NSW Border Rivers Long Term Water Plan

Parts A and B

Draft for exhibition

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Acknowledgement of Traditional Owners

The Office of Environment and Heritage 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 Office of Environment and Heritage 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.

Abbreviations

Basin Plan	Murray-Darling Basin Plan
BCT	Biodiversity Conservation Trust
BWS	Basin-wide environmental watering strategy
CAMBA	China-Australia Migratory Bird Agreement
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DOI-Water	NSW Department of Industry – Lands and Water
DPE	NSW Department of Planning and Environment
DPIF	NSW Department of Primary Industries Fisheries
EWAG	Environmental Water Advisory Group
EWR	Environmental water requirement
HEW	Held environmental water
JAMBA	Japan-Australia Migratory Bird Agreement
LLS	Local Land Services (NSW)
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	NSW National Parks and Wildlife Services
NRAR	Natural Resources Access Regulator
NSW	New South Wales
OEH	Office of Environment and Heritage
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

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 DOI–W, which is determined within the context of demand, inflows, rainfall forecasts and stored water.
Alluvial	Comprised of material deposited by water.
Bankfull flow	Flows that are above a large fresh and below maximum channel capacity. Inundates all in channel habitats including all benches, snags and backwaters, and engages the riparian zone, anabranches and flood runners and wetlands located within the meander train.
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.

Constraints management strategy	A strategy developed by the Murray-Darling Basin Authority which identified constraints to environmental water delivery. Specific NSW catchments covered by the strategy include: Murray-Lower Darling, Murrumbidgee and Gwydir.
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.
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.
Ecological objective	Objective for the protection and/or restoration of an ecological asset or function.
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).
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	The water required to support the completion of all elements of a lifecycle of an organism or group of organisms (taxonomic or spatial), consistent with the objective/target, measured at the most appropriate gauge. Includes all water in the system including natural inflows, held environmental water and planned environmental water.
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 component	The type of flow in a river defined by its magnitude (e.g. bankfull).
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	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	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. OEH 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.
Mitchell landscapes	A classification of ecosystems established through multivariate mapping information, including rainfall, temperature, topography, geology, soil and vegetation.
Overbank flow	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 the purpose of a 'stimulus flow' released between 1 August and 1 December.
Planned environmental water	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 ecological function	Ecological functions that can be managed with environmental water.
Priority ecological asset	A place of ecological significance that is water-dependent and can be managed with environmental water. This includes planned and held 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	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.
Targeted wetlands and floodplains	Areas of wetlands and floodplains that can be supported (at least partially) by the deliveries of managed environmental water.
Unregulated river	A waterway where flow is mostly uncontrolled by dams, weirs or other structures.
Very low flow	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 system	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) 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 (Pt 4, Ch. 8) 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 Office of Environment and Heritage (OEH) to cover the NSW portion of the Murray-Darling Basin. Development of the LTWP has involved five main steps:

- undertaking a comprehensive **stocktake** of water-dependent environmental assets and ecosystem functions across the catchment to identify native fish, water-dependent bird and vegetation species, and river processes that underpin a healthy river system.
- determining specific and quantifiable **objectives and targets** for the key species and functions in the NSW Border Rivers catchment

- determining the **environmental water requirements** (EWR's) (including volume, frequency, timing and duration) needed to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions
- identifying **risks, constraints and management strategies** to meet EWRs
- identifying actions for **going forward and measuring progress** to secure improvements in river and wetland health across the NSW Border Rivers.

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 Industry *NSW Border Rivers Water Resource Plan Risk Assessment* (DOI-W in prep.).

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 A summary of the environmental outcomes sought in the NSW Border Rivers

Environmental outcome	Overarching objectives	Example strategies
Maintain current species diversity, extend distributions, improve breeding success and numbers of native fish	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 condition of native vegetation	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.
Maintain the current species diversity, improve breeding success and numbers of waterbirds	Restoration of habitat for waterbirds to contribute to recovery of waterbird populations across the Murray-Darling Basin	• Maintain connection and disconnection of anabranches. (This could potentially be achieved with coordinated consumptive flows and held environmental water, once recovery is complete)
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. (This could potentially be achieved with coordinated consumptive flows and held environmental water, once recovery is complete)

Coordinated water management

Currently, it is thought that a significant portion of in channel EWRs are being met by consumptive flows. There is potential to achieve additional EWRs from sympathetic 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 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.

Complementary investments

There are complementary measures that may be required to ensure the LTWPs objectives and targets are achieved. 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.

Monitoring and evaluation of the Long Term Water Plan

Over the 20-year duration of this LTWP, NSW and Commonwealth agencies will, if sufficient resources and funding are made available, 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

There are significant knowledge gaps in the NSW Border Rivers, with various research underway to address these. 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 implemented. 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.

NSW Border Rivers Long Term Water Plan

Part A: 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). NSW Border Rivers runs 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 below Pindari Dam, which links to the Dumaresq River upstream of Goondiwindi. A schematic of the catchment is shown in Figure 1.

Downstream, the catchment is characterised by numerous anabranches and distributary channels including the Boomi River. The Macintyre continues its cross-country journey, meeting the Weir River out of Queensland 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 2015b).

The various wetlands and waterholes also support internationally and nationally significant waterbirds including brolgas, Australian painted snipe, 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. 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.

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).

