased productivity. It may also be necessary to increase the number of events, to restore the longer-term frequency to ideal. If moderate conditions are following a wet period, productivity of the system may be sufficient due to recent floodplain connection. This may change the relative emphasis between objectives and flows required. In moderate conditions, particularly if following wet conditions, it may be possible to carry over water for use in dry years. The priority objectives for moderate conditions are shown in Table 17.

	Broad water management priorities	Key management strategies for consideration
Moderate	Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna Promote low-lying floodplain-river connectivity Seek to meet ideal event frequencies Support medium flow river and floodplain functional processes Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna Support low flow lateral connectivity and end of system flows Set aside water for use in drier years	Management strategies for achieving these broad priorities will remain limited by the volume of held and planned environmental water available: Explore options for stimulus flow to contribute to EWRs Continue cooperative water with Water NSW and CEWO to maximise outcomes from consumptive water deliveries and coordinated releases of held environmental water Consider carry over of held and planned environmental water for drier times

Table 17 Priority objectives and flow categories in a moderate RAS

Priority LTWP objective	Flow categories								
	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
NV1: Improve the extent and viability of non-woody vegetation communities occurring within channels		X	X						
NV2: Increase the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains					X	X	X		X
NV3: Maintain the extent and improve the condition of river red gum communities closely fringing river channels						X	X		
NV4c: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – black box woodland							X		
NV4d: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – coolibah woodland							X		
NV4e: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – lignum shrublands						X	X		

Priority LTWP objective	Flow categories								
	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
WB1: Maintain the number and type of waterbird species		X	X	X	X	X	X		X
WB2: Increase total waterbird abundance across all functional groups					X	X	X		X
WB3: Increase opportunities for non-colonial waterbird breeding					X	X	X		X
WB5: Maintain the extent and improve condition of waterbird habitats					X	X	X		
NF1: No loss of native fish species			X	X	X	X			X
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish species				X					
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species				X	X	X	X		
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species					X				
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species				X					
NF6: A 25% increase in abundance of mature (harvestable sized) golden perch and Murray cod				X	X				
NF7: Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas					X				
NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas				X					
EF1: Provide and protect a diversity of refugia across the landscape	X	X	X		X				
EF2: Create quality instream, floodplain and wetland habitat	X	X	X			X			
EF3a: Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments					X	X			
EF3b: Provide movement and dispersal opportunities catchments for water-dependent biota to complete lifecycles and			X	X					

Priority LTWP objective	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
disperse into new habitats – between catchments									
EF4: Support instream and floodplain productivity	x			x		x	x		x
EF5: Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands					x	x	x		x
EF6: Support groundwater conditions to sustain groundwater-dependent biota					x	x	x		x
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries		x	x	x	x	x	x		x

6.1.4 Water resource availability scenario: Wet - Improve

In wet conditions, the broad management priority is to promote improvements in condition, increases in populations and population expansion of environmental assets and ecosystems functions. In wet conditions, natural events may provide lateral and longitudinal connectivity as larger volume events occur. The priority objectives, and if relevant, refocused objectives for wet conditions are shown in Table 18.

	Broad water management priorities	Key management strategies for consideration
Wet	Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna Support high flow lateral connectivity and end of system flows Set aside water for use in drier years	Management strategies for achieving these broad priorities will remain limited by the volume of held and planned environmental water available: Consider short term versus longer term environmental need for stimulus flow Continue cooperative water with WaterNSW and CEWO to maximise outcomes from consumptive water deliveries and coordinated releases of held environmental water Consider carry over of held and planned environmental water for drier times

Table 18 Priority objectives and flow categories in a wet RAS

Priority LTWP objective	Flow categories: Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
NV1: Improve the extent and viability of non-woody vegetation communities occurring within channels		X	X						
NV2: Increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains					X	X	X		
NV3: Maintain the extent and improve the condition of river red gum communities closely fringing river channels						X	X		
NV4c: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – black box woodland						X	X	X	X
NV4d: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – coolibah woodland						X	X	X	X
NV4e: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – lignum shrublands					X	X	X	X	X
WB1: Maintain the number and type of waterbird species	X	X	X			X	X	X	X
WB2: Increase total waterbird abundance across all functional groups	X	X	X			X	X	X	X
WB3: Increase opportunities for non-colonial waterbird breeding					X	X	X	X	X
WB5: Maintain the extent and improve condition of waterbird habitats					X	X	X	X	X
NF1: No loss of native fish species			X	X	X	X	X	X	X
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish species				X					
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species				X	X				
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species				X					
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species				X					
NF6: A 25% increase in abundance of mature (harvestable sized) golden perch and Murray cod				X	X	X	X	X	X
NF7: Increase the prevalence and expand the population of key short to moderate-lived floodplain specialist native fish species into new areas				X	X	X	X		

Priority LTWP objective	Flow categories								
	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
NF8: Increase the prevalence and expand the population of key moderate to long-lived riverine specialist native fish species into new areas				x					
EF1: Provide and protect a diversity of refugia across the landscape	x		x	x					
EF2: Create quality instream, floodplain and wetland habitat	x		x					x	
EF3a: Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments					x	x	x		
EF3b: Provide movement and dispersal opportunities catchments for water-dependent biota to complete lifecycles and disperse into new habitats – between catchments					x	x	x		
EF4: Support instream and floodplain productivity	x			x		x	x	x	x
EF5: Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands					x	x	x	x	x
EF6: Support groundwater conditions to sustain groundwater-dependent biota							x	x	
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries		x	x	x	x	x	x	x	x

6.2 Water management during extreme conditions and ecologically critical water quality incidents

The quantity and quality of water are important drivers of ecological processes and contribute to the overall health of a waterway. Physical and chemical properties such as temperature, pH, electrical conductivity, algal blooms, heavy metals, pesticides, and dissolved oxygen affect the biology and ecology of aquatic plants and animals, especially when outside tolerable levels (Watson et al. 2009).

Insufficient water or water of poor quality can impact all water users, including water used for crops or livestock, recreational activities, and drinking. The responsibility for managing water to prevent or reduce the severity of water quality issues or during extreme conditions therefore lies with all users.

The effective management of water quality incidents relies on the timely access to monitoring information at key sites and the identification of risk factors. Whilst environmental water may be used in certain instances to provide refuge habitat, there is insufficient environmental water to avoid, mitigate or offset water quality issues in NSW rivers, nor is it the responsibility of environmental water managers to do so. The NSW Extreme Events Policy (NSW DoI 2018) provides a framework for making decisions during extreme events. It is designed to facilitate early intervention and delay the need to suspend certain water sharing arrangements.

Table 19 and Table 20 describe critical water quality incidents and extreme conditions respectively, and recommended management strategies for environmental water managers. In these two instances, the management priorities of water managers are to:

1. avoid irretrievable damage or catastrophic events
2. avoid critical loss of species, communities and ecosystems
3. protect critical refuges
4. maximise the environmental benefits of all water in the system.

For a more detailed description of the roles and responsibilities for each critical incident stage, please refer to the *Incident Response Guide for the NSW Border Rivers Surface Water WRPA* (NSW DPIE-Water 2019c).

Table 19 Priorities and strategies for managing water during extreme conditions

Extreme conditions description	Identifying features	Management strategies for achieving priorities
A critical drought and/or water shortage where only restricted town water supply, stock and domestic and other restricted high priority demands can be delivered	Very low to no natural or regulated flows resulting in disconnected pools Limited water held in storages Limited ability to deliver water for critical human needs WSP may be suspended	DPIE–BC will develop priority environmental water needs in consultation with the key stakeholders to ensure that these needs are considered in the management of all water Sustain critical in-channel refuge pools and core wetland areas Work with WaterNSW to protect, or if possible, provide very low flows or replenishment flows[32] to relieve severe unnatural prolonged dry periods and support suitable water quality in critical refuge pools[33]

Table 20 Priorities and strategies for managing water during critical water quality incidents

Critical water quality incident description	Identifying features	Management strategies for achieving priorities
Water quality does not meet Australian and New Zealand Guidelines for Fresh and Marine Water Quality, and is causing or is likely to cause significant impact on aquatic ecosystems[27]	Weir/refuge pools are stratified Water quality sampling and analysis demonstrates unfavourable conditions: • lack of dissolved oxygen[28] • unnatural change in temperature • unnatural change in pH	DPIE–BC will develop priority environmental water needs in consultation with the key stakeholders to ensure that these needs are considered in the management of all water

[27] Description of the types of water quality degradation, their main causes, and where they are likely to occur in the NSW Border Rivers catchment can be found in the *Water quality management plan for the NSW Border Rivers Water Resource Plan Area* (NSW DPIE-Water 2019b)
[28] Dissolved oxygen levels should be high enough to prevent the asphyxiation of respiring organisms, typically >4mg/L

	• unnatural change in salinity • excess suspended particulate matter[29] • elevated levels of nutrients[30] • chemical contamination[31]	Work with WaterNSW to protect, or if possible, provide baseflows and very low flows[32] to support suitable water quality in rivers and critical refuge pools[33] Sustain critical in-channel refuge pools and instream habitat Limit exceedance of maximum inter-event periods for floodplain inundating flows to reduce the risk of hypoxic blackwater events

[29] Excess particulate matter may be identified through poor optical properties of waterbodies, the smothering of benthic organisms, or the reduction in photosynthesis (which will inhibit primary production)
[30] May lead to nuisance growth of aquatic plants
[31] Diffuse or point source pollutants may have lethal or sub-lethal effects on aquatic biota
[32] As described in the relevant EWRs in the LTWP
[33] Natural flows, operational water, PEW and water quality allowances (where they exist) should be used in the first instance before considering the use of HEW

6.3 Protection of ecologically important flow categories in unregulated areas

In areas where water cannot be delivered through a regulating structure (unregulated streams), the only means of protecting environmentally important flows is through rules in the *Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources 2012*. Table 21 sets out potential management strategies that could be implemented in the WSPs to ensure important flows are protected during very dry through to wet times. Many of these strategies are consistent with the NSW macro planning approach for pools (NOW 2011) which recommends that water access rules for in-river and off-river (wetland) pools be reviewed and alternative rules considered where moderate or high risks to instream environmental values are identified. In order for any of these strategies to be successful, adequate compliance measures need to be in place, and in some areas, improved water metering and gauging is also required.

Table 21 Potential management strategies to protect ecologically important flows in unregulated rivers and creeks

Flow category	Potential management strategies	Most relevant resource availability scenarios
Cease-to-flow	Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate Consider reviewing cease-to-pump rules to reduce the length of cease-to-flow periods Consider implementing a first flush rule to ensure cease-to-flow periods are broken at ecologically relevant times and with events of sufficient magnitude to avoid adverse water quality incidents	Very dry Dry
Low flows and baseflows	Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate. Consider reviewing cease-to-pump rules to better protect low flows and baseflows, especially during dry times or ecologically important months	Very Dry Dry
Freshes	Consider implementing a first flush rule to protect freshes at ecologically relevant times Consider implementing extraction limits[34, 24]	Very dry Dry Moderate

[34] Individual daily extraction limits or total daily extraction limits for a particular flow class may be considered to reduce extraction pressure on ecologically important flow categories

7. Going forward

7.1 Cooperative arrangements

River operations to benefit the environment

All water, including natural events and consumptive water, has the potential to contribute to improving the ecological condition of rivers, wetlands and floodplains (MDBA 2014). It may be possible for controlled river flows for consumptive deliveries to meet many EWRs, without any contribution of held environmental water. Preliminary investigation indicates that this is the current case for several EWRs. Further analysis is required to determine the gaps in flow regime and EWRs that are not achieved through consumptive flows or current PEW.

In the Border Rivers the relatively small volume of held environmental water increases reliance on environmentally effective operating practices to maximise the achievement of EWRs. There may be cases where the losses used in river operations could be adjusted to improve rates of rise and fall, or in drier times block releases can be grouped to meet minimum event durations. In long block releases, as can occur in moderate to wet years, a lack of rising and falling river levels is environmentally detrimental as variability in flows is needed to cue certain ecological functions. In these water delivery patterns, flow rates may be within the range required to inundate required features, but ecological outcomes may be limited due to the absence of flow variability or rising and/or falling cues. River operations can limit or prevent the achievement of ecological outcomes from the delivery of consumptive water, resulting in greater volumes of held environmental water required to maintain the environment.

The actual impact of unsympathetic water delivery practices on achievement of the EWRs requires further investigation. Pending the findings, it may be possible for increased collaboration between DPIE and WaterNSW to strike a balance between operational efficiency and environmental effectiveness. This may require:

- adjustment of delivery of irrigation orders to more closely mimic natural flow events
- refinement of water releases from Pindari Dam to mimic natural rates of fall
- consideration of environmental needs in the management and release of weir pools, for example, using the end of season release of weir pools to achieve baseflows or ecologically guided timing of the Boomi River replenishment flow.

Cooperative water management arrangements

Managing water for the environment at the catchment scale requires cooperation between stakeholders. Such cooperative arrangements ensure that all water in the system can be managed in a coordinated way that maximises environmental outcomes, and that the receiving environment is accessible and supported by appropriate management.

Water for the environment in NSW is managed cooperatively by two government agencies: DPIE and CEWO. Together these agencies manage NSW and Commonwealth held environmental water portfolios (DPIE–BC and CEWO), and the WSP's that provide planned environmental water throughout the system (DPIE–Water).

This management is supported by the water rule set – the Water Sharing Plan as part of the Water Resources Plan, development and managed by DPIE–Water with implementation of river operations under licence to WaterNSW. DPIF is also integral to several processes, like fish passage and in-stream structures compliance.

Agencies should consider establishing a multi-agency, intergovernmental working group to collaboratively scope and to develop an ongoing program to implement the LTWP for the NSW Border Rivers.

Discussions are underway between government agencies and key stakeholders on the most appropriate mechanism to gain regional input and build regional ownership of environmental water management in the NSW Border Rivers. Any mechanism established will need to recognise the interactions between northern systems and function across catchments. Implementation of Northern 'Toolkit measures' may also be a focus of work at a regional level.

Strategic use of environmental water

One approach to achieving EWRs in regulated portions of the catchment is through the direct intervention, with release of held environmental water. Currently, NSW does not hold any water entitlements in the NSW Border Rivers. The use of environmental water holdings to achieve the LTWP objectives will require cooperation with CEWO. Coordinating deliveries of held environmental water with consumptive deliveries can help to achieve greater flow volumes from the use of all water. Such arrangements might enable larger in-channel and anabranch connecting flows that would not be possible with held environmental water alone. This may require establishing better channel sharing arrangements by permitting environmental water to build on consumptive or stock and domestic deliveries to achieve better flow regimes for the environment.

The 2009 Water Sharing Plan provides for planned environmental water. Of the various rules for planned environmental water, only the Pindari Stimulus Flow can be used with some discretion. The timing (between 1 August to 1 December), rate, volume and duration of the stimulus flow released is determined by DPIE-BC and DPIE-Water. Fish monitoring of recent environmental uses of the Pindari stimulus flow shows that benefits can extend the full length of Border Rivers. In 2017 the late August release contributed to a small fresh at Terrewah and a baseflow at Mungindi. It is possible that the stimulus flow has contributed to the improvement in EWRs since 2009. Further investigation is required to confirm these results and determine the extent to which the stimulus flow has contributed to recent positive fish monitoring results.

In the past, strategic use of planned environmental water coordinated with held environmental water has enabled desired flow events to be achieved while minimising the use of held environmental water. For example, activation of translucency rules during release of held environmental should contribute to volume released, forming part of the environmental event and reducing the volume of held environmental water required.

A broad strategy for environmental water use in the NSW Border Rivers should also seek to:

- **Create, protect and maintain refuge pools**

In wetter years and years with sufficient held environmental water, this will require higher flows in the lower part of the Macintyre River to create pools in the anabranches and fill low lying wetlands. This may require coordinated releases of held environmental and consumptive environmental water from Coolmunda, Glenlyon and Pindari Dams to achieve the flow heights needed. The establishment of these pools in wetter years and persistence of pools as conditions dry will result in off channel refuges being available in drier conditions.

In drier years, protecting and maintaining pools may involve the use of held environmental water from Glenlyon Dam to replenish and maintain pools in-channel along the Dumaresq River. Releases from Coolmunda, Glenlyon and Pindari dams may contribute to maintaining pools in the lower Macintyre River.

- **Maintain disconnection and reconnection of the anabranches**

To establish and maintain refugia in the anabranches, regular periods of hydrological connection during moderate years is required to build the condition of these off-channel habitats. It is also known that the productivity gains from these anabranches can support in-channel ecosystems in between larger flood events, with the productivity benefits extending into the Barwon-Darling. In addition, it is thought that the lower Macintyre River and associated waterways provides critical spawning habitat for Golden Perch and other flow pulse specialists, with this contributing significantly to fish populations through the length of the Barwon-Darling. The higher flows required to connect the anabranches, if permitted to continue to end of system flows, can provide meaningful connectivity to the Barwon-Darling.

- **Ensure regular small freshes below Pindari Dam**

Growing experience with the use of the Pindari Stimulus Flow indicates that it can provide a small fresh sufficient to promote fish recruitment. The Stimulus Flow provides an important opportunity to maintain EWRs that would otherwise be missing from the current flow regime. The protection of native fish and enhancement of recruitment outcomes would be improved by opening the seasonal window of use for the Stimulus Flow from August – December to all year round to ensure native fish and river health can be supported during potentially critical summer and autumn periods. There is growing evidence that protection of the Stimulus Flow beyond the confluence with Frazers Creek would provide significant environmental benefits to the Border Rivers and beyond. Options to limit the take of the Stimulus Flow management options are restricted to timing releases to avoid periods of irrigation demand.

The size of flow that can be released from Pindari Dam limits the creation of large fresh events below the dam. Where it is possible to coordinate the Stimulus Flow with other tributary inflows, such as from Frazers Creek and the upper Macintyre River, it may be possible to create a large fresh. The timing and pattern of flow pulses achieved will impact on the extent to which productivity gains can also be made from the breakup of filamentous algae.

In addition to the above interim broad strategy for the use of held and planned environmental water, the following strategies will significantly contribute to achievement of this LTWP:

- protect inflows from unregulated water sources, including preventing any further development of regulating structures such as dams and weirs
- investigate opportunities to improve environmental effectiveness of river operations
- prevent growth in floodplain harvesting, and ensure floodplain developments do not change flows to and around environmental assets
- ensure that supplementary flow events provide end of system connectivity to the Barwon-Darling, maintaining the natural pattern of sequential flooding as required to restore ecosystems in both Border Rivers and downstream catchments.

Complementary natural resource management

To achieve the watering required to support the LTWPs ecological objectives, it is necessary to ensure that priority environmental assets and functions on private land can be accessed for management. This includes arrangements with landholders for these assets to be inundated at the required timing, frequency and duration. Access to these assets to evaluate how they are responding to management over time is also vital.