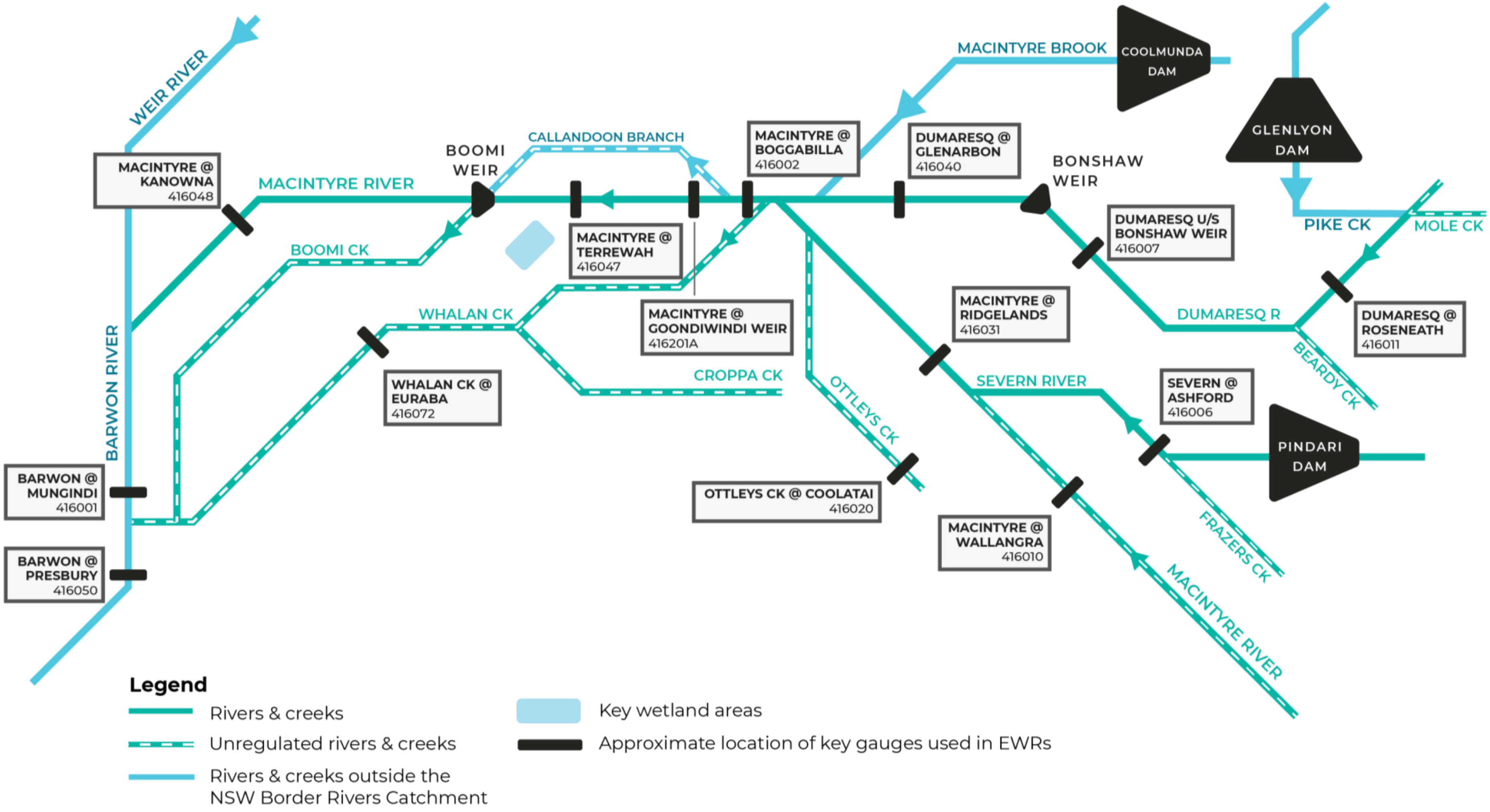

Figure 1 Schematic diagram showing river gauge locations on the main watercourses in the NSW Border Rivers

River flows in the NSW Border Rivers, like many Murray-Darling Basin catchments, has been altered by a headwater dam, weirs, river and creek modifications, and large-scale irrigation development of the floodplain. With the development of large scale irrigation industries, plans and rules that specify how water is to be share between users and the environment have been developed. Patterns and total volumes of flows, as well as the regularity of small to moderate-sized events, have reduced as a result. The condition of the catchment's riverine and floodplain ecosystems, and the plants and animals they support, has declined considerably because of this development.

Water resources are managed under two NSW Water Sharing Plans (WSPs) in the NSW Border Rivers. These WSP's 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) 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 access on days 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 plan 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

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

The NSW Border Rivers LTWP applies to the NSW Border Rivers 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 Murray-Darling Basin Plan (Basin Plan) (MDBA 2012).

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 five main steps:

- undertaking a **comprehensive stocktake** of water-dependent environmental assets and ecosystem functions across the NSW Border Rivers to identify native fish, water-dependent bird and vegetation species, and river processes that underpin a healthy river system
- determining **specific and quantifiable objectives and targets** for the key species and functions in the NSW Border Rivers
- determining the **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

- identifying potential **risks and constraints** to meeting the long-term water requirements of environmental assets and ecosystem functions.
- identifying **potential management strategies** for guiding water management decisions and investment into the future.

1.2 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 Office of Environment and Heritage (OEH) 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.

1.3 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

- **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 ecological objectives in the NSW Border Rivers and outlines potential strategies.
- **Chapter 6** outlines the workplan going forward to progress towards the objectives. This includes potential cooperative arrangements between government agencies.
- **Appendix A** details the ecological objectives relevant to each planning unit.

Part B

- **Chapter 7** introduces Part B of the LTWP and the planning unit scale specifics provided in this section.
- **Appendix B** details the assets in each planning unit.
- **Appendix C** details the planning unit scale EWRs.

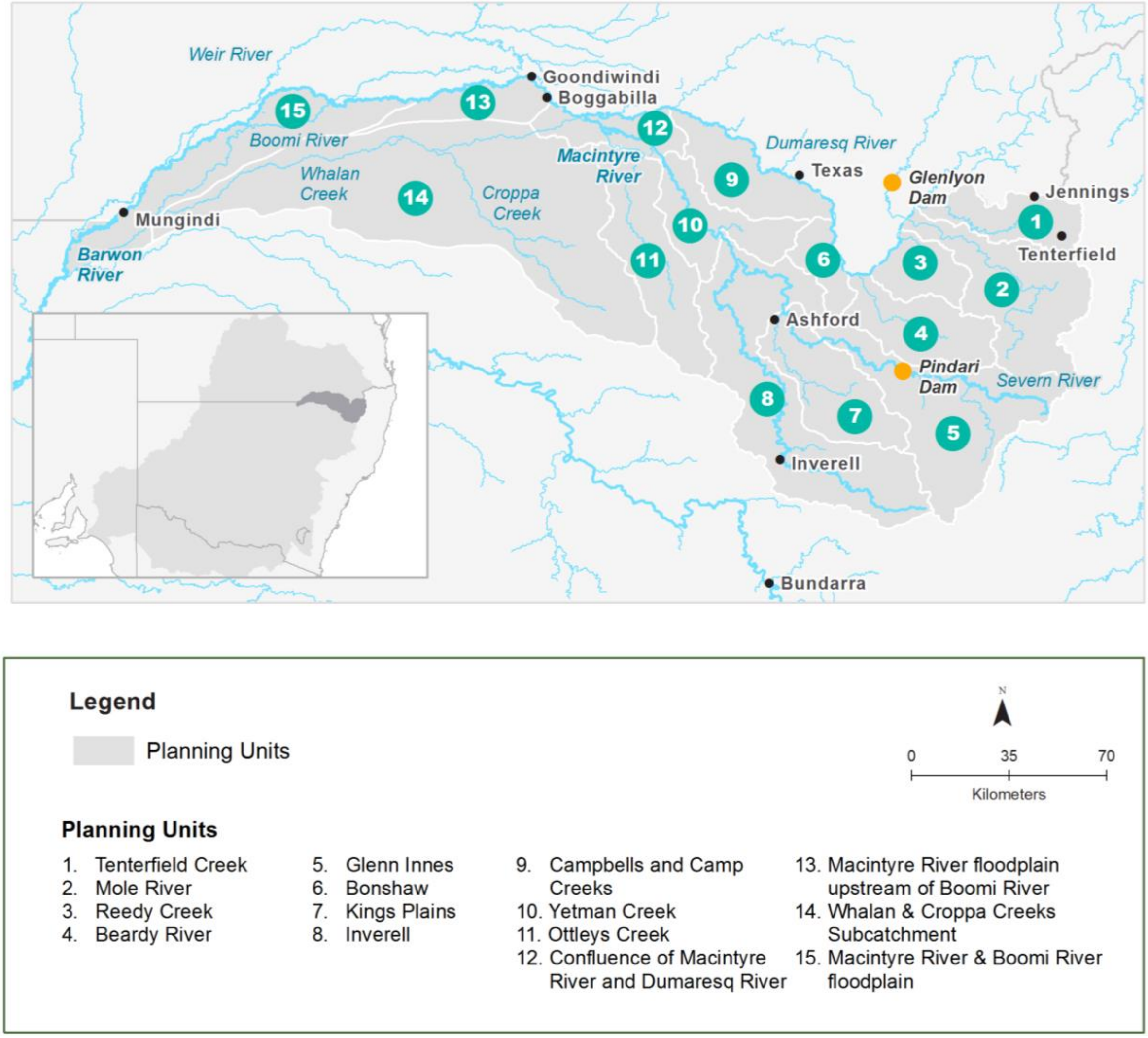

Figure 3 NSW Border Rivers showing the location of planning units in the LTWP

Planning units (PUs) 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 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 relevant differences to other planning units (Gordon et al. 2004).

- 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 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.

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 targets in the BWS, Schedule 8 of the Basin Plan outlines criteria for identifying water-dependent ecosystems as environmental assets. 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 4.

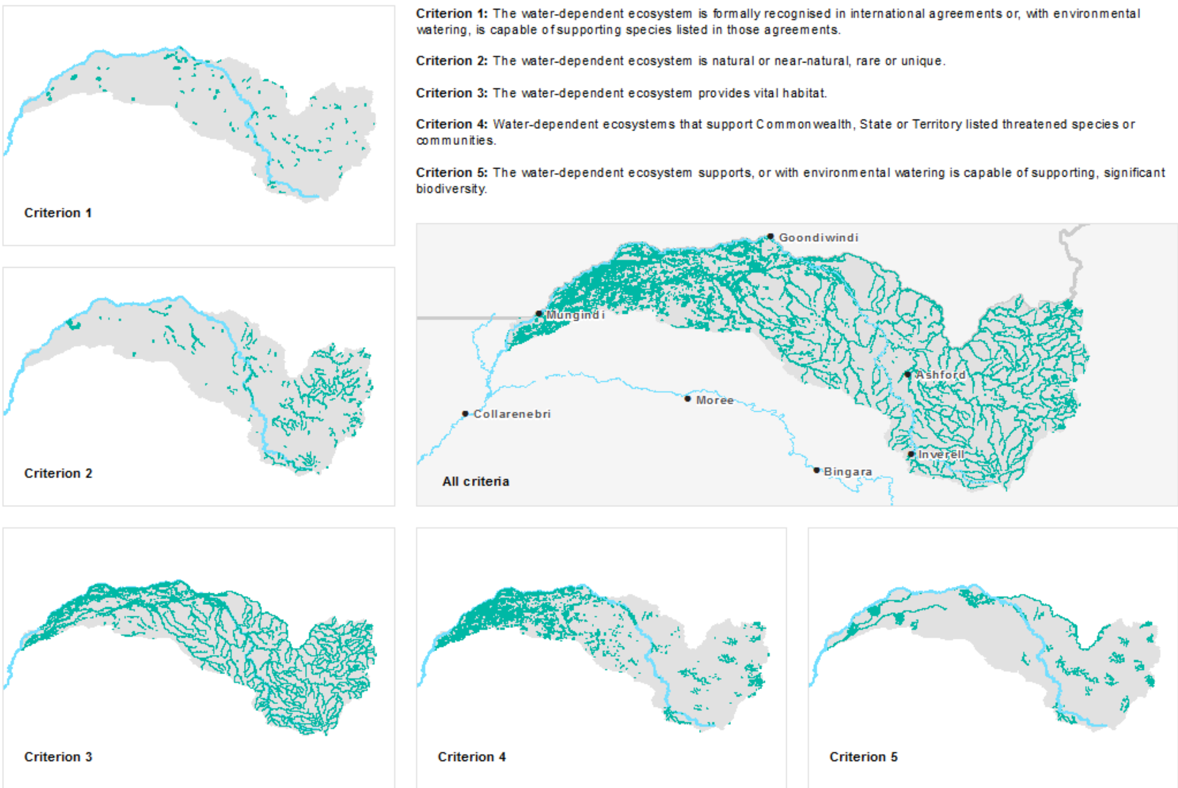

Figure 4 Five criteria for identification of environmental assets applied to NSW Border Rivers

Native fish assets

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 2015b). 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 5).

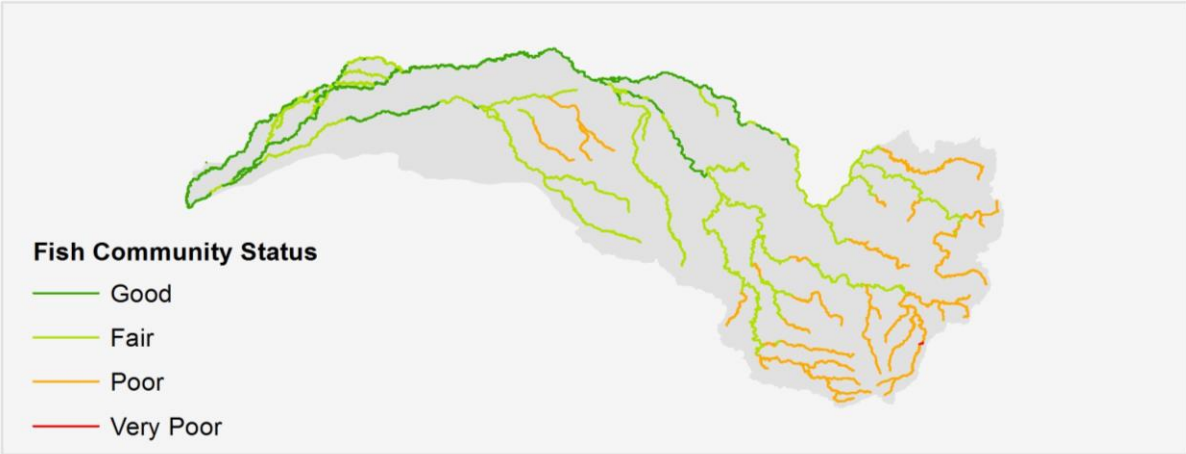

Figure 5 The current status of fish communities in NSW Border Rivers (NSW DPI 2016b).

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 MDBA's 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 2012). 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 6 (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.

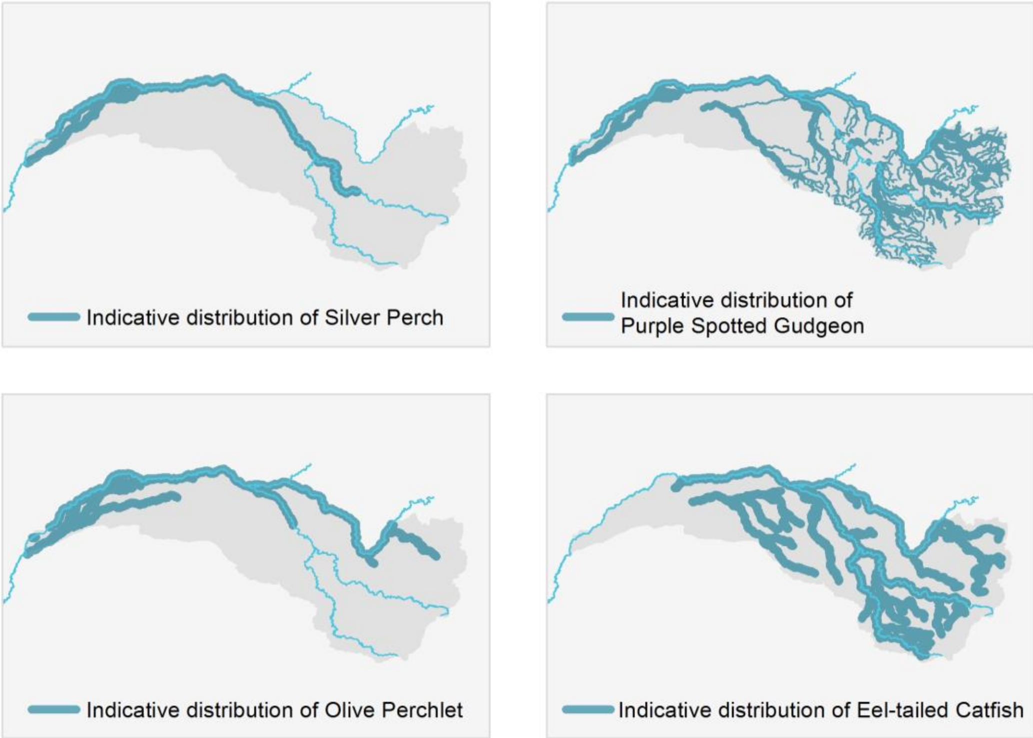

Figure 6 **Maps of indicative distribution of four key native fish species in the NSW Border Rivers (NSW DPI 2016b).**

Native vegetation assets

Foundational species are structurally and functionally significant for ecosystem function (Thompson et al. 2017), and may be used as indicators of watering requriements (Casanova 2015). A decline in the extent and/or condition of these species can be considered indicative of general environmental decline (Casanova 2015; MDBA 2010). The water-dependent native vegetation species and communities identified by the BWS are river red gum, black box, coolibah, lignum and non-woody vegetation closely fringing or within the main river corridors. Table 2 provides a summary of the extent of each of these within the NSW Border Rivers.