Complementary management of water-dependent environmental assets will assist achievement of the LTWP objectives. Degradation of assets through poor land management practices and inadequate legislative protection for assets such as native vegetation, may undermine environmental water management. Cooperative arrangements between government agencies such as Local Land Services, private industry groups, individual landholders and community groups that ensure adequate stewardship of environmental assets are essential to the success of this LTWP. A priority action from this LTWP is to secure and formalise the continuity of these arrangements with relevant landholders and agencies.

Cooperative investment opportunities

There are many opportunities in the NSW Border Rivers catchment to improve the way the LTWP is implemented (Table 22). Some of these are through joint projects or investments.

Identification of key project partners, funding opportunities and subsequent implementation of projects to address these priorities would contribute significantly to the ecological objectives identified in this plan.

Through the life of the plan, DPIE will seek opportunities to build links and partnerships to support implementation of projects that will contribute to the ecological objectives of the LTWP.

Table 22 Forward workplan and investment opportunities to improve environmental outcomes in the NSW Border Rivers catchment

Project idea or investment	Actions required	Potential project partners
Support and guide implementation of the 'toolkit' measures	Contribute to identification, planning and assessment of relevant toolkit measures. This may include analysis of the expected impacts of various toolkit measures on the achievement of EWRs.	DPI Fisheries, DPIE-BC, DPIE-Water, WaterNSW, CEWO
Cooperative water management	Ongoing collaboration with CEWO, DPIE-Water, DPI Fisheries and WaterNSW to plan and implement releases of held and planned environmental water and monitoring in NSW Border Rivers.	CEWO, DPI Fisheries, DPIE-Water, WaterNSW
	Investigate opportunities to achieve EWRs with consumptive flows.	WaterNSW, irrigation community, DPI Fisheries, DPIE-BC
	Identify opportunities to achieve EWRs from refined river operations.	
	Identify and maintain rules in the WSP and current river operations that are contributing to current achievement of EWRs.	DPIE-Water, DPIE-BC
Complete hydrological assessment of the EWRs	Identify which EWRs are currently being met by PEW and/or HEW and the gaps in the flow regime. Determine which criteria of the unmet EWRs is limiting (flow volume, duration, timing and/or spell duration) to inform targeted management strategies.	DPIE-BC, DPI Fisheries
Risks and constraints	Determine impacts of risks and constraints on specific EWRs and identify targeted management options.	DPIE-BC, DPI Fisheries, DPIE-Water
Climate change impacts	Investigate and monitor impacts of climate change, such as: • How will the volume of water captured and stored be affected? • How will water quality be affected? • How will changes to rainfall intensity change the shape of natural flow events (e.g. duration, rates or rise and fall)? • Will overland flow paths change as our climate changes? • How will the persistence of floodplain inundation change? • How will climate change affect native and non-native plants and animals?	DPIE-BC, DPI Fisheries, DPIE-Water
Floodplain harvesting	Assess the impacts of floodplain harvesting on EWRs and condition of floodplain ecosystems	DPIE-BC, DPI Fisheries,

Project idea or investment	Actions required	Potential project partners
		DPIE-Water, CEWO
Prioritisation of ecological objectives and watering	Prioritise ecological objectives and watering based on the: • extent of environmental assets that can be watered using planned and held environmental water; • ecological demand for water (time since last event and interflow thresholds); • condition of environmental values and assets; and • Basin-scale importance of values and assets.	DPIE-BC, DPI Fisheries
Knowledge gaps in the LTWP	Identify any changes to the LTWP required in response to findings from research currently underway.	DPIE-BC
	Monitor resource condition and impacts of flows to further build an evidence base for watering actions and inform adaptive management of annual EWR priorities.	DPIE-BC, CEWO, DPI Fisheries, DPIE-Water
	Establish a process to identify and incorporate cultural values and assets.	DPIE-BC
Addressing knowledge gaps and further research into EWRs	There is growing evidence and knowledge of water-dependent ecosystems and environmental flows in the NSW Border Rivers. The Short Term Intervention Monitoring project for fish, funded by CEWO and undertaken by NSW and QLD, has made a significant contribution to informing the objectives and EWRs in this plan. As experience in environmental watering builds, and recently detected outcomes such as improved population resilience of Murray cod, silver perch spawning aggregation and improved populations of carp gudgeon can be linked to specific flow events, the evidence base for EWRs will strengthen. Other research such as habitat mapping in Dumaresq River has been used to inform the spatial prioritisation of objectives and EWRs and research undertaken in QLD to inform water resource plans has informed the definition of specific flow categories, such as the baseflow. To determine the most effective and efficient protection and restoration of EWRs, greater knowledge is needed on the underlying reasons to why particular EWRs are no longer occurring. It is not known if EWRs have not been achieved due to missing flow categories (flow thresholds not reached), inappropriate timing of flows or insufficient event durations. In the absence of such investigation, it is difficult to propose relevant and targeted management solutions to protect or improve the achievement of EWRs.	DPIE-BC, CEWO, DPI Fisheries, DPIE-Water
Environmental water advisory group	DPIE-BC has been working with local communities over many years through Environmental Water Advisory Groups (or EWAG). These groups draw on the expertise and experience of community members to help inform the decision-making process. The EWAGs may include water managers, recreational fishers, landholders, Aboriginal groups, independent scientists, local government representatives and a variety of partner agencies. The groups meet regularly to discuss proposed or upcoming	DPIE-BC

Project idea or investment	Actions required	Potential project partners
	watering events, any issues or concerns, the results of watering events and future opportunities. The groups help decide which sites to target for watering as well as the best timing to maximise outcomes for rivers and wetlands and the plants and animals that depend on them. They also help to develop strategies for various weather scenarios and provide advice on how to minimise disruption to farmers and communities. Opportunites to establish a Border Rivers EWAG should be investigated.	

7.2 Measuring progress

Monitoring, evaluating and reporting are integral components of adaptive water management. Monitoring how water moves through the landscape and how the environment responds informs ongoing improvements to planning and operational decisions. This information will also assist in determining whether the LTWP is meeting its objectives and targets, and will inform revisions of this LTWP.

The NSW Government works with key agencies (the CEWO, MDBA and Queensland Government) and the community in the Border Rivers catchment to implement monitoring programs that inform and improve water management.

A recent successful program was the study into native fish populations, their distributions and responsiveness to environmental water management between 2015 and 2018 in the catchment. This study was able to confirm the presence and distribution of Murray Cod, freshwater catfish, purple-spotted gudgeon and olive perchlet in key rivers across the catchment. The study also detected that recruitment of native fish species was lacking, which enabled adaptive management of environmental flows in 2017 to target and trigger productivity and fish recruitment to recover native fish populations in the Border Rivers catchment.

The Border Rivers NSW Monitoring, Environmental and Reporting Plan (NSW MERP) coordinates NSW Government agencies' approach to MER to consistently deliver on Basin Plan and NSW requirements and avoid duplication between agencies. The NSW MERP includes the objectives of this LTWP, along with the WSP and Water Quality Management plan objectives to investigate how water resource management protects and enhances native frog, native vegetation, waterbird and frog communities (where possible). Current MER activities in the NSW Border Rivers catchment include:

- hydrologic monitoring of low flows and flow variability at identified refuge assets using selected gauges and remote sensing
- condition and extent of native water-dependent vegetation communities using the Basin-wide vegetation stand condition tool
- waterbird species richness, abundance and breeding through the long-running Aerial Waterbird Surveys of Eastern Australia (from 1983 onwards)
- hydrologic monitoring of flow connectivity between and within water sources at selected gauges including cross-border flow connectivity between QLD and NSW
- MDBA Basin-scale Acoustic Telemetry Fish Tracking coordination project to record fish movement, migration and expanded distribution of key species
- annual fish community sampling

- water quality monitoring for several variables and multiple sites, including turbidity, total nitrogen, total phosphorus, dissolved oxygen and pH
- upland river and stream surveys for Booroolong frog populations.

Pending the provision of funding for expanded MER programs, other monitoring and research programs will be carried out in the NSW Border Rivers catchment through the 20-year life of this LTWP.

7.3 Review and update

This LTWP brings together the best available information from a range of community, traditional and scientific sources. To ensure the information remains relevant and up-to-date, this LTWP will be reviewed and updated no later than five years after it is implemented. Additional reviews may also be triggered by:

- accreditation or amendment to the WSP or WRP
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit adjustment
- new information arising from evaluating responses to environmental watering
- new ecological knowledge that is relevant to environmental watering
- improved understanding of the effects of climate change and its impacts on the objectives and environmental water requirements
- changes to the river operating environment or the removal of constraints that affect watering strategies
- material changes to river and wetland health, not considered within this LTWP.

Figure 17 **Dumaresq River, NSW Border Rivers. Photo L. Cameron and J. St Vincent Welch**

PART B: NSW Border Rivers planning units

8. Introduction

To manage the complexity of the NSW Border Rivers Water Resource Plan Area (WRPA), the NSW Border Rivers Long Term Water Plan (LTWP) has been divided into 15 planning units (Figure 18). Planning units delineate areas with a unique set of mechanisms for managing water for environmental outcomes.

Planning units in the NSW Border Rivers catchment have largely been derived from the water source boundaries in the *2012 Water Sharing Plan for the NSW Border Rivers Unregulated and Alluvial Water Sources*. A few adjustments were made to the water source boundaries to reflect various features of river operations and the landscape. Overall these adjustments aim to create planning units that are somewhat uniform within and distinct from other planning units.

- Campbells Creek and Camp Creek have been merged as there is only one gauge within this section on which to set EWRs.
- the Ottleys Creek water source has been split to recognise the differences between the Macintyre and Dumaresq Rivers in the lower northern part from the more ephemeral nature of Ottleys Creek. Mitchell landscapes were used to identify a relevant boundary.
- a number of new planning units were created downstream of the junction between the Macintyre and Dumaresq Rivers.
  - Planning unit 14 – Whalan Creek & Croppa Creek subcatchment distinguishes the unregulated and ephemeral Croppa and Whalan Creeks from the Macintyre and Boomi rivers. The trade boundary in the unregulated WSP was adopted.

The division created above Terrewah on the Macintyre River to form planning units 13. Macintyre River floodplain u/s of Boomi River and 15. Macintyre River and Boomi River floodplain, recognises the change in the geomorphology of the river channel that occurs in this section of river. Mitchell landscapes were again used to identify a relevant boundary.

For each planning unit the following local-scale information is provided:

- the location of priority environmental assets identified as part of plan's development
- the ecological values, including native fish, waterbird species, native vegetation communities and cultural water-dependant assets that occur within the planning unit's priority environmental assets
- environmental water requirements (EWRs) to support key ecological values and related LTWP objectives and targets that are presented for representative gauge/s in the planning unit

EWRs are defined for representative gauges in each planning unit. These EWRs describe the flow (or inundation regime, in the case of large lake systems) to support ecological objectives and targets for all priority environmental assets in each planning unit. A guide to interpreting EWRs is provided in Table 8 (Part A). The location of representative gauges is shown in Figure 15 (Part A).

EWRs may be met with discretionary environmental water, consumptive deliveries, operational flows (e.g. conveyance flows or bulk water transfers between storages), unregulated flows (i.e. tributary flows and spills from dams), or a combination of these.

The EWR tables bring together the catchment scale EWR details provided in Table 10 (Part A) and the flow thresholds in Table 9 (Part A) with the refined planning unit scale details, where relevant. EWRs that are irrelevant to the planning unit are not shown. For most EWRs any flow above the stated flow threshold is regarded as contributing to that EWR, for example, meaning that flows that are above bankfull or overbank are also considered as meeting the objectives associated with baseflow EWRs. The only exception is the small fresh 2 where only flows within the band specified will meet the objectives associated with small fresh 2.

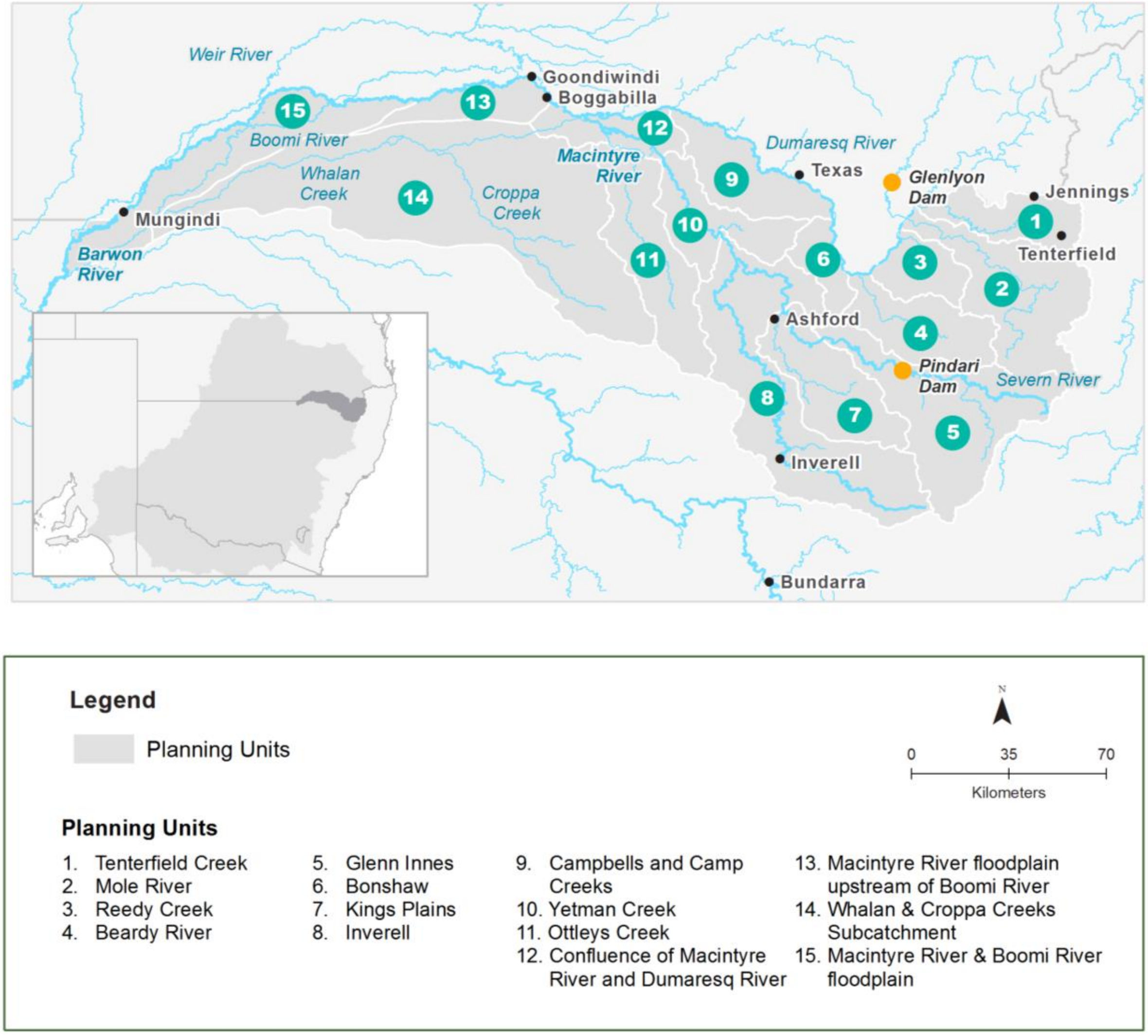
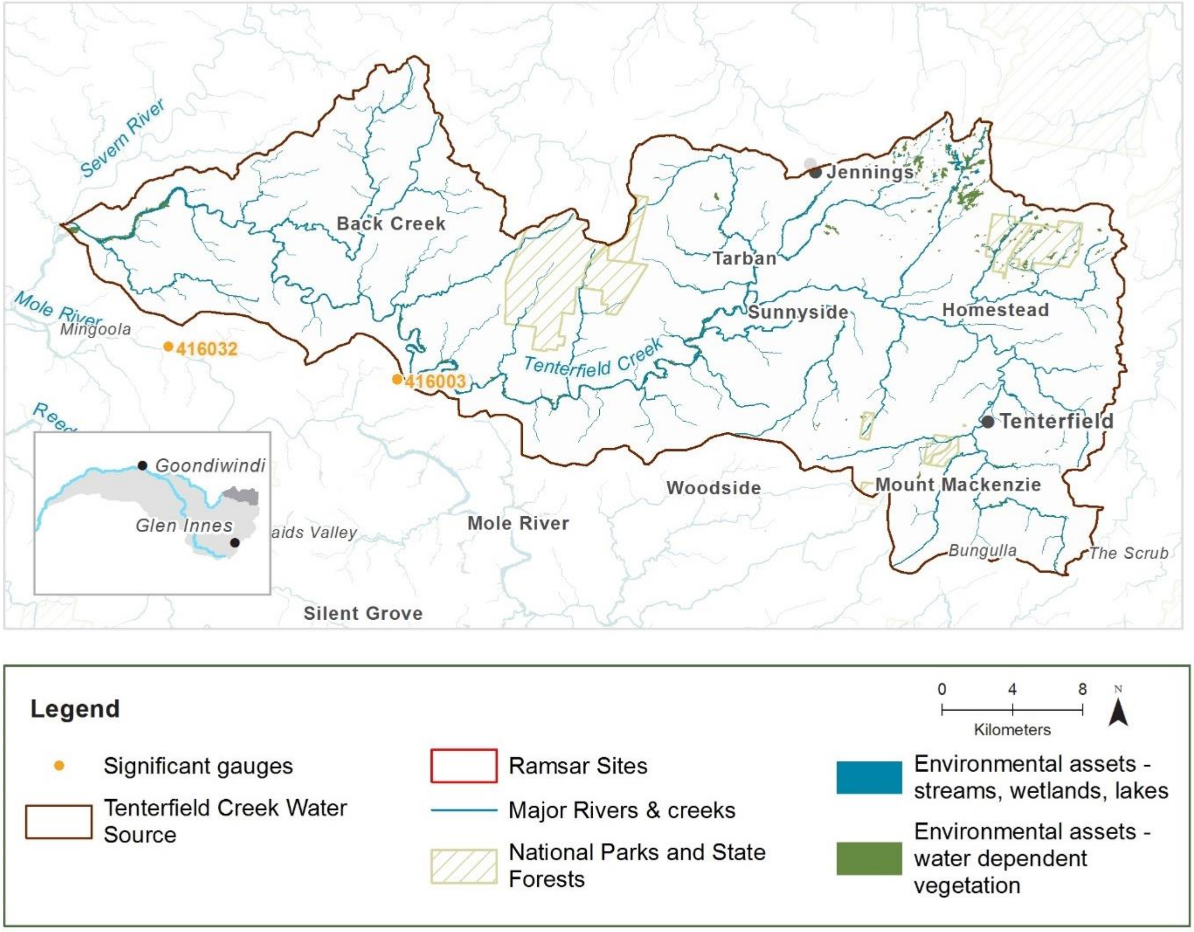


Figure 18 Planning units in the NSW Border Rivers LTWP

9. Planning unit report cards

9.1 Tenterfield Creek



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Tenterfield Creek
- Back Creek
- Garden Creek
- Horse Creek
- Gosling Swamp
- Green Gully
- Log Hut Creek
- Teatree Creek

- Instream habitat, including refuge pools, and fringing vegetation communities
- Unaltered flows contribute to persistence of refugia and a natural flow regime downstream. Any further loss or interruption of natural flows needs to be prevented to minimise ongoing decline in fish assets.

Native fish[35]

- golden perch X+Y
- olive perchlet (E) X+Y
- mountain galaxias X+Y

[35] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• spangled perch X • Murray cod (V) X+Y • freshwater catfish (E) X+Y • southern purple spotted gudgeon (E) X+Y • Darling River hardyhead X • Australian smelt X+Y • carp gudgeon X+Y • Murray-Darling rainbowfish X+Y • bony herring X • unspecked hardyhead X+Y
Waterbirds	38 water-dependent bird species recorded, including the listed[36] waterbird species: magpie goose (V), white-winged black tern (C,J), bar-tailed godwit (C,J,K) and Latham's snipe (J,K)
Native vegetation	7 water dependent Plant Community Types, with: • 951 ha of river red gum woodland • 408 ha of non-woody wetland • 225 ha of flood dependent shrubland wetland
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas: • modified trees

[36] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 23 Environmental watering requirements for Tenterfield Creek planning unit (Tenterfield creek at Clifton 416003)[37]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<2 ML/d		< 134 days			365 days above threshold per year[38] > 226 days above threshold in very dry years[39]
Baseflow	BF1	>2 ML/d					365 days above threshold each water year[38] > 292 days above threshold in very dry years[39] < 225 ML deficiency volume per year[40]
	BF2		September to March	Duration of timing window	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[41]
	BF3	2-20 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[41]
Small fresh	SF1	>20 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[41]
	SF2	20-450 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[41]
Large fresh	LF1	>450 ML/d	July to December	3 days	5 years in 10 (*50%*)	2 years	Rate of rise and fall[41]
	LF2		October to April	5 days	3 years in 10 (*30%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>3100 ML/d	Any time	1 day	5 years in 10 (*50%*)	4 years	
Overbank	OB1	>10000 ML/d	Any time	1 day	1-2 years in 10 (*15%*)	10 years	

[37] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

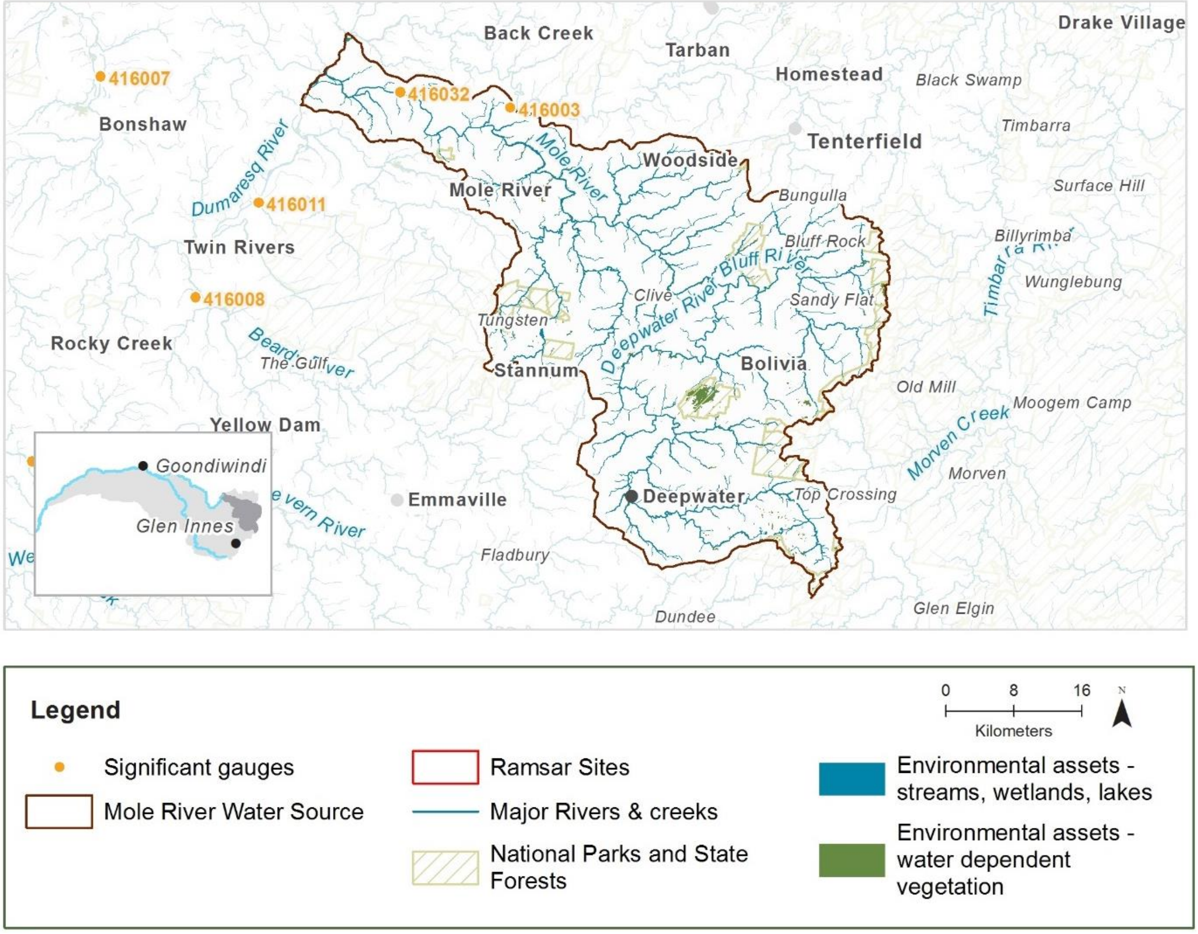
[38] This is set by the median number of days that flows were above threshold in each water year prior to 1997 (there is insufficient record pre-1976).

[39] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1997 (there is insufficient record pre-1976). There is no objective definition of a very dry year.

[40] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1997 (there is insufficient record pre-1976). The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[41] To be determined as part of a review of the NSW Border Rivers LTWP.

9.2 Mole River



Priority environmental assets
Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to): • Mole River • Deep Water River • Bluff River • Oaky Creek • Pyes Creek
• Instream habitat, including refuge pools, and non-woody wetland and fringing vegetation communities • Unaltered flows contribute to persistence of refugia and a natural flow regime downstream • Any further loss or interruption of natural flows needs to be prevented to minimise decline in fish assets

Native fish[42]	• golden perch X+Y • spangled perch X • Murray cod (V) X+Y • freshwater catfish (E) X+Y • bony herring Y • unspecked hardyhead X+Y	• southern purple spotted gudgeon (E) X+Y • olive perchlet (E) X+Y • Darling River hardyhead X • Australian smelt X+Y	• carp gudgeon X+Y • mountain galaxias X+Y • Murray-Darling rainbowfish X+Y
Waterbirds	23 water-dependent bird species recorded, including the listed[43] waterbird species: magpie goose (V), and Latham's snipe (J,K)		
Native vegetation	9 water-dependent Plant Community Types, with: • 2740 ha of river red gum woodland • 1021 ha of non-woody wetland • 1289 ha of flood dependent shrubland wetland		
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas: • modified trees		

[42] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

[43] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 24 Environmental watering requirements for Mole River planning unit (Mole River at Donaldson 416032[44])

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<5 ML/d		< 82 days			> 354 days above threshold per year[45] > 312 days above threshold in very dry years[46]
Very low flow	VL	>5 ML/d					> 354 days above threshold in each water year[45] > 312 days above threshold in very dry years[46]
Baseflow	BF1	>45 ML/d					> 283 days above threshold in each water year[45] > 178 days above threshold in very dry years[46] < 1456 ML deficiency volume per year[47]
	BF2		September to March	Duration of timing window	3 years in 10 (*30%*)	2 years	Rate of rise and fall[48]
	BF3	45-170 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[48]
Small fresh	SF1	>170 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[48]
	SF2	170-550 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[48]

44 Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

45 This is set by the median number of days that flows were above threshold in each water year prior to 1976

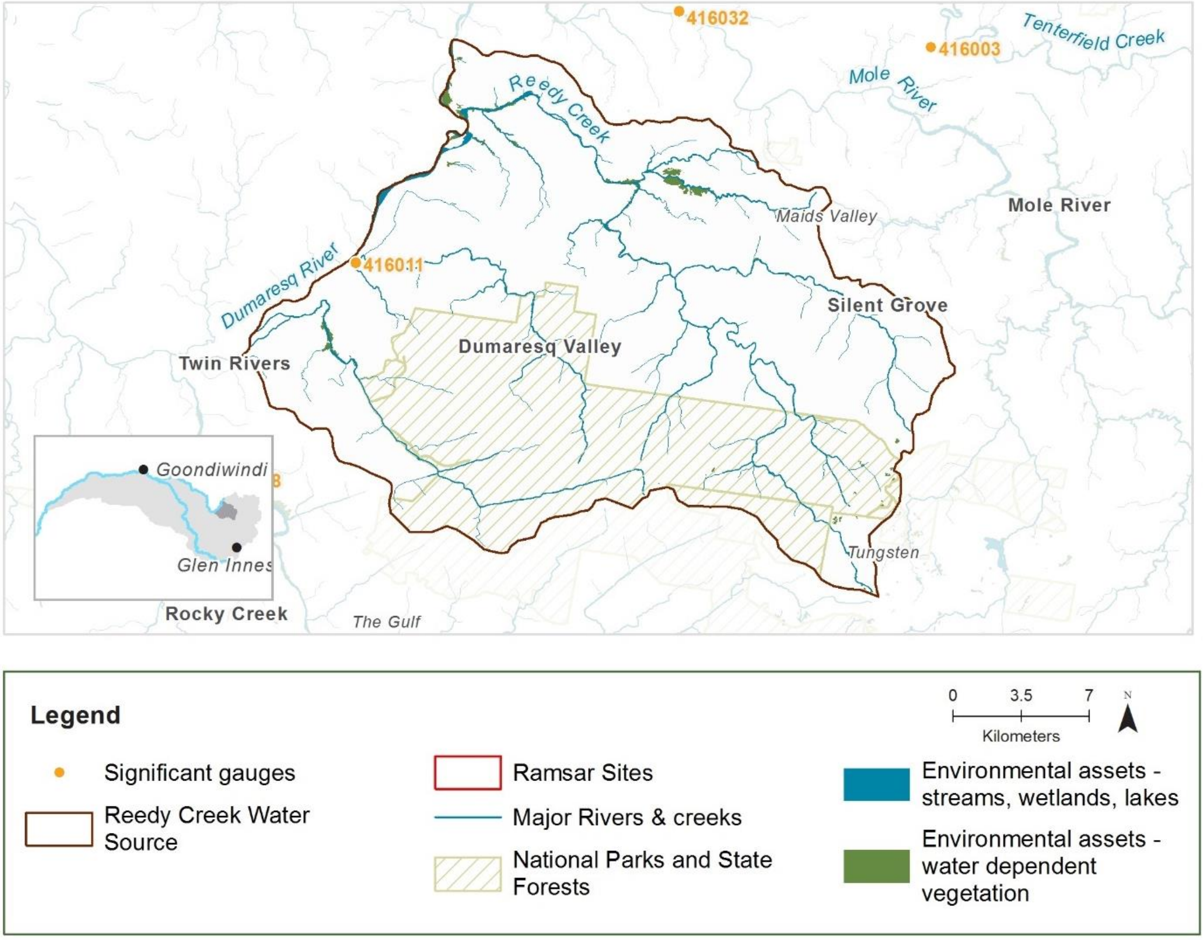
46 This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

47 This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

48 To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Large fresh	LF1	>550 ML/d	July to December	3 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[48]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>7100 ML/d	Any time	1 day	5 years in 10 (*50%*)	4 years	
Overbank	OB1	>16000 ML/d	Any time	1 day	2-3 in 10 years (*25%*)	4 years	

9.3 Reedy Creek



Priority environmental assets		
Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):		
• Reedy Creek • Gulf Creek	• Silent Grove Creek • Dingo Gully	• Black Swamp Gully • Bald Rock Creek
• Instream habitat in this section of the Dumaresq River includes instream vegetation and benches that may provide suitable spawning habitat and therefore require maintenance • Several connected wetlands off the Dumaresq River provide critical ecosystem function, wetland vegetation and low velocity fish spawning habitat • Unaltered flows contribute to persistence of refugia and a natural flow regime downstream		
Native fish[49]	• golden perch X+Y • spangled perch Y • Murray cod (V) X+Y	• southern purple spotted gudgeon (E) X+Y • mountain galaxias Y • Murray-Darling rainbowfish X+Y

[49] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• freshwater catfish (E) X+Y	• olive perchlet (E) Y • Australian smelt X+Y • carp gudgeon X+Y	• bony herring X+Y • unspecked hardyhead X+Y
Waterbirds	19 water-dependent bird species recorded.		
Native vegetation	4 water-dependent Plant Community Types, with: • 847 ha of river red gum woodland • 30 ha of non-woody wetland • 196 ha of flood dependent shrubland wetland		
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas • modified trees		

Table 25 Environmental watering requirements for Reedy Creek planning unit (Dumaresq River at Roseneath 416011[50])

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<1 ML/d		<148 days			365 days above threshold in per year[51] > 289 days above threshold in very dry years[52]
Very low flow	VL	>1 ML/d					> 365 days above threshold per year[51] > 289 days above threshold in very dry years[52]
Baseflow	BF1	>10 ML/d					> 365 days above threshold in per year[51] > 263 days above threshold in very dry years[52] < 432 ML deficiency volume per year[53]
	BF2		September to March	Duration of timing window	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[54]
	BF3	10-160 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[54]
Small fresh	SF1	>160 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[54]
	SF2	160-1050 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[54]
Large fresh	LF1	>1050 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[54]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only

[50] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

[51] This is set by the median number of days that flows were above threshold in each water year prior to 1976

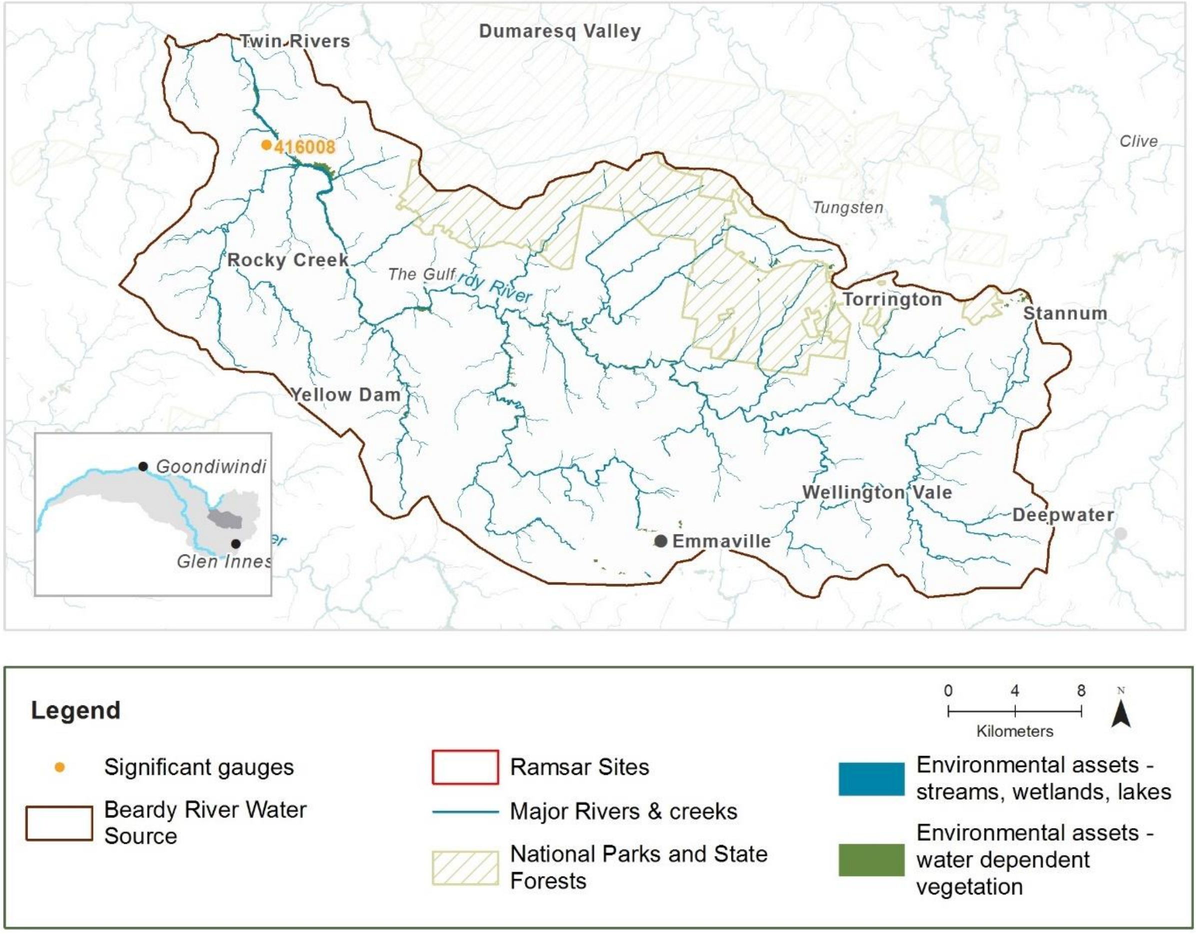
[52] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

[53] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[54] To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
	LF3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	
Bankfull	BK1	>6250 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
	BK2		October to April		1-2 events per year in 10 years (*100%)*	4 years	
Overbank	OB1	>19000 ML/d	Any time	1 day	2-3 in 10 years (25%)	4 years	

9.4 Beardy River



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Beardy River
- Rocky Creek
- Dry Creek
- Bark Hut Creek
- Highland Home Creek
- Vegetable Creek

- Instream habitat and fringing vegetation communities, including wetland vegetation
- Unaltered flows contribute to persistence of refugia and a natural flow regime downstream, any further loss or interruption of natural flows needs to be prevented to minimise further decline in fish assets
- Torrington SCA is the largest protected area in Border Rivers, providing an important biodiversity corridor