River red gum is found throughout the catchment, in areas closely adjoining the main river channels, while black box and coolibah are generally limited to the lower floodplain and there is only a few small patches of lignum shrublands around Goondiwindi (see Figure 7).

Table 2 **Summary of native vegetation assets in the NSW Border Rivers**

Native vegetation species or community	Area of vegetation extent (ha)
River red gum	30,147
Black box	424
Coolibah	60,311
Lignum	4,063
Non-woody vegetation	6,685

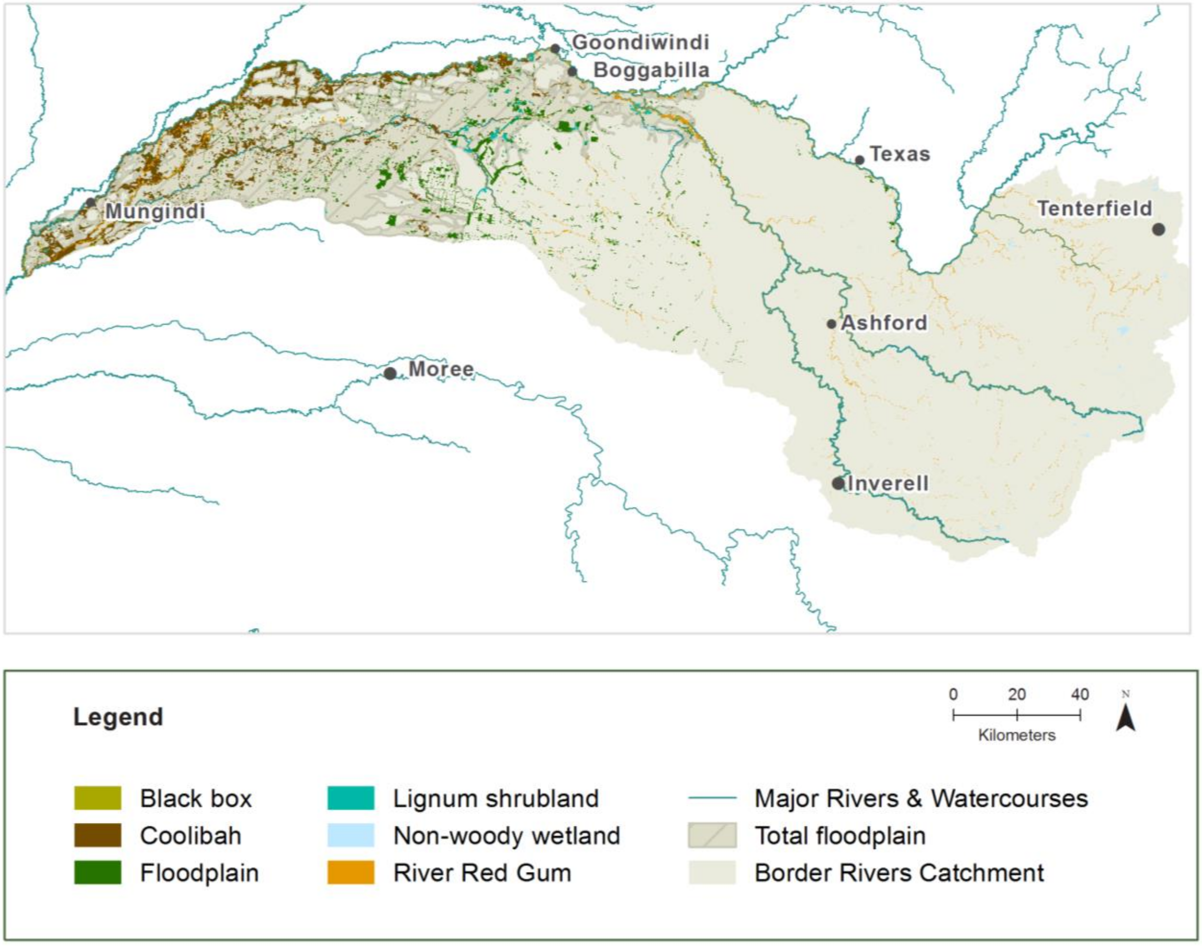

Figure 7 Map of native vegetation assets in the NSW Border Rivers

Waterbird assets

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). This means that wetlands in good condition, which have vegetation in good health and a variety of habitats with varying water depths, tend to support the greatest diversity and types 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).

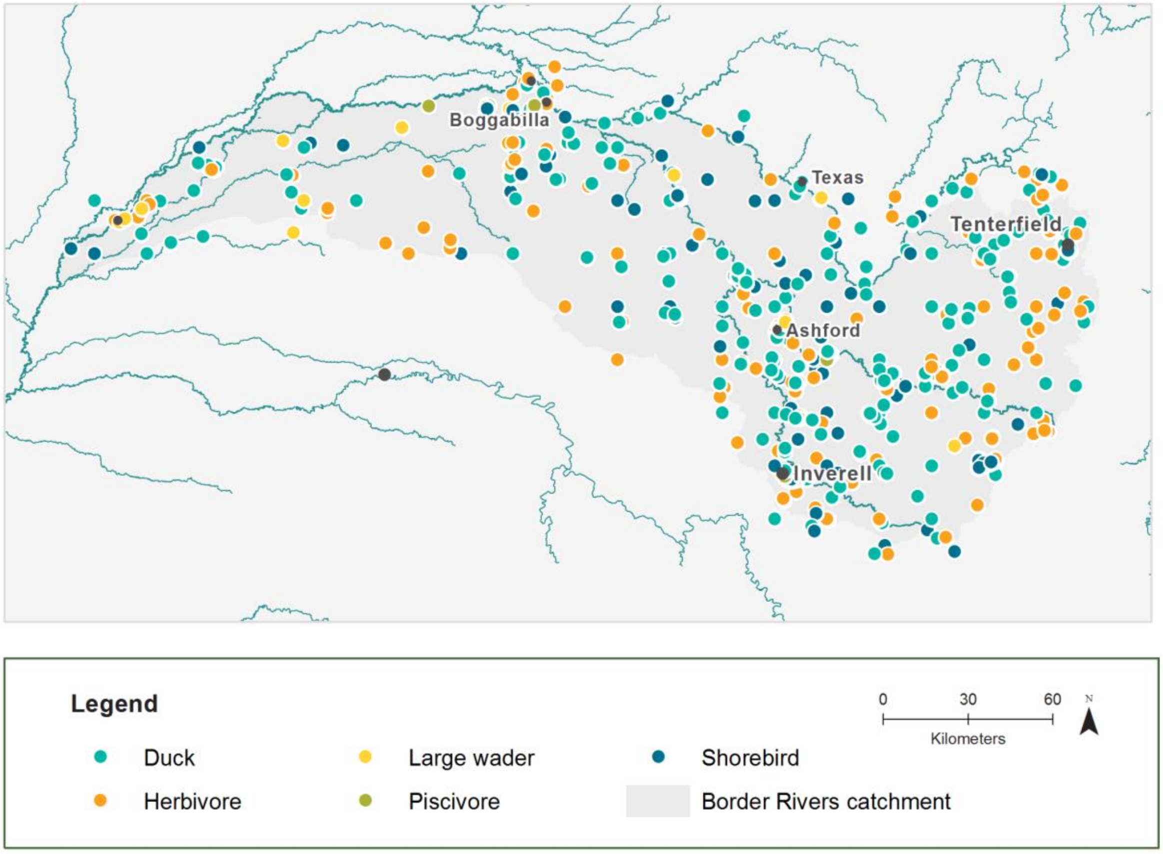

Figure 8 Locations of waterbird records in the NSW Border Rivers by functional group.

In the NSW Border Rivers waterbird records include sightings across all functional groups (see Figure 8), however there are no significant sites of colonial nesting waterbirds. There are records of vulnerable and endanged waterbirds in NSW Border Rivers, including species recognised internationally (Table 3).

Table 3 Vulnerable and endangered species grouped by the five functional waterbird groups for NSW Border Rivers.

Functional waterbird groups	Species and status[1]
Ducks	Blue-billed duck (V), Freckled duck (V)
Herbivores	Magpie goose (V)
Large waders	Black-necked stork (E), Brolga (V)
Piscivores	Australian gull-billed tern (C), White-winged black tern (C, J)
Shorebirds	Bar-tailed godwit (C, J, K), 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)

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

Ecosystem functions assets

The NSW Border Rivers catchment is comprised of streams and rivers, anabranches with semi-permanent lagoons and wetlands, and floodplain features (NSW DPI 2015b). Within 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 includes 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 can be identified based on the location of niche habitats, parts of the landscape where these processes are particularly critical and known condition of channels. The DOI-W NSW Border Rivers Risk Assessment (NSW DOI-W in prep.) has incorporated information on changes to overall flows (hydrological stress), channel fragility and the 'style' of the channel (e.g. riffles, deep channels and gravel bed formations) as shown in Figure 9. In implementing the LTWP, this information can be used to prioritise water management to meet EWRs for ecosystem functions to parts of the catchment and river sections.

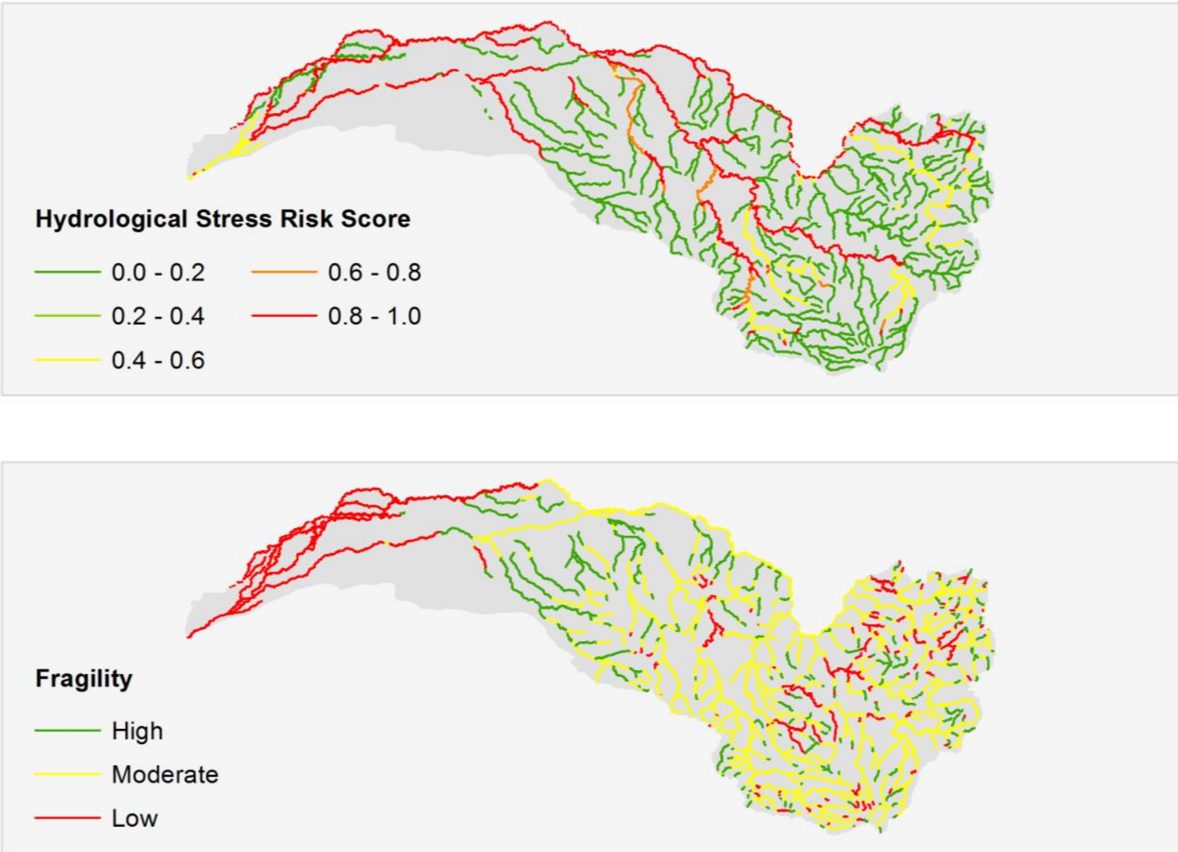

Figure 9 Examples of information that can be used to prioritise ecosystem functions.

Figure 10 Dumaresq River from Bonshaw Weir
Photo: L Cameron and J St Vincent-Welch.

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 BWS, the objectives are grouped into four themes: native fish, native vegetation, waterbirds and ecosystem functions (MDBA 2014). 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. The ecological objectives recognise environmental assets (e.g. native fish species, native vegetation communities, waterbirds) or the ecosystem functions (e.g. provides vital instream habitat), and align to the BWS targets.

3.1 Native fish objectives

There is range of spawning and recruitment behaviours of native fish species of the Murray-Darling Basin that evolved with a variable flow regime. A range of flows is required to meet the diverse needs of the fish community of a system (Baumgartner et al. 2013; NSW DPI 2015b). An effective approach is to form functional groups of fishes based on certain flow related attributes (Lloyd, Walker & Hillman 1991; Humphries, King & Koehn 1999; Baumgartner 2011; Baumgartner et al. 2013; NSW DPI 2015b; Mallen-Cooper & Zampatti 2015). Functional groups can then be used to simplify flow requirements, maximising efficiency of water use and environmental benefits (Humphries, King & Koehn 1999; Growns 2004; NSW DPI 2015b; Mallen-Cooper & Zampatti 2015). The effective and efficient management of water is even more pertinent in systems of the Northern Basin where water availability is limited and exacerbated by competing needs (Thoms et al. 2004; NSW DPI 2015b).

The functional groups formed were based around specific flow related attributes for spawning, recruitment, movement, maintenance, and condition (NSW DPI 2015b). This included consideration of:

- cues for migration, dispersal and spawning (temperature and/or flow)
- scale of spawning migration (from metres to kilometres)
- whether a nesting species or not
- spawning in still/slow-flowing water or in fast-flowing habitats
- egg hatch time (days to weeks) and egg morphology
- temporal and spatial scales of larval drift and recruitment

Table 4 Native fish (NF) ecological objectives

Objective		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			
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[2]	Minimum of 2 significant recruitment events in 10 years	Minimum of 4 significant recruitment events in 20 years
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*	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[3]	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		

[2] young-of-year comprise more than 30% of the population
[3] young-of-year comprise more than 30% of the population

Objective		Target fish species	Targets 5 years (2024)	 10 years (2029)	 20 years (2039)
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	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*	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

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

Figure 11 Purple-spotted gudgeon and freshwater catfish
Photos: G. Schmida

3.2 Native vegetation objectives

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).

Table 5 Native vegetation (NV) ecological objectives

<table>
<tr><th colspan="2" rowspan="2">Objective</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 within the regulated flow paths</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 extent 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
• 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>

<table>
<tr><th colspan="3" rowspan="2">Objective</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">Maintain the 2016 extent of lignum shrubland and coolibah wetland woodland communities</td><td>Increase the total area of lignum shrublands and coolibah wetland woodlands by 10% occurring within the actively managed floodplain</td></tr>
<tr><td>NV4e</td><td>Lignum shrublands</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>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</td></tr>
<tr><td>NV4d</td><td>Coolibah woodland</td><td>• 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>
</table>

3.3 Waterbird objectives

More than 100 waterbird species have been recorded in the NSW portion of the MDB 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*.* (2014a) 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 colonial waterbird 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 6 Waterbird (WB) ecological objectives[4] for NSW Border Rivers.