Native fish[55]	• golden perch Y • spangled perch X+Y • freshwater catfish (E) X+Y • southern purple spotted gudgeon (E) X+Y • olive perchlet (E) Y • Darling River hardyhead X • Australian smelt X+Y • carp gudgeon X+Y • mountain galaxias Y • Murray-Darling rainbowfish X+Y • bony herring Y • unspecked hardyhead Y
Waterbirds	23 water-dependent bird species recorded.
Native vegetation	7 water-dependent Plant Community Types, with: • 1227 ha of river red gum woodland • 77 ha of non-woody wetland • 25 ha of flood dependent shrubland wetland
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas • modified trees

[55] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

Table 26 Environmental watering requirements for Beardy River planning unit (Beardy River at Haystack 416008)[56]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<1 ML/d		< 172 days			> 286 days above threshold in per year[57] > 159 days above threshold in very dry years[58]
Baseflow	BF1	>1 ML/d					> 286 days above threshold in per year[57] > 159 days above threshold in very dry years[58] < 163ML deficiency volume per year[59]
	BF2		September to March	Duration of season	5-10 years in 10 (*75%*)	765 days	Rate of rise and fall[60]
	BF3	1-50 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[60]
Small fresh	SF1	>50 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[60]
	SF2	50-700 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[60]
Large fresh	LF1	>700 ML/d	July to December	3 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[60]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>4700 ML/d	Any time	1 day	5 years in 10 (*50%*)	4 years	
Overbank	OB1	>15200 ML/d	Any time	1 day	2-3 in 10 years (25%)	4 years	

[56] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

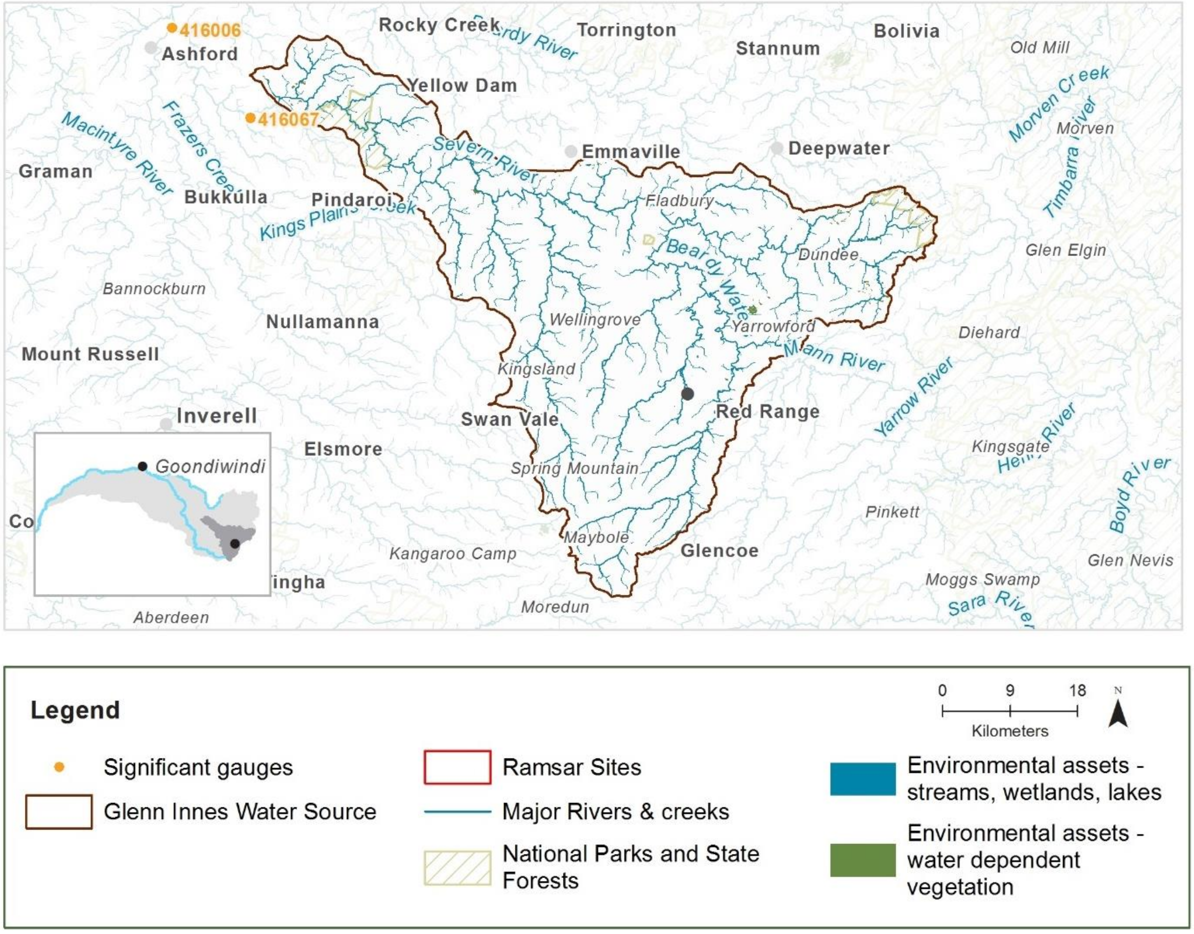
[57] This is set by the median number of days that flows were above threshold in each water year prior to 1976.

[58] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

[59] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[60] To be determined as part of a review of the NSW Border Rivers LTWP.

9.5 Glen Innes



Priority environmental assets			
Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):			
	• Severn River • Beardy Waters • Wellingrove Creek • Ironbark Creek	• Arrawatta Creek • Camerons Creek • Cam Creek	• Nine Mile Creek • Furracabad Creek • Reddestone Creek
• Instream habitat and fringing vegetation communities, including wetland vegetation • Unaltered flows contribute to persistence of refugia within the planning unit			
Native fish[61]	• golden perch X+Y • silver perch (CE) Y • Murray cod (V) X+Y	• freshwater catfish (E) X+Y	• carp gudgeon X+Y • mountain galaxias X+Y

[61] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• river blackfish [Y] • Australian smelt [Y]	• southern purple spotted gudgeon (E) [Y] • Darling River hardyhead [X]	• Murray-Darling rainbowfish [Y] • unspecked hardyhead [Y]
Waterbirds	43 water-dependent bird species recorded, including the listed[62] waterbird species: blue-billed duck (V), black-necked stork (E1), Latham's snipe (J,K), marsh sandpiper (C,J,K) and pectoral sandpiper (J,K)		
Native vegetation	9 water-dependent Plant Community Types, with: • 1430 ha of river red gum woodland • 612 ha of non-woody wetland • 630 ha of flood dependent shrubland wetland		
Cultural assets	• Aboriginal ceremony and dreaming • Aboriginal resource and gathering • modified trees • ceremonial ring • stone quarry		

[62] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 27 Environmental watering requirements for Glen Innes planning unit (Severn River at Strathbogie 416039)[63]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<2 ML/d		<98 days			365 days above threshold per year[64] > 184 days above threshold in very dry years[65]
Very low flow	VL	>2 ML/d					> 365 days above threshold per year[64] > 184 days above threshold in very dry years[65]
Baseflow	BF1	>20 ML/d					> 288 days above threshold in per year[64] > 102 days above threshold in very dry years[65] > 1242 ML deficiency volume in per year[66]
	BF2		September to March	Duration of season	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[67]
	BF3	20-110 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[67]
Small fresh	SF1	>110 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[67]
	SF2	110-560 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[67]
Large fresh	LF1	>560 ML/d	July to December	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[67]

[63] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

[64] This is set by the median number of days that flows were above threshold in each water year prior to 1997 as records at this gauge only commenced in 1974.

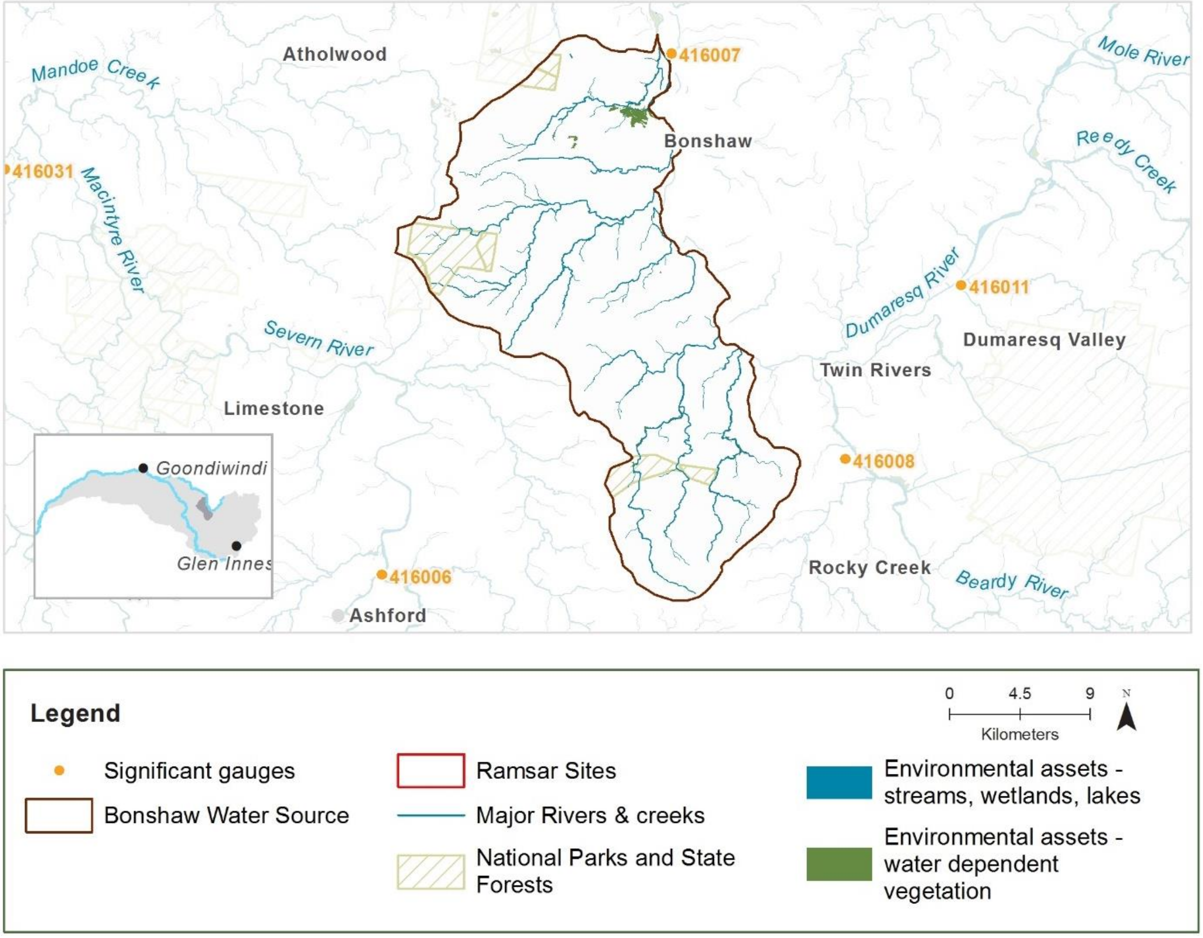
[65] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1997. There is no objective definition of a very dry year.

[66] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1997 (there is insufficient record pre-1976). The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[67] To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>3840 ML/d	Any time	1 day	5-10 years in 10 (*75%*)	4 years	
Overbank	OB1	>10000 ML/d	Any time	1 day	3 in 10 years (*30%*)	4 years	

9.6 Bonshaw



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Myall Creek
- Spring Creek
- Log Creek
- Crooked Creek
- Little Oaky Creek
- Boughyard Creek

- Instream habitat includes vegetation and benches that may provide suitable spawning habitat
- Several connected wetlands off the Dumaresq River provide critical ecosystem function, instream vegetation and low velocity fish spawning habitat
- Unaltered flows contribute to persistence of refugia and a natural flow regime downstream

Native fish[68]

- golden perch X+Y
- spangled perch X+Y
- Murray cod (V) X+Y
- freshwater catfish (E) X+Y
- olive perchlet (E) X+Y
- Australian smelt X+Y
- carp gudgeon X+Y
- bony herring X+Y
- flat-headed gudgeon Y
- Murray-Darling rainbowfish X+Y
- unspecked hardyhead X+Y

[68] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• southern purple spotted gudgeon (E) [X+Y]	
Waterbirds	19 water-dependent bird species recorded	
Native vegetation	7 water-dependent Plant Community Types, with: • 533 ha of river red gum woodland • 38 ha of non-woody wetland	• 417 ha of floodplain vegetation
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas	
	• Aboriginal ceremony and dreaming, artefacts	• modified tree
Other	Bonshaw Weir is a high priority for fish passage remediation	

Table 28 Environmental watering requirements for Bonshaw planning unit (Dumaresq River upstream Bonshaw 416007)[69]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<5 ML/d		<148 days			365 days above threshold per year[70] > 306 days above threshold in very dry years[71]
Very low flow	VL	>5 ML/d					> 365 days above threshold per year[70] > 306 days above threshold in very dry years[71]
Baseflow	BF1	>40 ML/d					> 364 days above threshold per year[70] > 192 days above threshold in very dry years[71] < 2601 ML deficiency volume per year[72]
	BF2		September to March	Duration of timing window	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[73]
	BF3	40-150 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[73]
Small fresh	SF1	>150 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[73]
	SF2	150-600 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[73]
Large fresh	LF1	>600 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[73]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>10000 ML/d	Any time	3 days	5-10 years in 10 (*50%*)	4 years	
	BK2		October to April	1 day	1-2 events per year in 10 years (*100%*)	4 years	
Overbank	OB1	>15000 ML/d	Any time	1 day	3 in 10 years (*30%*)	4 years	

[69] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

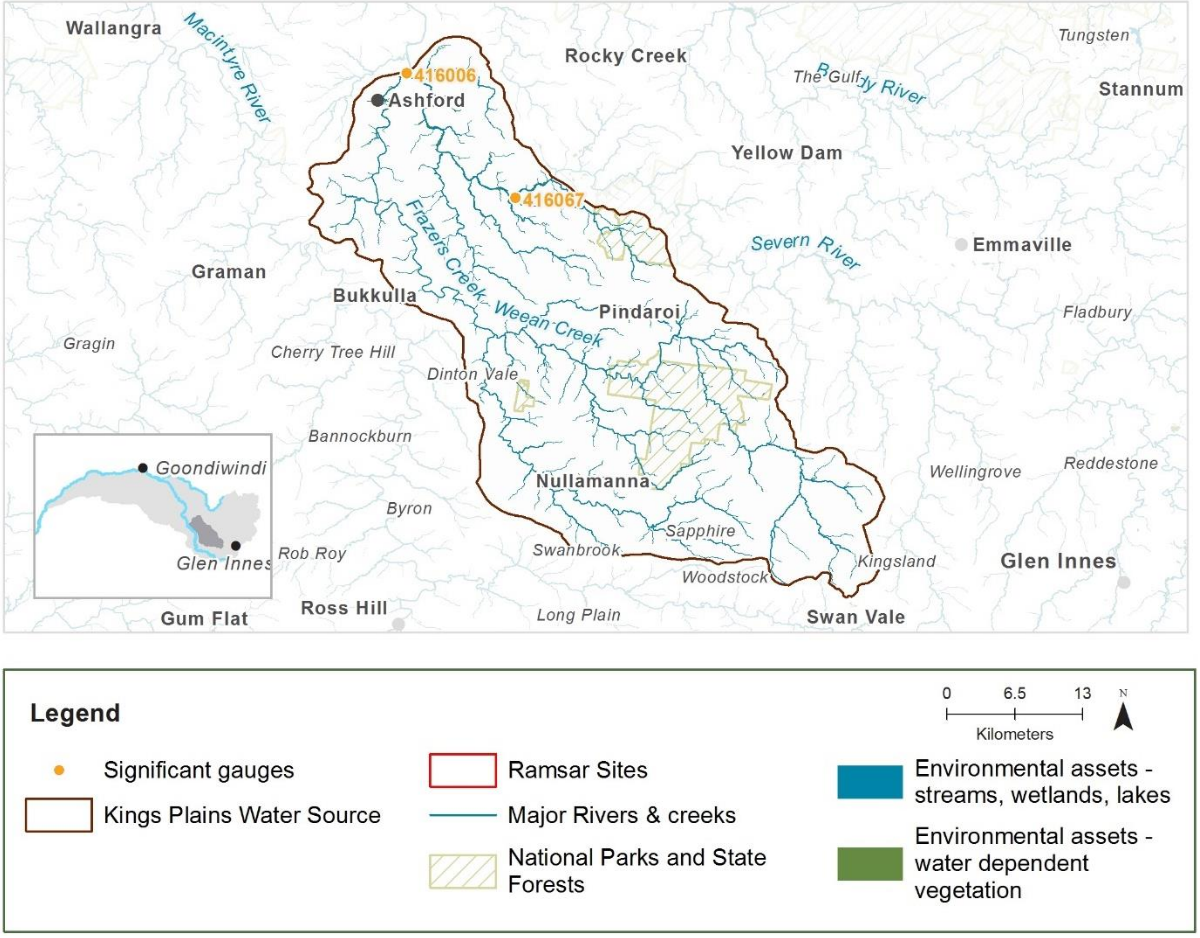
[70] This is set by the median number of days that flows were above threshold in each water year prior to 1976.

[71] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

[72] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[73] To be determined as part of a review of the NSW Border Rivers LTWP.