Ecological objectives		Targets		
		5 years (2024)	10 years (2029)	20 years[5] (2039)
WB1	Maintain the number and type of waterbird species	Maintain a 5-year rolling average of 6[6] 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

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 flooding flows to maintain ecosystem functions such as in-channel complexity (e.g. benches) (Boulton et al. 2000; Thoms & Sheldon 2002).

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

[5] 20-year targets will be further refined following additional data collection.

[6] This value is low and represents an absolute minimum target. There is limited waterbird survey coverage for NSW Border Rivers due to resourcing shortages.

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 et al. 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 limit 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 & Mitrovoc 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 et al. 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.

Table 7 Priority ecosystem function (EF) ecological objectives

Objective			Targets 5 years (2024)	10 years (2029)	20 years (2039)
EF1	Provide and protect a diversity of refugia across the landscape		Maintain dissolved oxygen and salinity levels in key refuge pools at ecologically tolerable levels		
EF2	Create quality instream, floodplain and wetland habitat		Rates of rise and fall do not exceed the 5th and 95th percentiles (respectively) of natural rates in areas of high hydrological stress Rates of rise and fall do not exceed the 5th and 95th percentiles (respectively) of natural rates during regulated water deliveries		
EF3	Provide movement and dispersal opportunities within, and between, catchments for water-dependent biota to complete lifecycles and disperse into new habitats	a. within catchments	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		
		b. between catchments	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		
EF4	Support instream and floodplain productivity		Maintain soil nitrogen, phosphorus and carbon levels at long-term natural levels Maintain/Improve the abundance and distribution of decapod crustaceans		

Objective		Targets		
		5 years (2024)	10 years (2029)	20 years (2039)
		No decline in key native fish species condition metrics (e.g. weight:length ratio)	Improve key native fish species metrics (e.g. weight:length ratio)	
EF5	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	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	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	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.		

Figure 12 Barwon River at Mungindi
Photo: E Wilson

4. Environmental water requirements

A river's flow or inundation regime influences the ecological characteristics of that river's ecosystems (Poff & Zimmermann 2010). A flow regime is the totality of patterns of flows of different volumes, durations and timings. Flow regimes shape river channels, provide cues for key biological processes such as breeding or migration, support dispersal of plants and animals and shape how a river links with its floodplain.

Flow regimes can be partitioned into flow components, such as base flows, freshes and overbank flows, that describe the height or level of the flow within a river channel or its extent across a floodplain (see Figure 13 and Table 8).

Flow components can be defined hydrologically and ecologically. The LTWP defines flow components ecologically, with each flow component providing for a range of ecological roles. 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. The volumes that define each of the flow components in the NSW Border Rivers are shown in Table 13.

An environmental water requirement (EWR) is the flow needed for a species, or group of species to ensure its survival and persistence. An EWR is based on knowledge of a species' biological and ecological needs, such as what it needs to feed, breed, migrate and disperse.

EWRs are defined based on the volume of flow required, as generalised to a flow component (e.g. baseflow, small fresh) as well as specific flow criteria such as timing, duration and interflow period (see for example Table 9 and Table 12). The LTWP applies a flow event method that is based on ecological processes rather than hydrological statistics (Stewardson & Gippel 2003).

Meeting the full life-history needs of an aquatic organism (plant or animal) might require a combination of several different EWRs 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. The EWRs collectively represent an ideal flow regime.

4.1 Describing the EWRs to support ecological objectives

Development of EWRs for LTWPs was an iterative process that started with an assessment of the water requirements of individual species, then guilds or functional groups. Where requirements (flow component, duration, timing etc.) overlapped between species or groups with similar watering needs, the requirements were combined to provide a single EWR for component group of ecological objectives.

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

Important flow regime characteristics to meet life-history needs and each of the LTWP objectives are described within the following tables in this chapter. The combined EWRs, grouped by flow component, for all biota and functions in the NSW Border Rivers catchment are presented in Table 9, Table 10 and Table 11. Each EWR is named as the flow component it sits within, and then assigned a number reflective of specific details such as ideal timing, duration and frequency based on the suite of plants, animals and functions it supports. Specific EWRs at each planning unit in the NSW Border Rivers, including flow rates and total volumes, can be found in Appendix C.

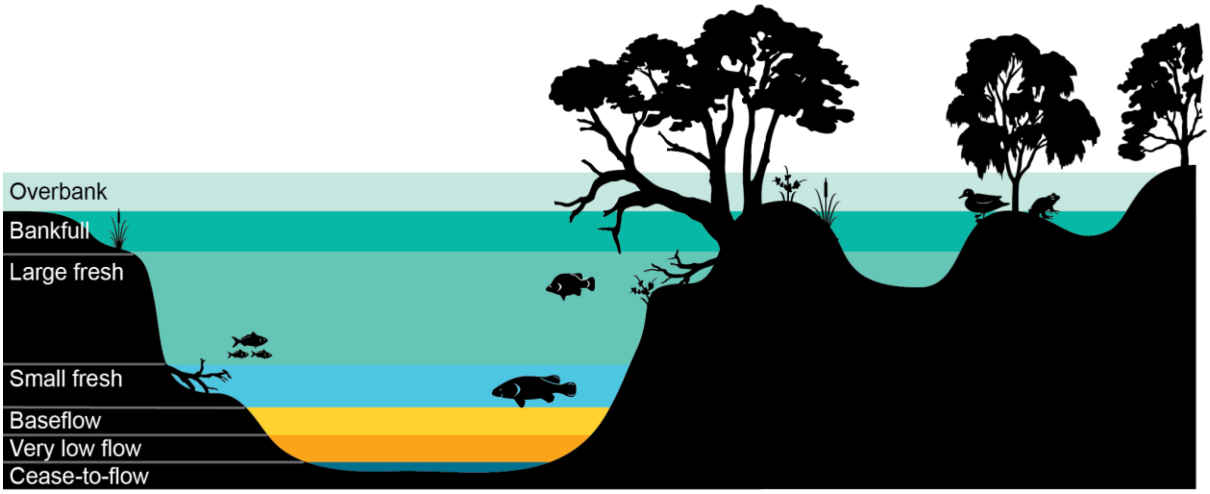

Figure 13 A simplified conceptual model of the role of each flow regime components

Table 8 Description of the role provided by each flow component shown in Figure 13

Flow component	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 small in-channel barriers (e.g. small 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.
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 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.

Cease-to-flow and very low flow

Cease-to-flow conditions occur when surface water stops flowing and streams and rivers contract to a series of disconnected pools. There is a partial or total drying of sections of the channel. The start of cease-to-flow events are defined by the daily flow rate falling below a threshold that is indicative of a loss of hydrological connectivity. For the purposes of flow analysis, a flow threshold that is greater than '0' is required. Flows below either 1ML/d or 10% of the lower baseflow threshold are nominally regarded as cease-to-flow, indicative of a loss of ecologically meaningful hydrological connectivity.

There is a balance between cease-to-flow conditions as occurring in dry times, and the flows experienced in wet times. When flows are low, exposed benches can accumulate organic matter that can later provide carbon and nutrients when larger flows reconnect these benches. However, if cease-to-flow conditions persist for too long refuge and weir pools can dry out too much and stratification that promotes blue-green algal outbreaks occur, reducing both the quantity and quality of valuable drought refugia.

A balance between dry and wet conditions is also relevant for very low flows; that is a minimum flow that prevents a cease-to-flow. In very low flow conditions, there is hydrological connectivity between some pools. Flow depths are not sufficient to allow any significant movement of water biota, but flows may maintain the volume of refuge pools.