9.7 Kings Plain



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Severn River
- Frazers Creek
- Weean Creek
- Oaky Creek
- Dingo Creek
- Kings Plain Creek
- Pindari Creek
- Five Mile Creek

- Instream habitat of high conservation value with rare or rare and threatened river styles
- Fringing vegetation communities
- Unaltered flows contribute to persistence of refugia and a natural flow regime downstream
- Quality of aquatic ecosystems in Frazers Creek is high and requires conservation

Native fish[74]

- golden perch X
- silver perch (CE) X+Y
- southern purple spotted gudgeon (E) X+Y
- Murray-Darling rainbowfish X+Y

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[74] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• Murray cod (V) $^{X+Y}$ • freshwater catfish (E) $^{X+Y}$ • Australian smelt $^{X+Y}$ • carp gudgeon $^{X+Y}$ • unspecked hardyhead ^{Y} • mountain galaxias ^{Y}
Waterbirds	29 water-dependent bird species recorded, including the listed[75] waterbird species: brolga (V) and common greenshank (C,J,K)
Native vegetation	5 water-dependent Plant Community Types, with: • 1492 ha of river red gum woodland • 12 ha of non-woody wetland • 6 ha of flood dependent shrubland wetland
Cultural assets	• Aboriginal ceremony and dreaming • burial sites • modified tree

[75] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 29 Environmental watering requirements for Kings Plain planning unit (Severn River at Ashford 416006)[76]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<4 ML/d		<202 days			364 days above threshold per year[77] > 200 days above threshold in very dry years[78]
Very low flow	VL	>4 ML/d					> 364 days above threshold per year[77] > 200 days above threshold in very dry years[78]
Baseflow	BF1	>40 ML/d					> 253 days above threshold per year[77] > 127 days above threshold in very dry years[78] < 6869 ML deficiency volume per year[79]
	BF2		September to March	Duration of timing window	5 years in 10 (*50%*)	6 years	Rate of rise and fall[80]
	BF3	40-170 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[80]
Small fresh	SF1	>170 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[80]
	SF2	170-1520 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[80]
Large fresh	LF1	>1520 ML/d	July to December	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[80]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>8210 ML/d	Any time	1 day	5-10 years in 10 (*75%*)	4 years	
Overbank	OB1	>20000 ML/d	Any time	3 days	3 in 10 years (*30%*)	4 years	

[76] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

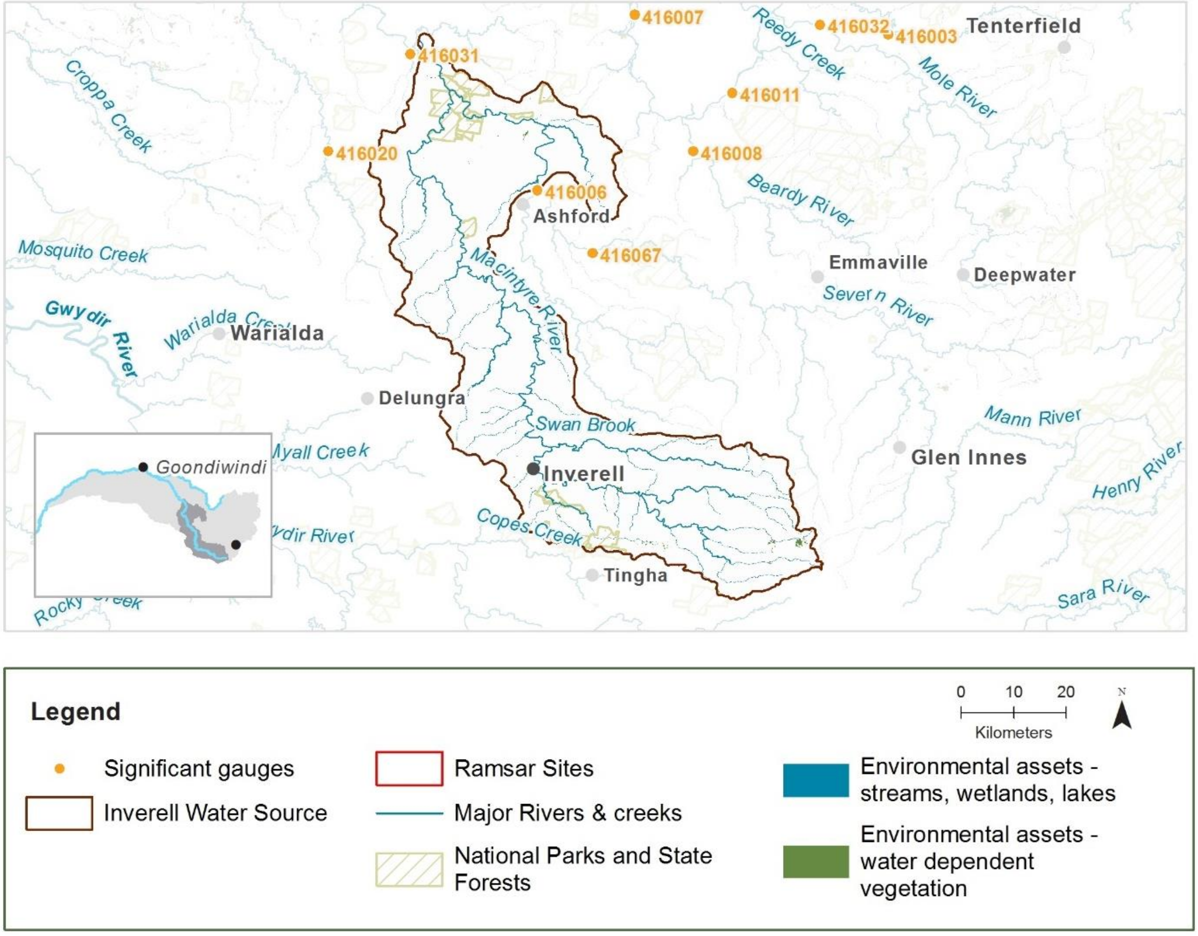
[77] This is set by the median number of days that flows were above cease to flow in each water year prior to 1976.

[78] This is set by the 5th percentile of the number of days above cease to flow in each water year prior to 1976. There is no objective definition of a very dry year.

[79] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[80] To be determined as part of a review of the NSW Border Rivers LTWP.

9.8 Inverell



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Macintyre River
- Myall Myall Creek
- Severn River
- Reedy Creek
- Swamp Creek
- Graman Creek
- Cherry Tree Creek
- Bannockburn Creek
- Swan Brook
- Middle Creek
- Rob Roy Creek
- Jessies Gully

- Macintyre River is a key movement corridor with high biodiversity, instream habitat and fringing vegetation communities, including a large area of river red gum, hydrodynamic diversity, occurrence of threatened species and dry period/drought refuge
- Unaltered flows contribute to persistence of refugia and a natural flow regime downstream

Native fish[81]

- golden perch X+Y
- silver perch (CE) X+Y
- spangled perch Y
- Murray cod (V) X+Y
- river blackfish Y
- freshwater catfish (E) X+Y
- Darling river hardyhead X
- Australian smelt X+Y
- carp gudgeon X+Y
- mountain galaxias X+Y

[81] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• flat-headed gudgeon Y	• southern purple spotted gudgeon (E) Y • olive perchlet (E) X • Murray-Darling rainbowfish X+Y	• bony herring Y • unspecked hardyhead X+Y
Waterbirds	40 water-dependent bird species recorded, including the listed[82] waterbird species: blue-billed duck (V) and Latham's snipe (J,K)		
Native vegetation	9 water-dependent Plant Community Types, with: • 2948 ha of river red gum woodland • 350 ha of non-woody wetland • 292 ha of flood dependent shrubland wetland		
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas: • Aboriginal ceremony and dreaming • modified trees		

[82] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 30 Environmental watering requirements for Inverell planning unit (Macintyre River at Ridgelands 416031)[83]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<20 ML/d		< 63 days			365 days above threshold per year[84] > 214 days above threshold in very dry years[85]
Very low flow	VL	>20 ML/d					> 365 days above threshold per year[84] > 214 days above threshold in very dry years[85]
Baseflow	BF1	>130 ML/d					> 223 days above threshold per year[84] > 127 days above threshold in very dry years[85] < 6470 ML deficiency volume per year[86]
	BF2		September to March	7 days	5-10 years in 10 (*75%*)	245 days	Rate of rise and fall[87]
	BF3	130-435 ML/d	September to April	10 days	Annual (*100%*)	2 years	Rate of rise and fall[87]
Small fresh	SF1	>435 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[87]
	SF2	435-2600 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[87]
Large fresh	LF1	>2600 ML/d	July to December	5 days	5 years in 10 (*50%*)	2 years	Rate of rise and fall[87]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>12000 ML/d	Any time	1 day	5-10 years in 10 (*75%*)	4 years	
Overbank	OB1	>30000 ML/d	Any time	3 days	3 in 10 years (*30%*)	4 years	

[83] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

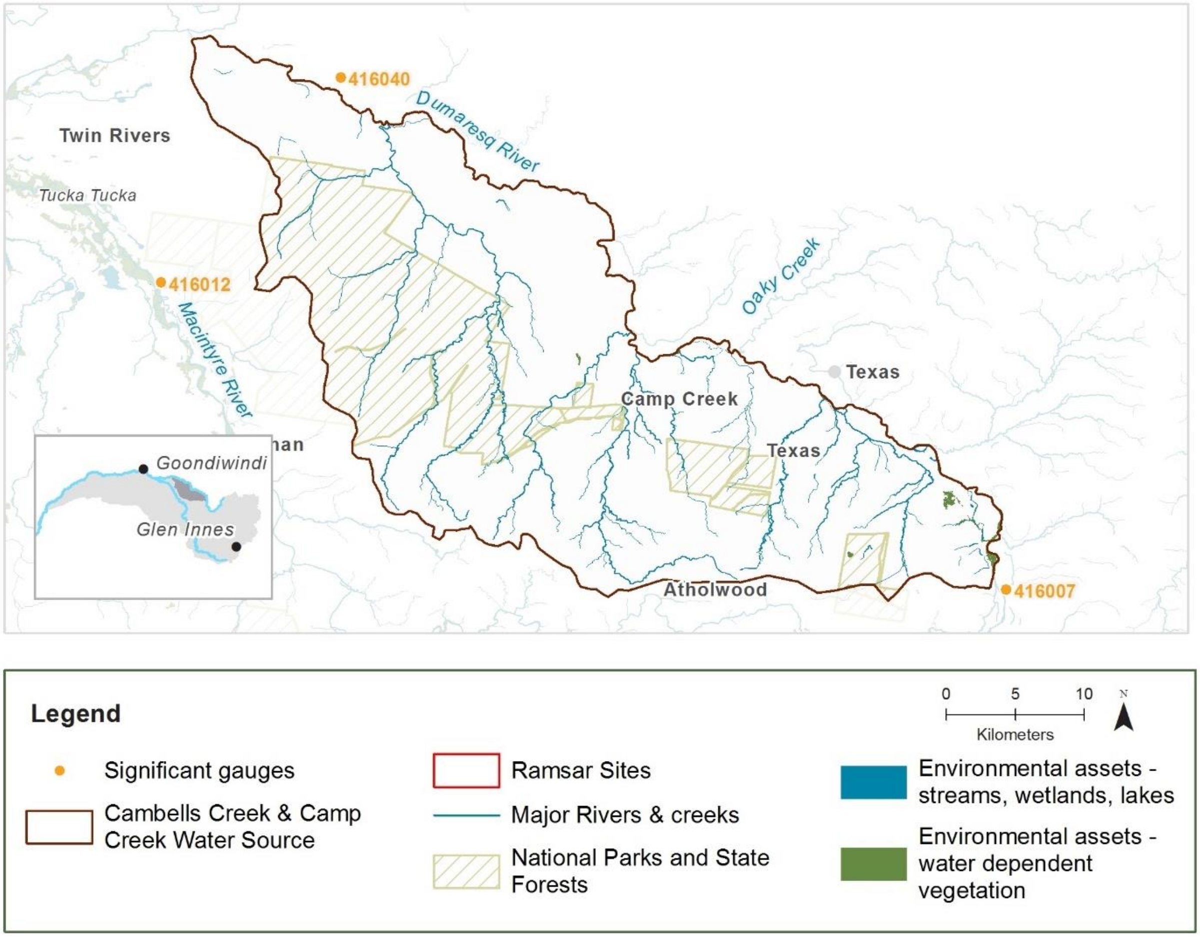
[84] This is set by the median number of days that flows were above threshold in each water year prior to 2009 as observed data only commences in 1997 at this gauge.

[85] This is set by the 5th percentile of the number of days above threshold in each water year prior to 2009 as observed data only commences in 1997 at this gauge. There is no objective definition of a very dry year.

[86] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 2009 (there is insufficient record pre-1976). The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[87] To be determined as part of a review of the NSW Border Rivers LTWP

9.9 Campbells Creek & Camp Creek



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Campbells Creek
- Camp Creek
- Browns Creek
- Texas Creek
- Stony (Middle) Creek

- Instream habitat in this part of the Dumaresq River is of greater complexity, quality and drought refugia
- Connected wetlands provide critical productivity, wetland vegetation and low velocity fish spawning habitat
- Unaltered flows contribute to persistence of refugia and a natural flow regime downstream

Native fish[88]

- golden perch X+Y
- spangled perch X+Y
- Murray cod (V) X+Y
- southern purple spotted gudgeon (E) Y
- olive perchlet (E) X+Y
- carp gudgeon X+Y
- flat-headed gudgeon Y

[88] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• freshwater catfish (E) X+Y • bony herring X+Y • Darling river hardyhead X • Australian smelt X+Y • Murray-Darling rainbowfish X+Y • unspecked hardyhead X+Y
Waterbirds	29 water-dependent bird species recorded, including the listed[89] waterbird species: black-necked stork (E)
Native vegetation	6 water-dependent Plant Community Types including the TSC Act listed Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions • 1238 ha of river red gum woodland • 60 ha of non-woody wetland • 617 ha of floodplain vegetation
Cultural assets	• Aboriginal ceremony and dreaming, artefacts, conflict • habitation structure • waterhole • modified tree
Other	Glenarbon Weir is a high priority for fish passage remediation

[89] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 31 Environmental watering requirements for Campbells Creek & Camp Creek planning unit (Dumaresq River at Glenarbon 416040)[90]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<10 ML/d		< 114 days			> 326 days above threshold per year[91] > 168 days above threshold in very dry years[92]
Very low flow	VL	>10 ML/d					> 326 days above threshold per year[91] > 168 days above threshold in very dry years[92]
Baseflow	BF1	>80 ML/d					> 196 days above threshold per year[91] > 65 days above threshold in very dry years[92] < 8334 ML deficiency volume per year[93]
	BF2		September to March	Duration of timing window	5 years in 10 (*50%*)	3 years	Rate of rise and fall[94]
Small fresh	SF1	>150 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[94]
	SF2	150-1300 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[94]
Large fresh	LF1	>1300 ML/d	July to December	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[94]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
	LF3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	Rate of rise and fall[94]
Bankfull	BK1	>8500 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
Overbank	OB1	>25000 ML/d	Any time	1 day	3 in 10 years (*30%*)	4 years	

[90] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

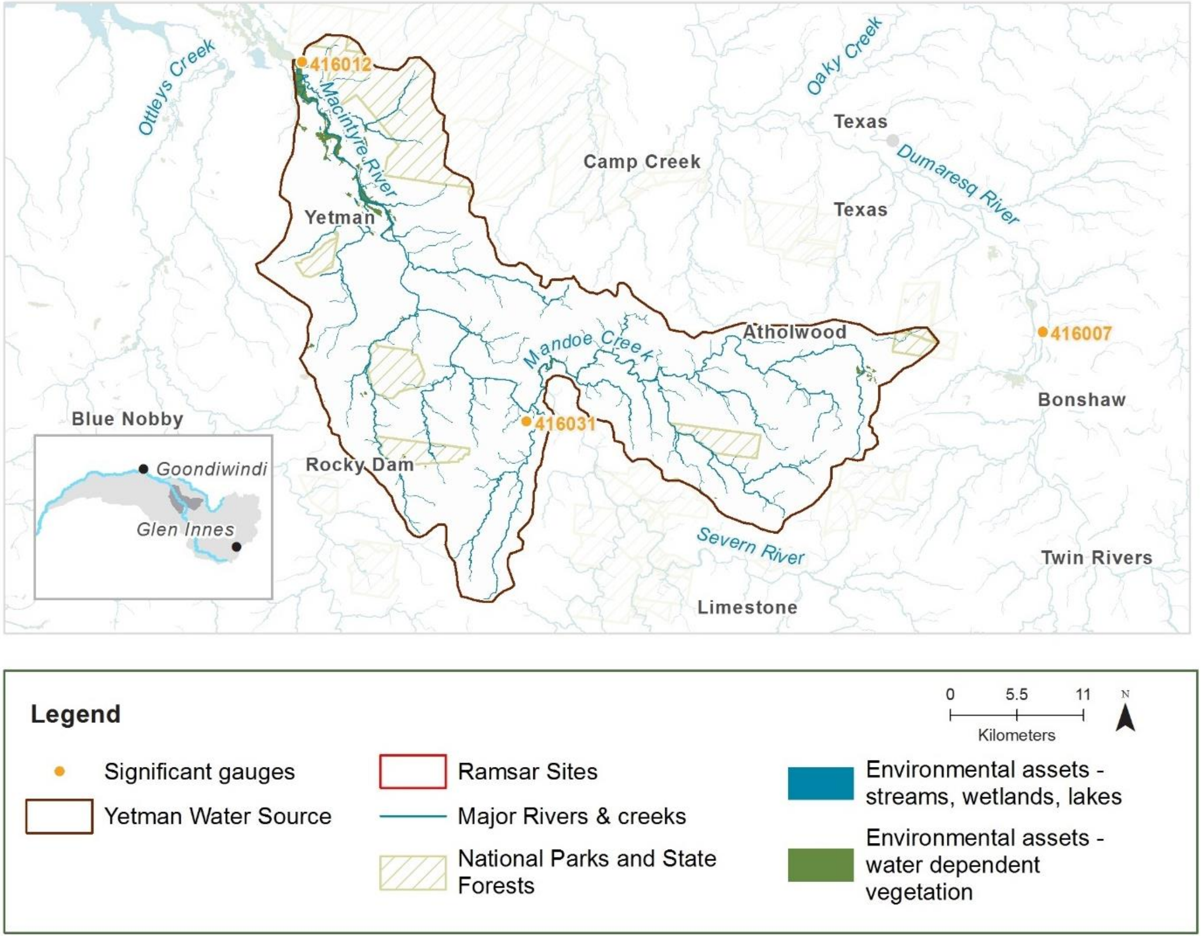
[91] This is set by the median number of days that flows were above threshold in each water year prior to 2009, due to insufficient record pre 1976.

[92] This is set by the 5th percentile of the number of days above threshold in each water year prior to 2009. There is no objective definition of a very dry year.

[93] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 2009. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[94] To be determined as part of a review of the NSW Border Rivers LTWP.

9.10 Yetman



Priority environmental assets			
Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):			
	• Macintyre River • Simpsons Creek • Morell Creek • Oaky Creek	• Reedy Creek • Pine Creek • Back Creek • Ena Creek	• Bunal Creek • Branch Creek • Mandoe Creek
• Macintyre River is a key movement corridor with high biodiversity, hydrodynamic diversity, occurrence of threatened species and dry period/drought refuge • Instream habitat and fringing vegetation communities, with water dependent listed PCTs • Rare or rare and threatened river styles requiring protection from hydrological stress			
Native fish[95]	• golden perch X+Y • silver perch (CE) X+Y	• freshwater catfish (E) X+Y	• carp gudgeon X+Y • flat-headed gudgeon Y

[95] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• spangled perch X+Y • Murray cod (V) X+Y • bony herring X+Y	• southern purple spotted gudgeon (E) Y • olive perchlet (E) X+Y • Australian smelt X+Y	• Murray-Darling rainbowfish X+Y • unspecked hardyhead X+Y
Waterbirds	24 water-dependent bird species recorded, including the listed[96] waterbird species: black necked stork (E1)		
Native vegetation	9 water-dependent Plant Community Types, including the TSC Act listed Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion • 1485 ha of river red gum woodland • 105 ha of non-woody wetland • 299 ha of floodplain vegetation • 24 ha of coolibah		
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas: • grinding grooves • modified trees		

[96] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 32 Environmental watering requirements for Yetman planning unit (Macintyre at Holdfast 416012)[97]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<10 ML/d		< 135 days			365 days above threshold per year[98] > 243 days above threshold in very dry years[99]
Very low flow	VL	>10 ML/d					> 365 days above threshold per year[98] > 243 days above threshold in very dry years[99]
Baseflow	BF1	>260 ML/d					> 287 days above threshold per year[98] > 230 days above threshold in very dry years[99] < 9569 ML deficiency volume per year[100]
	BF2		September to March	Duration of timing window	5 years in 10 (*50%*)	2 years	Rate of rise and fall[101]
Small fresh	SF1	>400 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[101]
	SF2	400-3000 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[101]
Large fresh	LF1	>3000 ML/d	July to December	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[101]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>10000 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
Overbank	OB1	>45000 ML/d	Any time	3 days	3 in 10 years (*30%*)	4 years	

[97] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

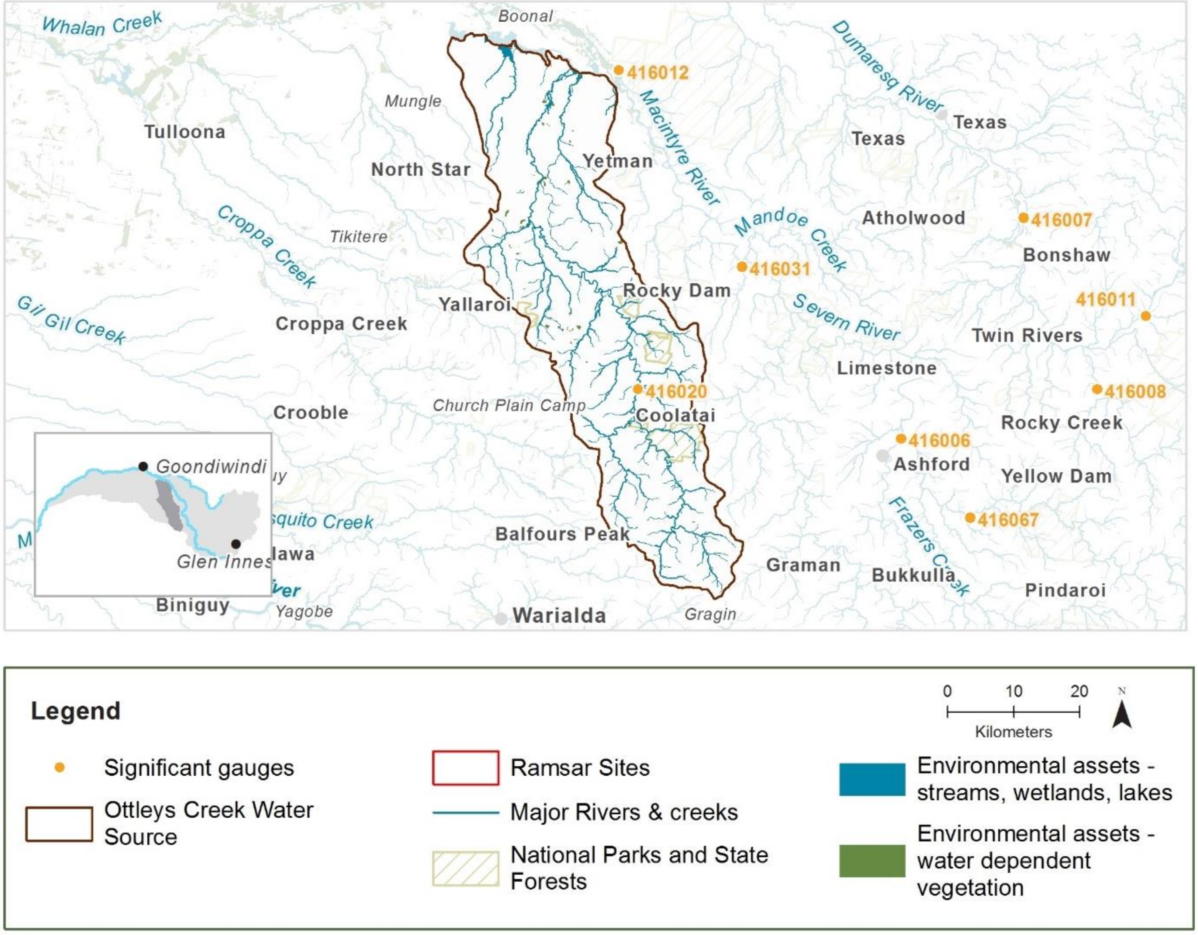
[98] This is set by the median number of days that flows were above threshold in each water year prior to 1976.

[99] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

[100] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[101] To be determined as part of a review of the NSW Border Rivers LTWP.

9.11 Ottleys Creek



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Ottleys Creek
- Seereys Creek
- Long Plain Creek
- Scrubby Creek
- Jardines Creek
- Middle Creek
- Flaggy Creek
- Blue Nobby Creek
- Seereys Creek

- Ephemeral flows provide significant pulses of productivity to downstream areas
- Unaltered flows contribute to persistence of refugia and a natural flow regime downstream
- Water dependent listed PCTs

Native fish[102]

- golden perch Y
- spangled perch X+Y
- Murray cod (V) Y
- freshwater catfish (E) Y
- southern purple spotted gudgeon (E) Y
- Australian smelt Y
- carp gudgeon Y
- flat-headed gudgeon Y
- Murray-Darling rainbowfish Y
- bony herring Y
- unspecked hardyhead Y

[102] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

Waterbirds	22 water-dependent bird species recorded.
Native vegetation	9 water-dependent Plant Community Types, including the TSC Act listed Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion and Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions • 839 ha of river red gum woodland • 254 ha of non-woody wetland • 1188 ha of floodplain vegetation • 523 ha of coolibah
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas: • modified trees

Table 33 Environmental watering requirements for Ottleys Creek planning unit (Ottleys Creek at Coolatai 416020)[103]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<55 ML/d		< 1398 days[104]			> 18 days above threshold per year[105] > 6 days above threshold in very dry years[106]
Bankfull	BK1	>400 ML/d	Any time	3 days	3 years in 10 (*30%*)	4 years	
Anabranch connection	AC1	>400 ML/d				439 days	> 6 days above threshold per year[105] > 1 day above threshold in very dry years[106]

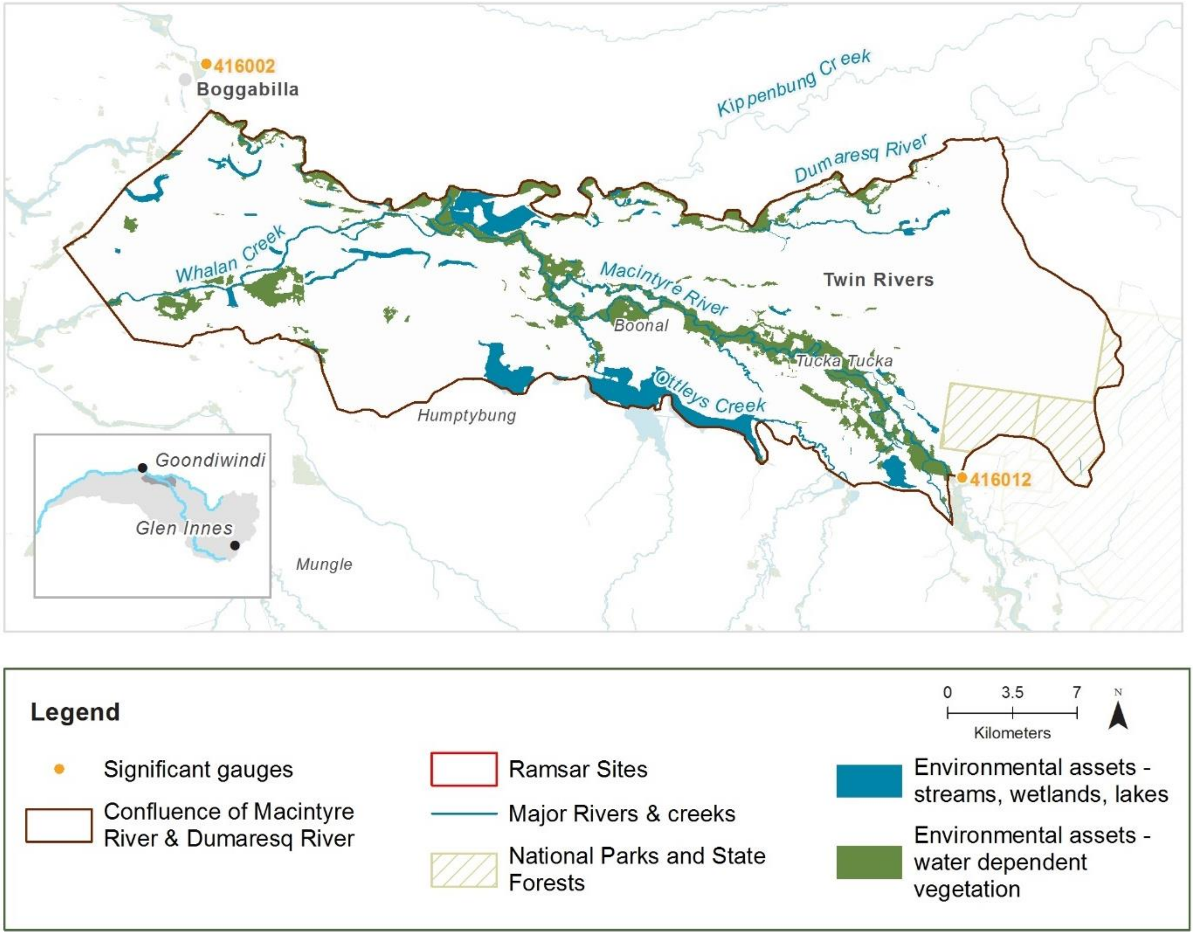
[103] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

[104] Event based criteria require a defined end of event. End of cease to flow usually requires 5 days of baseflow. For this gauge, 5 days of flows greater than 75ML/d is used.

[105] This is set by the median number of days that flows were above threshold in each water year prior to 1976

[106] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

9.12 Confluence of Macintyre River and Dumaresq River



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Macintyre River
- Dumaresq River
- Tucka Tucka Creek
- Malgarai Lagoon
- Whalan Creek
- Borah Creek
- Maynes Lagoon
- Ottleys Creek
- Seereys Creek
- Bora Wetland
- Gobbooyallana Lagoon

- Macintyre River is a key movement corridor and has high biodiversity, hydrodynamic diversity, occurrence of threatened species and dry period/drought refuge
- Large areas of river red gum, coolibah and lignum and water dependent listed PCTs
- Significant area of vital habitat providing drought refuge and rare river styles

Native fish[107]

- golden perch X+Y
- silver perch (CE) Y
- freshwater catfish (E) X+Y
- carp gudgeon X+Y

[107] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

	• spangled perch X+Y • Murray cod (V) X+Y	• southern purple spotted gudgeon (E) Y • olive perchlet (E) X+Y • Australian smelt X+Y	• Murray-Darling rainbowfish X+Y • bony herring X+Y • unspecked hardyhead X+Y
Waterbirds	41 water-dependent bird species recorded, including the listed[108] waterbird species: freckled duck (V) and Latham's snipe (J,K)		
Native vegetation	12 water-dependent Plant Community Types, including the TSC Act listed Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion and Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions • 3419 ha of river red gum woodland • 790 ha of coolibah • 1222 ha of floodplain vegetation • 240 ha of non-woody wetland • 740 ha of lignum		
Cultural assets	Boobera Lagoon has significant Aboriginal heritage value. The Gamilaraay (Kamilaroi) people believe that the lagoon is the resting place of the rainbow serpent Garriya. The site is estimated to contain millions of stone artefacts as well as scar trees and canoe trees. • two culturally significant wetlands • Aboriginal resource and gathering, artefacts • Aboriginal ceremony and dreaming • artefacts, shells • modified trees		
Other	Cunningham Weir is a high priority for fish passage remediation		

[108] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 34 Environmental watering requirements for Confluence of Macintyre River and Dumaresq River planning unit (Macintyre at Boggabilla 416002)[109]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<25 ML/d		< 230 days			> 347 days above threshold per year[110] > 278 days above threshold in very dry years[111]
Very low flow	VL	>25 ML/d					> 347 days above threshold per year[110] > 278 days above threshold in very dry years[111]
Baseflow	BF1	>230 ML/d					> 217 days above threshold per year[110] > 70 days above threshold in very dry years[111] < 59913 ML deficiency volume per year[112]
	BF2		September to March	Duration of timing window	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[113]
Small fresh	SF1	>840 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[113]
	SF2	840-3100 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[113]
Large fresh	LF1	>3100 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[113]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only

[109] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

[110] This is set by the median number of days that flows were above threshold in each water year prior to 1976.

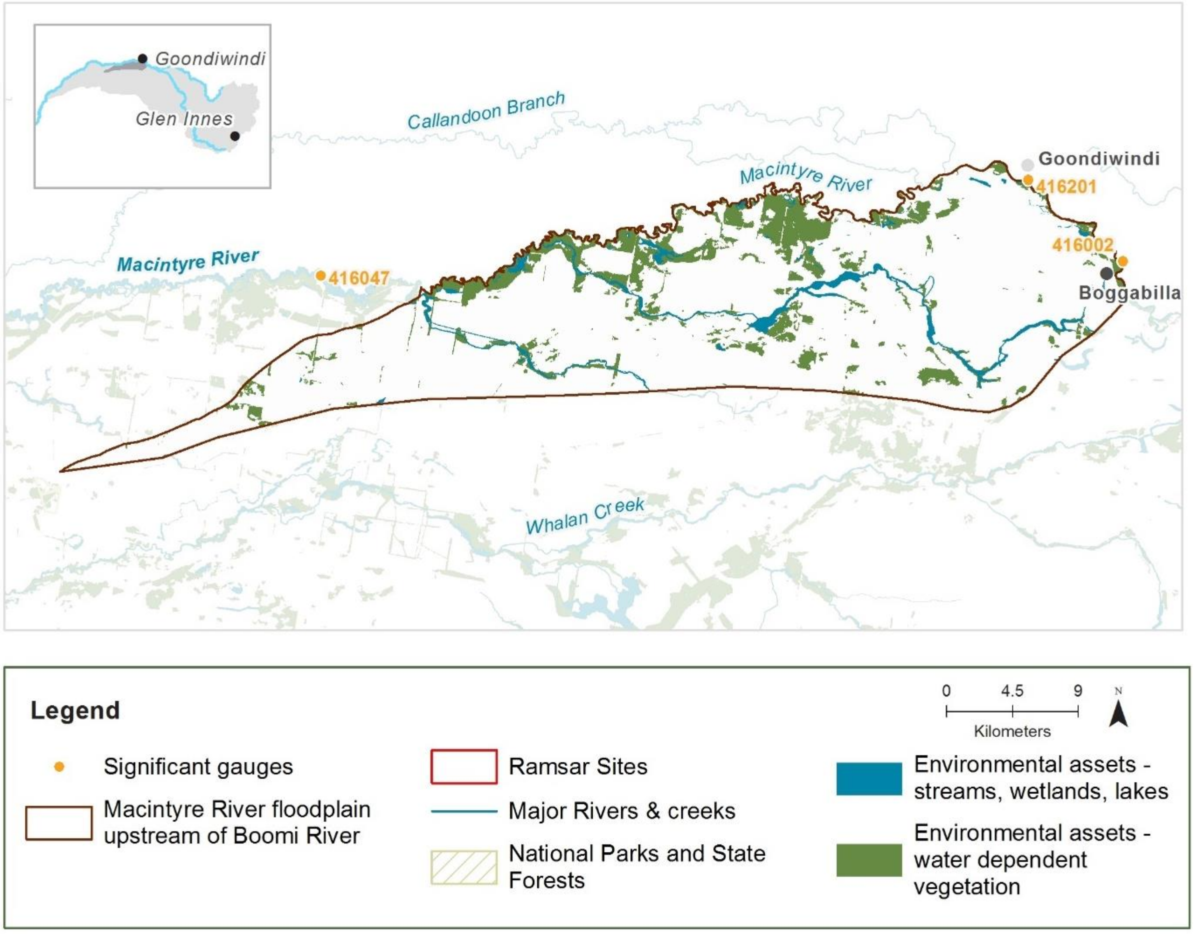
[111] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

[112] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[113] To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
	LF3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	Rate of rise and fall[113]
Bankfull	BK1	>10900 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
	BK2		October to April		1-2 events per year in 10 years (*100%)*	4 years	
	BK3		October to April	10 days	2 years in 10 (*20%*)	7 years	
Anabranch connection	AC1	>10900 ML/d				373 days	> 13 days above threshold per year[110] > 2 days above threshold in very dry years[111]
	AC2		Any time	4 days		7 years	Historically, the 95th percentile of spell duration between events of 4 or more days duration was 718 days.
Overbank	OB1	>21400 ML/d	Any time	3 days	3 in 10 years (*30%*)	4 years	
	OB2	>60000 ML/d	Any time		1-1.4 in 10 years (*12%*)		

9.13 Macintyre River floodplain upstream of Boomi River



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Macintyre River
- Boobera Watercourse
- Boobera Lagoon
- Morella Watercourse
- Pungbougal Lagoon
- Poopoopirby Lagoon
- Uathery Lagoon

- Significant anabranches with billabongs and wetlands provide drought refugia and productivity pulses between floods that maintains ecosystem functions
- Billabongs and wetlands are known to provide habitat variability for a range of water dependent species, including protected waterbirds such as brolga and black-necked stork
- Large areas of river red gum, coolibah, floodplain vegetation, lignum and water dependent listed PCTs
- Macintyre River and floodplain lagoons are a key movement corridor with high biodiversity, hydrodynamic diversity, threatened species and dry period/drought refuge
- Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon is a wetland of national importance, a naturally occurring permanent waterhole and one of the most important Aboriginal places in eastern Australia

Native fish[114]	• golden perch X+Y • silver perch (CE) Y • spangled perch X+Y • Murray cod (V) X+Y • freshwater catfish (E) X+Y • southern purple spotted gudgeon (E) Y • olive perchlet (E) X+Y • Australian smelt X+Y • carp gudgeon X+Y • Murray-Darling rainbowfish X+Y • bony herring X+Y • unspecked hardyhead X+Y
Waterbirds	45 water-dependent bird species recorded, including the listed[115] waterbird species: black-necked stork (E1), brolga (V), Australian gull-billed tern (C), Latham's snipe (J,K), marsh sandpiper (C,J,K) and sharp-tailed sandpiper (C,J,K)
Native vegetation	12 water-dependent Plant Community Types, including the TSC Act listed Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions • 1359 ha of river red gum woodland • 4724 ha of coolibah • 2536 ha of floodplain vegetation • 107 ha of non-woody wetland • 428 ha of lignum
Cultural assets	Significant cultural history but with limited recorded sites in water dependent areas: • Aboriginal ceremony and dreaming • modified trees

[114] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

[115] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 35 Environmental watering requirements for the Macintyre River floodplain upstream of Boomi planning unit (Macintyre at Goondiwindi 416201A)[116]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<10 ML/d		<122 days			> 363 days above threshold per year[117] > 215 days above threshold in very dry years[118]
Very low flow	VL	<120 ML/d					> 363 days above threshold per year[117] > 215 days above threshold in very dry years[118]
Baseflow	BF1	>120 ML/d					> 346 days above threshold per year[117] > 206 days above threshold in very dry years[118] < 9255 ML deficiency volume per year[119]
	BF2		September to March	Duration of timing window	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[120]
Small fresh	SF1	>260 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[120]
	SF2	260-1300 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[120]
Large fresh	LF1	>1300 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[120]

[116] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

[117] This is set by the median number of days that flows were above threshold in each water year prior to 1976

[118] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1976. There is no objective definition of a very dry year.