EWRs for cease-to-flow and very low flow components of the hydrograph need to be described using a number of measures. These include spell duration (number of consecutive days below flow threshold) (Gordon et al. 2004), the deficiency volume (volume that would be required to keep the flow at threshold (Gordon et al. 2004) , and the total number of days below a flow threshold relative to the total number of days above a flow threshold, within a set period of time (such as a season or water year). The objectives and the important flow regime characteristics that have been considered in the development of the cease-to-flow and very low flow EWRs are shown in Table 9.

Table 9 Objectives and related important flow components used to set EWRs for cease-to- flow and very low flow.

Environmental watering requirement		Environmental objective		Important flow regime characteristics
CEASE-TO-FLOW				
CF	No significant change to the number of days below cease to flow (ML/d): number of days above cease to flow in each water year, from the historical observed data. In addition, the 5th percentile of the rate of rise and the rate of fall in stream level is set at within 20% of natural.	No loss of native fish species	NF1	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.
		Maintain the number and type of waterbird species	WB1	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.
		Provide and protect a diversity of refugia across the landscape	EF1	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 2015a; NSW DPI 2018).
		Support instream and floodplain productivity	EF4	No increase in the cease-to-flow duration or frequency at Mungindi, Presbury and Goondiwindi gauges to support downstream productivity. This also requires activation of anabranches and floodplains, as described in AC1 and AC2.
		Create quality instream, floodplain and wetland habitat	EF2	Rapid draw down can cause excessive bank slumping more likely in areas with higher pumping capacities, as reflected by the hydrological stress ratings (NSW DOI-W in prep.). 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.

Environmental watering requirement		Environmental objective		Important flow regime characteristics
VERY LOW FLOW				
VL1	No significant change to the number of days below very low flow (ML/d): number of days within very low flow: number of days above very low flow in each water year, from the historical observed data. Rate of fall within 20% of natural.	No loss of native fish species	NF1	Very low flows in dry times may maintain or minimise loss of pools, as critical for fish survival and maintenance.
		Provide and protect a diversity of refugia across the landscape	EF1	Very low flows in dry times may maintain or minimise loss of pools. Water quality (e.g. dissolved oxygen, temperature and salinity) may inform timing and urgency of response. Flow rate used to replenish pools needs to be of sufficient velocity and for sufficient duration to de-stratify the pools.
		Create quality instream, floodplain and wetland habitat	EF2	See above, as per cease-to-flow.
		No loss of native fish species	NF1	In extended dry periods, a very low flow is required to maintain or minimise the loss of water volume from refuge pools. 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).
		Maintain the number and type of waterbird species	WB1	See above, as per cease-to-flow.
HYDROLOGICAL CONNECTION				
HC	No further reduction in the 5 year running average annual flow volume	Increase the contribution of flows into the Murray and Barwon-Darling from tributaries	EF7	Hydrological connection occurs at very low flows and above (Mallen-Cooper & Zampatti 2018). The Intergovernmental Agreement (NSW DPI 2008), Basin Plan and BWS all include considerations for long term flow. 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 end of PU gauges (contributing flows).

Baseflow and freshes

At baseflow there is some fish movement connectivity between pools and riffles and along channels. At baseflow, within reaches there is sufficient depth for fish movement.

A small fresh improves longitudinal connectivity, triggering movement and breeding for aquatic animals. At this flow rate lower banks, bars, snags and in-channel vegetation are inundated. These flows can also flush pools and may stimulate productivity and food webs.

A large fresh inundates benches, snags and inundation-tolerant vegetation higher in the channel. At this flow rate productivity is supported with some transfer of nutrients, carbon and sediment. It provides fast-flowing habitat, with rises in flow providing an important trigger for some species to breed. A large fresh may connect wetlands and anabranches with low commence-to-flow thresholds.

The EWRs for baseflow 1 is described in terms of the ratio of days below, within band and above band, while the remainder of these in-channel EWRs are described as events. These events are defined as a flow rate (ML/d) within a band of flows, for a minimum duration and in an ideal season. The recurrence of these events that is required to sustain populations or maintain landscape condition is defined. Lastly the desired maximum spell between events is set based on known vegetation condition requirements or species' life cycles.

The objectives and the important flow regime characteristics (duration, season, frequency and spell) that have been considered in the development of the baseflow, small fresh and large fresh EWRs are shown in Table 10.

Table 10 Objectives and related important flow components used to set EWRs for baseflow and freshes

Environmental watering requirement		Environmental objective		Important flow regime characteristics
BASEFLOW				
BF1	No significant change in number of days below baseflow (ML/d): number of days in baseflow: number of days above baseflow in each water year, from the historical observed data. The 5th percentile of rate of rise and rate of fall in flow is set at within 20% of natural.	No loss of native fish species	NF1	A flow at least 30cm above the cease-to-flow will maintain refuge, provide hydrological connection and movement for small to moderate body size fish. In wide channels, habitat mapping and/or local knowledge is used to determine the appropriate flow rate.
		Maintain the number and type of waterbird species	WB1	See above, as per cease-to-flow.
		Create quality instream, floodplain and wetland habitat	EF2	See above, as per cease-to-flow. 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.
		Provide movement and dispersal opportunities within, and between catchments for water-dependent biota to complete lifecycles and disperse into new habitats	EF3a	A flow at least 30cm above the cease-to-flow will maintain refuge, provide hydrological connection and movement for small to moderate body size fish. In wide channels, habitat mapping and/or local knowledge is used to determine the appropriate flow rate. The achievement of native fish objectives requires productivity flows for fish condition and movement of fish. Acheivement of this ecosystem functions objective will contribute to achievement of the outcomes associated with NF2, NF3, NF4, NF5, NF6, NF7 and NF8.
BF2	Frequency is once in every 1 or 2 years, the ideal timing is Sept to March, minimum duration is 7 days, or 12 days if the flow is responding to a blue-green algal outbreak, and maximum inter-	No loss of native fish species	NF1	A baseflow, 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. 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
		Increase the distribution and abundance of short to moderate-lived generalist native fish species	NF2	

Environmental watering requirement	Environmental objective		Important flow regime characteristics
event period is two years. The 5th percentile of rate of rise and rate of fall in flow is set at within 20% of natural.	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	NF5	flows for riverine specialists require a minimum of 24 days flow (NSW DPI 2018).
	A 25% increase in abundance of mature (harvestable size) Golden perch and Murray cod	NF6	
	Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish into new areas (within historical range)	NF8	
	Provide and protect a diversity of refugia across the landscape	EF1	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 (Mitorvic et al 2003).
	Maintain the extent and viability of non-woody vegetation communities occurring within channels	NV1	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).

Environmental watering requirement		Environmental objective		Important flow regime characteristics
SMALL FRESH				
SF1	Frequency is annually, ideal timing is October to April, minimum duration is 10 days, and maximum inter-event period is one years. The 5th percentile of rate of rise and rate of fall in flow is set at within 20% of natural.	Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish into new areas (within historical range)	NF8	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 to 10 days. This objective relates to all PUs.
		Provide movement and dispersal opportunities within, and between catchments for water-dependent biota to complete lifecycles and disperse into new habitats	EF3a	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. Achievement of this ecosystem function objective will contribute to the outcomes associated with NF1, NF4, NF7.
		Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles	EF3b	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.
		Support instream and floodplain productivity	EF4	Wetting of in-channel benches will release nutrients and carbon. A small fresh will enable some longitudinal connectivity.
		A 25% increase in abundance of mature (harvestable size) golden perch and Murray cod	NF6	In addition to flows above for Murray cod and golden perch, connectivity/movement flows are needed for NF6
SF2	Frequency is once in every 1 to 2 years, ideal timing is September to April, minimum duration is 14 days, and maximum inter-event period is two years.	Increase the distribution and abundance of short to moderate-lived generalist native fish species	NF2	An annual small fresh between October and April for a minimum of 14 days, with a slow recession will provide opportunities for spawning and recruitment. Most native fish require water temperatures above 20°C.
		Improve native fish population structure for moderate to long-	NF5	A small fresh for at least 14 days, ideally between September to December (water temperatures above 18 °C) encourages