[119] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1976. The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[120] To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
	LF3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	Rate of rise and fall[120]
Bankfull	BK1	>7000 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
	BK2		October to April		1-2 events per year in 10 years (*100%)*	4 years	
	BK3		October to April	10 days	3-5 years in 10 (*42%*)	4 years	
Anabranch connection	AC1	>7000 ML/d				< 296 days	> 26 days above threshold per year[117] > 5 days above threshold in very dry years[118]
	AC2	>7000 ML/d	Any time	5 days		7 years	Historically the 95th percentile spell duration of events of 5 days or longer was 506 days
Overbank	OB1	>27000 ML/d	Any time	3 days	3 in 10 years (*30%*)	4 years	
	OB2	>56000 ML/d	Any time		1-1.4 in 10 years (*12%*)		

Table 36 Environmental watering requirements for Macintyre River floodplain upstream of Boomi planning unit (Macintyre at Terrewah 416047)[121]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<5 ML/d		< 158 days			365 days above threshold per year[122] > 207 days above threshold in very dry years[123]
Very low flow	VL	>5 ML/d					> 365 days above threshold per year[122] > 207 days above threshold in very dry years[123]
Baseflow	BF1	>40 ML/d					> 364 days above threshold per year[122] > 114 days above threshold in very dry years[123] < 8 ML deficiency volume per year[124]
	BF2		September to March	7 days	5-10 years in 10 (*75%*)	440 days	Rate of rise and fall[125]
Small fresh	SF1	>110 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[125]
	SF2	110-1300 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[125]
Large fresh	LF1	>1300 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[125]

[121] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

[122] This is set by the median number of days that flows were above threshold in each water year prior to 1997, as there is insufficient record pre-1976.

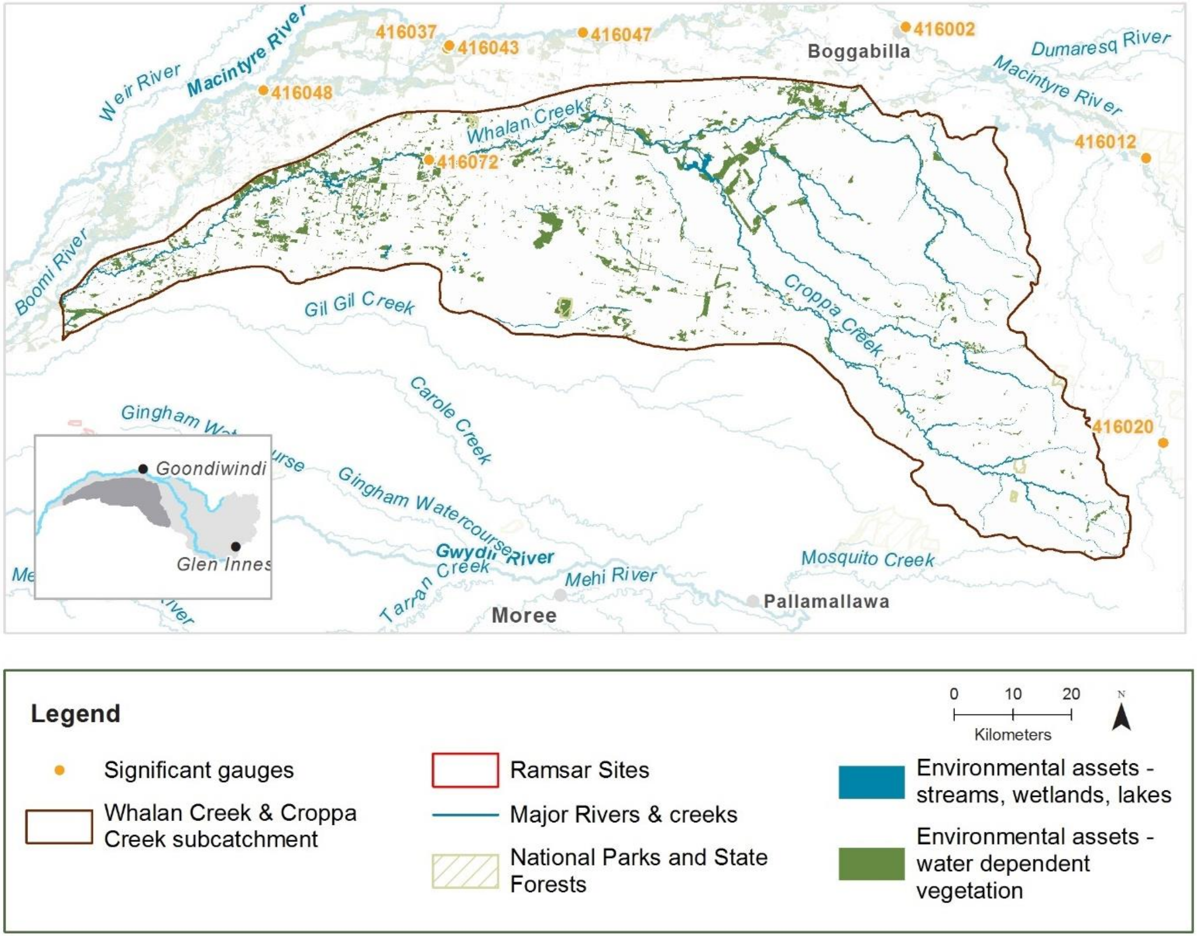
[123] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1997, as there is insufficient record pre-1976. There is no objective definition of a very dry year.

[124] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1997 (there is insufficient record pre-1976). The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[125] To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
	LF3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	Rate of rise and fall[125]
Bankfull	BK1	>3300 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
	BK2		October to April	1 day	1-2 events per year in 10 years (*100%)*	4 years	
	BK3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	
Overbank	OB1	>7900 ML/d	Any time	3 days	3 in 10 years (*30%*)	4 years	
	OB2	>11400 ML/d	Any time		1-1.4 in 10 years (*12%*)		

9.14 Whalan & Croppa Creeks



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Whalan Creek
- Croppa Creek
- Mobbindry Creek
- Tackinbri Creek
- Mungle Creek
- Back Creek
- Forest Creek
- Yallaroi Creek

- Significant anabranches with billabongs and wetlands provide drought refugia and productivity pulses between floods that maintains ecosystem functions.
- Billabongs and wetlands are known to provide habitat variability for a range of water dependent species, including protected waterbirds such as brolga and black-necked stork.
- Large areas of river red gum, coolibah, floodplain vegetation, lignum and water dependent listed PCTs

Native fish[126]	• golden perch X+Y • silver perch (CE) Y • spangled perch X+Y • Murray cod (V) Y • bony herring X+Y • freshwater catfish (E) Y • southern purple spotted gudgeon (E) Y • olive perchlet (E) Y • Australian smelt Y • carp gudgeon Y • flat-headed gudgeon Y • Murray-Darling rainbowfish X+Y • unspecked hardyhead Y
Waterbirds	19 water-dependent bird species recorded, including the listed[127] waterbird species: freckled duck (V), black-necked stork (E1), Latham's snipe (J,K) and marsh sandpiper (C,J,K)
Native vegetation	17 water-dependent Plant Community Types, including the TSC Act listed Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion, Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions and Native Millet - Cup Grass grassland of the Darling Riverine Plains Bioregion • 2371 ha of river red gum woodland • 21,713 ha of floodplain vegetation • 26,020 ha of coolibah • 220 ha of non-woody wetland • 2672 ha of lignum
Cultural assets	• two culturally significant wetlands • waterhole • Aboriginal ceremony and dreaming, burials • modified trees

[126] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016)

[127] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 37 Environmental watering requirements for Whalan & Croppa Creeks planning unit (Whalan at Euraba 416072)[128]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<150 ML/d		< 379 days[129]			> 45 days above threshold per year[130] > 6 days above threshold in very dry years[131]
Bankfull	BK1	>850 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
Anabranch connection	AC1	>2000 ML/d				685 days	> 12 days above threshold per year[130] > 0 days above threshold in very dry years[131]
	AC2		Any time	5 days		7 years	In the modelled without development data, the 95th percentile of spell duration between events 5 days or longer was 973 days.
Overbank	OB1	>2000 ML/d	Any time	3 days	3 in 10 years (*30%*)	4 years	
	OB2		Any time		1-1.4 in 10 years (*12%*)		

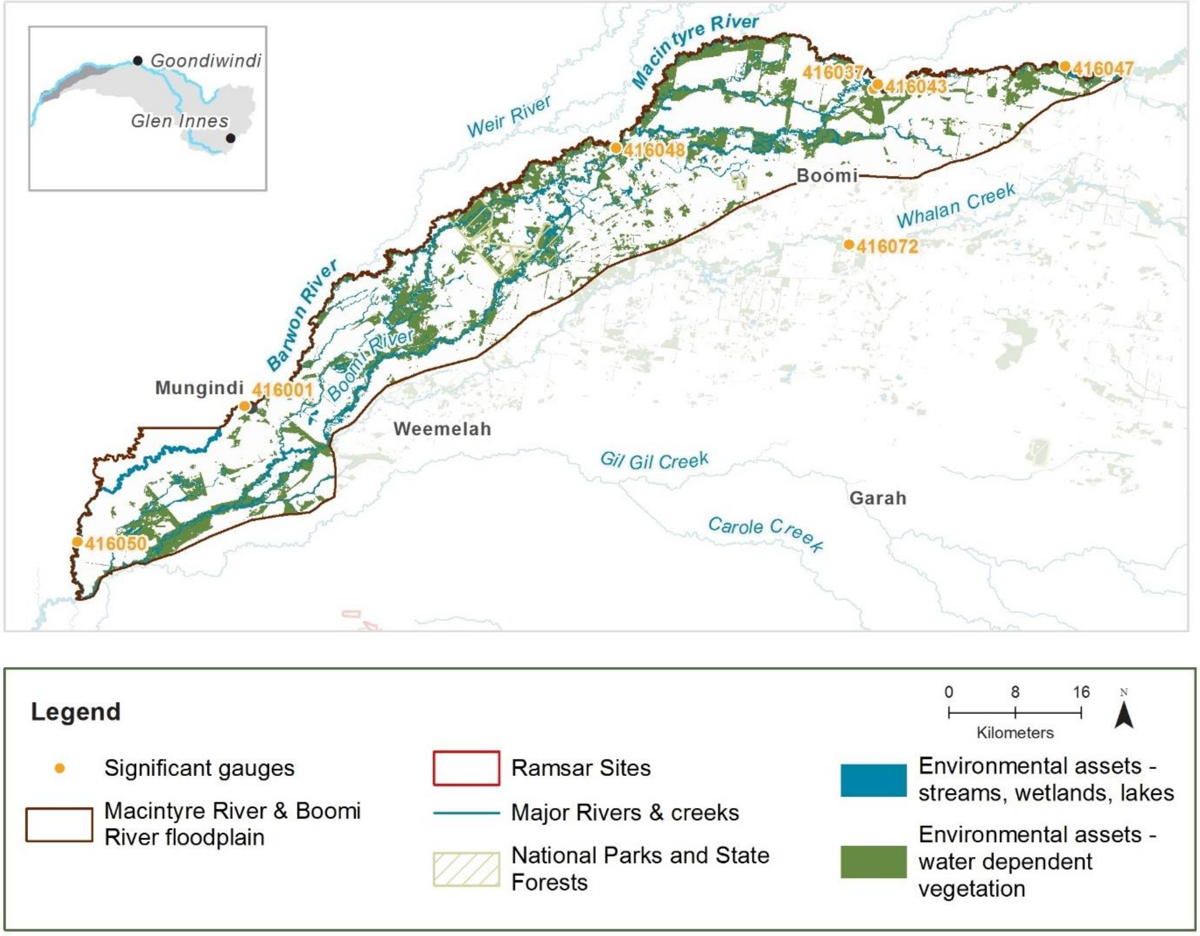
[128] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

[129] The observed record at this gauge commences in 2013. There is insufficient historical record to guide EWR setting. The best available evidence is the model data, despite known issues with event based accuracy at low flows, particularly in ephemeral rivers. These EWRs are likely to require revision over time as additional knowledge becomes available.

[130] This is set by the median number of days that flows were above threshold in each water year in the modelled data. The observed record at this gauge commences in 2013. There is insufficient historical record to guide EWR setting. The best available evidence is the model data, despite known issues with event based accuracy at low flows, particularly in ephemeral rivers. These EWRs are likely to require revision over time as additional knowledge becomes available.

[131] This is set by the 5th percentile of the number of days above threshold in the modelled data. There is no objective definition of a very dry year. The observed record at this gauge commences in 2013. There is insufficient historical record to guide EWR setting. The best available evidence is the model data, despite known issues with event based accuracy at low flows, particularly in ephemeral rivers. These EWRs are likely to require revision over time as additional knowledge becomes available.

9.15 Macintyre River and Boomi River floodplain



Priority environmental assets

Rivers, creeks, wetlands & their associated floodplains & water-dependant native vegetation, including (but not limited to):

- Boomi River
- Barwon River
- Tarpaulin Creek
- Gnoura Gnoura Creek
- Commillamori Creek
- Goodlayamma Creek
- Boomangera Creek
- Gravelly Creek
- Doondoona Creek
- Bonanga Billabong
- Breenie Creek
- Crooked Creek
- Geary Creek
- Carwal Creek

- Significant anabranches with billabongs and wetlands provide habitat variability, drought refugia and productivity pulses between floods that maintains ecosystem functions
- Large areas of river red gum, coolibah, floodplain vegetation, lignum and water dependent listed PCTs
- Boomi River flows provide an important hydrological connection and contribution to downstream flows
- Macintyre River and floodplain lagoons are a key movement corridor with high biodiversity, hydrodynamic diversity, occurrence of threatened species and dry period/drought refuge

Native fish[132]	• golden perch X+Y • silver perch (CE) Y • spangled perch X+Y • Murray cod (V) X+Y	• freshwater catfish (E) Y • southern purple spotted gudgeon (E) Y • olive perchlet (E) X+Y • Australian smelt X+Y	• carp gudgeon X+Y • Murray-Darling rainbowfish X+Y • bony herring X+Y
Waterbirds	32 water-dependent bird species recorded, including the listed[133] waterbird species: black-necked stork (E1) and brolga (V)		
Native vegetation	12 water-dependent Plant Community Types, including the TSC Act listed Weeping Myall open woodland of the Darling Riverine Plains Bioregion and Brigalow Belt South Bioregion and Belah woodland on alluvial plains and low rises in the central NSW wheatbelt to Pilliga and Liverpool Plains regions • 7268 ha of river red gum woodland • 37,023 ha of coolibah • 424 ha of black box • 3354 ha of floodplain vegetation • 313 ha of non-woody wetland • 221 ha of lignum		
Cultural assets	• 6 culturally significant wetlands • artefact, shells • ceremonial ring • modified trees		

[132] Native fish species marked with a (X) recorded in the planning unit via catch records and/or Australian Museum Records where they exist. Species marked with a (Y) are expected to occur in the planning unit based on MaxEnt modelling with a minimum 33% probability of occurrence (Richies et al. 2016). CE = Critically Endangered, E = Endangered, V = Vulnerable.

[133] Listed as Commonwealth or NSW threatened (Vulnerable [V], Endangered [E] or Critically Endangered [CE]) or under international migratory bird agreements (JAMBA [J], CAMBA [C], ROKAMBA [K])

Table 38 Environmental watering requirements for Macintyre River and Boomi River floodplain planning unit (Barwon River at Mungindi 416001)[134]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<1 ML/d	Anytime	Maximum duration: Typically, events should not persist for more than 20 days.	CtF events should occur in no more than 50% of years	NA	When managing water to restart flows, avoid harmful water quality impacts, such as de-oxygenation of refuge pools.
Very low flow	VL	>45 ML/d	Anytime	In typical years, at least 310 days per year. In very dry years, at least 220 days per year.	Every year	In accordance with maximum duration of cease-to-flow events	Flows that provide replenishment volumes to refuge pools. Waterhole persistence can also be supported by groundwater.
Baseflow	BF1	>160 ML/d	Anytime	In typical years, at least 220 days per year. In very dry years, at least 110 days per year.	Every year	130 days	Aiming to provide a depth of 0.3 m to allow fish passage. Also to manage water quality, prevent destratification and reduce risk of blue-green algal blooms.
	BF2		September to March	In typical years, at least 145 days per year (within timing window). In very dry years, at least 80 days per year (within timing window).	3 years in 10 (*30%*)	205 days	Aiming to provide a depth of 0.3 m to allow fish passage Rate of rise and fall[135]
Small fresh	SF1	>540 ML/d	Anytime, but ideally October to April	10 days	Annual (*100%*)	1 year	Ideal timing is based on preferred temperature range for fish spawning - >20°C for most

[134] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

[135] To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
							native fish and >18°C for Murray cod. Aiming to provide a depth of greater than 0.5 metres to allow movement of large fish. Flow velocity ideally up to 0.3 to 0.4 m/s (depending on channel form). Ideally shortly after LF2 for increased likelihood of successful recruitment of fish, productivity and dispersal. Rate of rise and fall[135]
	SF2	540-3000 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Timing is based on preferred temperature range for fish spawning - >20°C for most native fish and >18°C for Murray cod. Aiming to provide a depth of greater than 0.5 metres to allow movement of large fish. Flow velocity ideally up to 0.3 to 0.4 m/s (depending on channel form). Rate of rise and fall[135]
Large fresh	LF1	>3000 ML/d	Anytime, but ideally July to September	15 days	5-10 years in 10 (*75%*)	2 years	This flow in Jul to Sep will improve pre-spawning fish condition. Aiming to provide a depth of 2 m to cover in-stream features and trigger response from fish.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
							Flow velocity ideally 0.3 to 0.4 m/s (depending on channel form).
	LF2		October to April	15 days	3-5 years in 10 (*42%*)	2 years	Flow velocity ideally 0.3 to 0.4 m/s (depending on channel form). Temp preferably >17°C to maximise spawning outcomes. Ideally shortly before SF1.
Bankfull	BK1	>7900 ML/d	Anytime	5 days	5 years in 10 (*50%*)	4 years	
Overbank	OB1	>10000 ML/d	Anytime	5 days	2-4 years in 10 years (*30%*)	5 years	
	OB2	>19000 ML/d	Anytime	5 days	0.5 to 1 years in 10 years (*10%*)	15 years	

Table 39 Environmental watering requirements for Macintyre River floodplain upstream of Boomi planning unit (Macintyre u/s Boomi 416043)[136]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<5 ML/d		<661 days			> 362 days above threshold per year[137] > 266 days above threshold in very dry years[138]

[136] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs

[137] This is set by the median number of days that flows were above cease to flow in each water year prior to 1997 as there is insufficient record prior to 1976.

[138] This is set by the 5th percentile of the number of days above cease to flow in each water year prior to 1997. There is no objective definition of a very dry year.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Very low flow	VL	>5 ML/d					> 362 days above threshold per year[137] > 266 days above threshold in very dry years[138]
Baseflow	BF1	>60 ML/d					> 348 days above threshold per year[137] > 132 days above threshold in very dry years[138] < 1770 ML deficiency volume per year[139]
	BF2		September to March	7 days	5-10 years in 10 (*75%*)	79 days	Rate of rise and fall[140]
Small fresh	SF1	>100 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[140]
	SF2	100-650 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[140]
Large fresh	LF1	>650 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[140]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only
Bankfull	BK1	>1200 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
	BK2		October to April	1 day	1-2 events per year in 10 years (*100%*)	4 years	
	BK3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	
Anabranch connection	AC1	>1200 ML/d				223 days	> 98 days above threshold per year[137] > 18 days above threshold in very dry years[138]
	AC2	>1200 ML/d	Any time	10 days		7 years	Historically the 95th percenitle of spells between events of 10 days or longer was 332 days.

139 This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1997 (there is insufficient record pre-1976). The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

140 To be determined as part of a review of the NSW Border Rivers LTWP.

Table 40 Environmental watering requirements for Macintyre River floodplain upstream of Boomi planning unit (Boomi River at Boomi Weir Offtake 416037)[141]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<5 ML/d		<123 days			> 265 days above threshold per year[142] > 97 days above threshold in very dry years[143]
Baseflow	BF1	>5 ML/d					> 265 days above threshold per year[142] > 97 days above threshold in very dry years[143] < 768 ML deficiency volume per year[144]
	BF2		September to March	7 days	5-10 years in 10 (*75%*)	126 days	Rate of rise and fall[145]
Small fresh	SF1	>20 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[145]
	SF2	20-750 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[145]
Large fresh	LF1	>750 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[145]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only

[141] Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

[142] This is set by the median number of days that flows were above threshold in each water year prior to 1997 as there is insufficient record pre 1976.

[143] This is set by the 5th percentile of the number of days above threshold in each water year prior to 1997. There is no objective definition of a very dry year.

[144] This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1997 (there is insufficient record pre-1976). The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

[145] To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
	LF3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	Rate of rise and fall[145]
Bankfull	BK1	>1100 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
	BK2		October to April	1 day	1-2 events per year in 10 years (*100%)*	4 years	
Anabranch connection	AC1	>1100 ML/d				611 days[146]	> 18 days above threshold per year[142] > 3 days above threshold in very dry years[143]
	AC2	>1100 ML/d	Any time	8 days		7 years	Historically, the 95th percentile spell duration between events of 8 days or longer was 1070 days.

[146] This is the 95th percentile spell duration in the observed data pre-1997. There is insufficient record pre-1976.

Table 41 Environmental watering requirements for Macintyre River floodplain upstream of Boomi planning unit (Macintyre at Kanowna 416048)[147]

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Cease to flow	CF	<5 ML/d		< 202 days			365 days above threshold per year[148] > 156 days above threshold in very dry years[149]
Very low flow	VL	>5 ML/d					> 365 days above threshold per year[148] > 156 days above threshold in very dry years[149]
Baseflow	BF1	>40 ML/d					> 300 days above threshold per year[148] > 122 days above threshold in very dry years[149] < 53 ML deficiency volume per year[150]
	BF2		September to March	7 days	5-10 years in 10 (*75%*)	157 days	Rate of rise and fall[151]
Small fresh	SF1	>90 ML/d	October to April	10 days	Annual (*100%*)	1 year	Rate of rise and fall[151]
	SF2	90-900 ML/d	September to April	14 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[151]
Large fresh	LF1	>900 ML/d	July to September	5 days	5-10 years in 10 (*75%*)	2 years	Rate of rise and fall[151]
	LF2		October to April	5 days	3-5 years in 10 (*42%*)	4 years	Commencing as a rising flow only

147 Refer to Table 8 in Part A for definitions of terms and explanatory text for EWRs.

148 This is the median number of days that flows were above threshold in each water year prior to 1997.

149 This is the 5th percentile of the number of days above threshold in each water year prior to 1997. There is no objective definition of a very dry year.

150 This is set by the 95th percentile of annual deficiency volume in the observed data prior to 1997 (there is insufficient record pre-1976). The deficiency volume is the amount of water that would be required to ensure that flows are at the lower baseflow threshold each day. A higher deficiency volume indicates a drier river.

151 To be determined as part of a review of the NSW Border Rivers LTWP.

Flow category and EWR code		Flow threshold	Timing	Duration	Frequency (*LTA frequency*)	Maximum inter-event period	Additional requirements
Bankfull	BK1	>2500 ML/d	Any time	3 days	5-10 years in 10 (*75%*)	4 years	
	BK2		October to April		1-2 events per year in 10 years (*100%)*	4 years	
	BK3		October to April	10 days	5-10 years in 10 (*75%*)	4 years	
Anabranch connection	AC1	>2500 ML/d				443 days	> 53 days above threshold per year[148] > 7 days above threshold in very dry years[149]
	AC2	>2500 ML/d	Any time	13 days		7 years	Historically, the 95th percentile of spells between events of 13 days or more was 770 days.

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Appendix A. Ecological objectives relevant to each planning unit

Table 42 Ecological objectives for each planning unit in the NSW Border Rivers catchment

Code	Ecological objective	1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glen Innes	6. Bonshaw	7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
NATIVE FISH																
NF1	No loss of native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF3	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species											X	X	X	X	X
NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF6	A 25% increase in abundance of mature (harvestable sized) Golden perch and Murray cod	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Code	Ecological objective	1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glen Innes	6. Bonshaw	7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
NF7	Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas (within historical range)	X	X	X	X	X				X	X	X	X	X	X	X
NF8	Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NATIVE VEGETATION																
NV1	Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NV2	Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains											X	X	X	X	X
NV3	Maintain the extent and improve the condition of river red gum communities closely fringing river channels	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NV4b	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland											X	X	X	X	X

Code	Ecological objective	1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glen Innes	6. Bonshaw	7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
	communities on floodplains – river red gum woodland															
NV4c	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – black box woodland															X
NV4d	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – coolibah woodland												X	X	X	X
NV4e	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – lignum shrublands												X	X	X	X
WATERBIRDS																
WB1	Maintain the number and type of waterbird species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WB2	Increase total waterbird abundance across all functional groups	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WB3	Increase opportunities for non-colonial waterbird breeding											X	X	X	X	X

Code	Ecological objective	1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glen Innes	6. Bonshaw	7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
WB5	Maintain the extent and improve condition of waterbird habitats											X	X	X	X	X
ECOLOGICAL FUNCTION																
EF1	Provide and protect a diversity of refugia across the landscape	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF2	Create quality instream, floodplain and wetland habitat	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF3a	Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments						X			X			X	X		
EF3b	Provide movement and dispersal opportunities catchments for water-dependent biota to complete lifecycles and disperse into new habitats – between catchments													X		X
EF4	Support instream and floodplain productivity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF5	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands											X	X	X	X	X

Code	Ecological objective	1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glen Innes	6. Bonshaw	7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
EF6	Support groundwater conditions to sustain groundwater-dependent biota			X	X	X				X		X	X	X		
EF7	Increase the contribution of flows into the Murray and Barwon-Darling from tributaries	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Appendix B. Resource availability scenario

Guidelines for the method to determine priorities for applying environmental water[152]

The assessment of the RAS occurs throughout the water year. The critical information required for this assessment is the water availability and the condition of the environment (antecedent conditions). These can be determined with reference to existing data sourced from the Bureau of Meteorology and state water agencies. As set out in section 8.61 of the Basin Plan, a RAS will be one of: very dry, dry, moderate, wet, or very wet.

To determine the RAS, the following steps are followed:

a. determine the antecedent conditions for a given water resource plan area by (the ‘X’ axis of the matrix in Table 24):
    i selecting a representative number of water accounting periods preceding the current water year (e.g. 3–5 years)
    ii assessing the water received by the environment for those years
    iii comparing the amount in (ii) to all the historical data
    iv categorising the antecedent conditions as a percentile relative to all historical water years
b. determine the surface water availability by (the ‘Y’ axis of the matrix in Table 24):
    i assessing all sources of water available for the environment for a given period
    ii comparing these to all the historical data
    iii categorising the surface water availability as a percentile relative to all historical water years
c. for the relevant water accounting period, determine the surface water availability relative to the antecedent conditions for the water resource plan area using all the historical climate condition data that are available (in Table 24), this is the surface water availability percentile)
d. using the following matrix below, determine the applicable water RAS.

Table 43 Default matrix for determining the RAS

Surface water availability	Antecedent conditions				
	Very dry (0–15%)	Dry (16–45%)	Medium (46–60%)	Wet[153] (61–85%)	Very wet22 (86–100%)
Very low (0–15%)	Very dry	Very dry	Dry	Dry	N/A
Low (16–45%)	Very dry	Dry	Dry	Moderate	Wet
Medium (46–60%)	Dry	Dry	Moderate	Wet	Wet
High (61–85%)	Dry	Moderate	Wet	Wet	Very wet
Very high (86–100%)	N/A	Moderate	Wet	Very wet	Very wet

[152] As outlined by the Murray-Darling Basin Authority in https://www.mdba.gov.au/publications/policies-guidelines/guidelines-method-determine-priorities-applying-environmental-water.
[153] Wet and Very wet RAS are combined in this LTWP because the management strategies are the same.

Appendix C. Collation of assets across the catchment

The following series of tables provide summaries of the environmental assets found in each NSW Border Rivers planning unit.

Table 44 Hectares (ha) of native vegetation in each planning unit (compiled by DPIE in 2016 based on NSW OEH 2015)

Vegetation	1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glen Innes	6. Bonshaw	7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
River red gum	951	2,740	847	1,227	1,430	533	1,492	2,948	1,238	1,485	839	3,419	1,359	2,371	7,268
Black box															424
Coolibah												416	4,724	18,248	36,923
Floodplain						243			617	324	1,710	1596	2,536	29,496	3,455
Lignum		1								1		740	428	2,672	221
Non-woody wetland	634	2,310	226	102	1,242	212	18	642	60	105	254	240	107	220	313

Table 45 Native fish species catch records (C) and expected distribution (E) in each planning unit

Native fish species by functional group	1. Threatened species status[154]	2. 1. Tenterfield Creek	3. 2. Mole River	4. 3. Reedy Creek	5. 4. Beardy River	6. 5. Glen Innes	7. 6. Bonshaw	8. 7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
Flow pulse specialists																
Golden perch		CE	CE	CE	E	CE	CE	C	CE	CE	CE	E	CE	CE	CE	CE
Silver perch	V, CE					E		CE	CE		CE		E	E	E	CE
Spangled perch		C	C	E	CE		CE	C	E	CE	CE	CE	CE	CE	CE	CE
River specialists																
Murray cod	V	CE	CE	CE		CE	CE	CE	CE	CE	CE	E	CE	CE	E	CE
River blackfish						E			E							
Freshwater catfish	e	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	E	CE	E	E	CE
Southern purple-spotted gudgeon*	e	CE	CE	CE	CE	E	CE	CE	E	E	E	E	E	E	E	E
Olive perchlet*	e	CE	CE	E	E		CE		C	CE	CE		CE	CE	E	CE
Darling River hardyhead		C	C		C	C			C	C						

[154] ce = critically endangered in FM Act 1994, e = listed as endangered in FM Act 1994, v = listed as vulnerable in FM Act 1994, CE = critically endangered in EPBC Act, V = listed as vulnerable in EPBC Act

Native fish species by functional group	1. Threatened species status[154]	2. 1. Tenterfield Creek	3. 2. Mole River	4. 3. Reedy Creek	5. 4. Beardy River	6. 5. Glen Innes	7. 6. Bonshaw	8. 7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
Floodplain specialists																
Olive perchlet*	e	CE	CE	E	E		CE		C	CE	CE		CE	CE	E	CE
Southern purple-spotted gudgeon*	e	CE	CE	CE	CE	E	CE	CE	E	E	E	E	E	E	E	E
Rendahl's tandan																
Flat-headed galaxias	ce, CE															
Generalists																
Australian smelt		CE	CE	CE	CE	E	CE	CE	CE	CE	CE	E	CE	CE	E	CE
Carp gudgeon		CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	E	CE	CE	E	CE
Mountain galaxias		CE	CE	E	E	CE		E	CE							
Dwarf flat-headed gudgeon							E		E	E	E	E			E	
Murray-Darling rainbowfish		CE	CE	CE	CE	E	CE	CE	CE	CE	CE	E	CE	CE	CE	CE
Bony herring		C	E	CE	E		CE		E	CE	CE	E	CE	CE	CE	CE
Unspecked hardyhead		CE	CE	CE	E	E	CE	E	CE	CE	CE	E	CE	CE	E	E

Table 46 Waterbird sightings recorded in each planning unit

Waterbird species by functional group	1. Threatened species status[155]	2. 1. Tenterfield Creek	3. 2. Mole River	4. 3. Reedy Creek	5. 4. Beardy River	6. 5. Glen Innes	7. 6. Bonshaw	8. 7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
Ducks																
Australasian grebe		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Australasian shoveler		X				X			X				X	X		
Blue-billed duck	V					X			X							
Buff-banded rail		X							X							
Chestnut teal		X				X							X			
Freckled duck	V												X		X	
Great crested grebe						X			X					X		
Grey teal		X	X	X	X	X		X	X	X	X	X	X	X	X	X
Hardhead		X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Hoary-headed grebe		X				X		X	X	X		X		X		
Musk duck		X				X			X				X			
Pacific black duck		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pink-eared duck		X				X			X				X	X	X	

[155] V = NSW Vulnerable, E = Commonwealth Endangered, C = CAMBA, J = JAMBA, K = ROKAMBA

Waterbird species by functional group	1. Threatened species status[155]	2. 1. Tenterfield Creek	3. 2. Mole River	4. 3. Reedy Creek	5. 4. Beardy River	6. 5. Glen Innes	7. 6. Bonshaw	8. 7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
Herbivores																
Australian wood duck		X	X	X	X		X	X	X	X	X	X	X	X	X	X
Black-tailed native-hen						X					X		X	X	X	X
Black swan		X			X	X	X	X	X	X	X		X	X	X	X
Dusky moorhen		X	X	X	X	X	X	X	X	X	X		X	X		X
Eurasian coot		X		X	X	X		X	X	X			X	X	X	
Magpie goose	V	X	X													
Plumed whistling-duck													X	X	X	X
Purple swamphen		X	X	X	X	X		X	X	X			X	X		
Large waders																
Australian white ibis		X	X	X	X		X		X	X	X	X	X	X	X	X
Black-necked stork	E1									X	X			X	X	X
Brolga	V							X						X		X
Cattle egret	J												X	X	X	
Eastern great egret	J	X	X			X		X	X	X	X	X	X	X	X	X
Glossy ibis						X			X				X	X		X
Intermediate egret		X			X	X	X			X		X	X	X	X	X
Little egret		X				X			X				X	X		X

Waterbird species by functional group	1. Threatened species status[155]	2. 1. Tenterfield Creek	3. 2. Mole River	4. 3. Reedy Creek	5. 4. Beardy River	6. 5. Glen Innes	7. 6. Bonshaw	8. 7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
Nankeen night heron		X	X	X	X	X		X	X	X		X	X	X	X	X
Royal spoonbill						X	X	X	X		X	X	X	X	X	X
Straw-necked ibis		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
White-faced heron		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
White-necked heron		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Yellow-billed spoonbill		X	X			X	X	X	X	X	X	X	X	X	X	X
Piscivore														**X**		
Australasian darter		X			X		X	X	X	X	X	X	X		X	X
Australian gull-billed tern														X		
Australian pelican		X			X		X	X	X	X	X	X	X		X	X
Great cormorant		X	X		X	X	X	X	X	X		X	X	X	X	X
Little black cormorant		X	X	X	X	X	X	X	X	X	X		X	X	X	X
Little pied cormorant		X	X	X	X	X		X	X	X	X	X	X	X	X	X
Pied cormorant		X	X	X	X	X		X	X	X			X	X	X	X
Silver gull									X							
Whiskered tern								X	X				X	X	X	

Waterbird species by functional group	1. Threatened species status[155]	2. 1. Tenterfield Creek	3. 2. Mole River	4. 3. Reedy Creek	5. 4. Beardy River	6. 5. Glen Innes	7. 6. Bonshaw	8. 7. Kings Plain	8.Inverell	9. Campbells Creek & Camp Creek	10. Yetman	11. Ottleys Creek	12. Confluence of Macintyre & Dumaresq	13. Macintyre floodplain u/s Boomi	14. Whalan Creek & Croppa Creek	15. Macintyre River & Boomi River floodplain
White-winged black tern	CJK	X														
Shorebirds																
Banded lapwing			X				X	X	X	X		X	X		X	X
Bar-tailed godwit	CJK CE	X														
Black-fronted dotterel		X	X	X	X	X		X	X		X	X	X	X	X	X
Black-winged stilt		X		X		X			X				X	X	X	X
Common greenshank	CJK							X								
Latham's snipe	JK	X	X			X			X				X	X	X	
Marsh sandpiper	CJK					X								X	X	
Masked lapwing		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pectoral sandpiper	JK					X										
Red-capped plover											X					
Red-kneed dotterel		X				X			X		X		X	X		X
Red-necked avocet						X								X		
Sharp-tailed sandpiper	CJK													X		