Environmental watering requirement		Environmental objective		Important flow regime characteristics
		lived riverine specialist native fish species		spawning of Murray cod (to March and temperatures above 16ºC for other species). Frequency is annual or biannual and maximum interflow period is 2 years. A BF2 immediately following will increase recruitment outcomes.
		Improved distribution and abundance of short-lived floodplain specialist fish	NF3	At low velocity flows, of at least 10 days, in upland rivers Olive perchlet can spawn in channel using niche bank habitat. Ideal timing is between October and April. This flow is needed on average five to 10 times in 10 years with a maximum interflow period of four years.
LARGE FRESH				
LF1	Frequency is once in every 1 to 2 years, the ideal timing is July to September but can occur anytime, minimum duration is 5 days, and maximum inter-event period is two years	No loss of native fish species	NF1	An annual large fresh that wets higher in-channel surfaces (ideally between July and September) for at least five days, releases carbon and nutrients and provides for fish condition. Rate of release peaks in the first day (Southwell 2008). In upland valley confined settings, flows are naturally faster passing events and a shorter duration event is relevant (Poff et al. 1997).
		A 25% increase in abundance of mature (harvestable size) Golden perch and Murray cod	NF6	In addition to spawning flows above for Murray cod and Golden perch, productivity flows are needed for objective NF6.
		Maintain groundwater conditions to sustain groundwater-dependent ecosystems	EF6	Recharge to groundwater is more likely at higher flows when downwards pressure is greater. Groundwater-dependent ecosystems further from the main river channels will require a small overbank flood or greater to reach and recharge groundwater.
		Provide and protect a diversity of refugia across the landscape	EF1	In cobble dominated riffle sections higher velocities of approximately 1.2 m/s scour and reduce filamentous algae (Davie & Mitrovic 2014).

Environmental watering requirement		Environmental objective		Important flow regime characteristics
		Provide movement and dispersal opportunities within, and between catchments for water-dependent biota to complete lifecycles and disperse into new habitats	EF3a	Upstream dispersal of fish requires weir drown outs. 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.
LF2	Frequency is once every 2 to 3 years, ideal timing is October to April, minimum duration is 5 days, and maximum inter-event period is four years.	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	NF4	A large fresh for at least five days is required for spawning. Ideal timing is between October and April. This flow needs to occur once every two to three years with a maximum inter-flow period of 4 years. A rapid rise with temperatures greater than 17ºC, ideally 2-3 weeks before SF1 will enhance spawning outcomes. Rate of fall no faster than 5th percentile of natural.
LF3	Frequency is once every 1 to 2 years, ideal timing is October to April, minimum duration is 14 days, and maximum inter-event period is 4 years.	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species[7]	NF3	Inundation off channel habitat between October and April for at least 10 days is required for spawning for olive perchlet. This is needed on average five to 10 times in 10 years with a maximum interflow period of four years. A bankfull about two to four weeks after a spawning flow is beneficial for productivity.
		Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas	NF7	
		No loss of native fish species	NF1	
		Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	NV2	At this flow rate, several low lying anabranches will be connected.

[7] Specifically, for olive perchlet in the lower Macintyre River

Bankfull, anabranch connecting and overbank flows

Bankfull refers to flows that are high enough to wet the upper portion of the channel. At this flow rate most in channel habitats and most low-lying wetlands are inundated. There is partial or full longitudinal connectivity with most small in-channel barriers (e.g. weirs) drowned out.

Anabranch connecting flows are sufficient to start wetting this off-channel habitat, with durations that provide for wetting of this habitat and ideally for flows to extend the length of reconnecting anabranches. Characterisation of these flows may require comparison of flows across multiple gauges or for full connection to occur across several events over several weeks.

Overbank flows provide broad scale lateral connectivity between the river and the floodplain. At this flow rate nutrient, carbon and sediment cycling between the floodplain and channel occurs, promoting large-scale productivity. Wetlands are fully inundated and water may persist in these off-channel habitats for longer.

The EWRs for bankfull, anabranch connecting and overbank flows are generally defined as events (see Table 11). In some cases, the pattern of these events across time is also relevant. For example, a flow may commence to fill an anabranch and then recede disconnecting the anabranch. A second flow not long after the first may reconnect the anabranch and enable additional productivity gains or reconnect fish species to the river following off-channel breeding events.

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

Table 11 Objectives and related important flow components used to develop EWRs for bankfull, anabranch connecting and overbank flows

Environmental watering requirement		Environmental objective		Important flow regime characteristics
BANKFULL				
BK1	The frequency of bankfull flows is determined at a planning unit scale in response to landscape and channel structure. It ranges from 1 in 1 through to 1 in 3 years. There is no specified ideal timing, minimum duration is 3 days, and maximum inter-event period is four years.	Maintain the extent and improve the condition of river red gum communities closely fringing river channels	NV3	Condition of riparian vegetation, such as river red gum in the mid to upper parts of the catchment, will benefit from bankfull and above flows anytime of the year. A frequency of 1 in 1–2 years is ideal to maintain good condition, with longer time between flows reducing condition reaching a critical threshold at 4 (Casanova 2015).
		Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	NV2	At this flow rate, additional anabranches will be connected. The pattern of connective flows influences the structure of wetland plant communities, with impacts to diversity and abundance (Reid, Reid & Thoms 2015).
		Maintain the number and type of waterbird species	WB1	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 dryier times.
		Increase total waterbird abundance across all functional groups	WB2	
		Maintain the extent and improve condition of waterbird habitats	WB5	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.
		Create quality instream, floodplain and wetland habitat	EF2	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-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).
		Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	EF5	

Environmental watering requirement		Environmental objective		Important flow regime characteristics
		Support instream and floodplain productivity	EF4	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).
		Provide movement and dispersal opportunities within, and between catchments for water-dependent biota to complete lifecycles and disperse into new habitats	EF3a	Upstream dispersal of fish requires weir drown outs. This 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. The achievement of this ecosystem function objective will contribute to achievement of native fish objectives that require productivity and fish movement. These are objectives NF1, NF2, NF3, NF4, NF5 and NF8.
		A 25% increase in abundance of mature (harvestable size) Golden perch and Murray cod	NF6	In addition to spawning flows above for Murray cod and Golden perch, connectivity and productivity flows are needed for this objective.
BK2	Bankfull 2 or greater: Frequency two or more events in every 1 to 2 years, the ideal timing is October to April, minimum duration is no less than natural, and maximum inter-event period is four years	Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	NV2	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).

Environmental watering requirement		Environmental objective		Important flow regime characteristics
		Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains: lignum shrublands	NV4c	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).
		Maintain the number and type of waterbird species	WB1	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.
		Increase opportunities for non-colonial waterbird breeding	WB3	
ANABRANCH CONNECTION				
AC1	To be determined based on number of days below commence to flow (ML/d), number of days above commence to flow in each water year, using the historical observed data.	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	EF5	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). Achievement of this objective will contribute to achievement of outcomes associated with objectives NF1, NF2, NF3, NF4, NF5, NF6, NF7 and NF8.
		Increase opportunities for non-colonial waterbird breeding	WB3	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.

Environmental watering requirement		Environmental objective		Important flow regime characteristics
		Maintain the extent and viability of non-woody vegetation communities occurring within channels	NV1	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).
		Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	NV2	
		Provide and protect a diversity of refugia across the landscape	EF1	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 et al. 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).
		Maintain the number and type of waterbird species	WB1	
		Increase total waterbird abundance across all functional groups	WB2	
AC2	To be determined based on duration of connecting flows (days). This may require comparison of flows across more than one gauge.	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	EF5	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 important factors in the movement of organic carbon and nutrients (McGinness 2007; McGinness & Arthur 2011).
		Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	NV2	
		Support instream and floodplain productivity	EF4	

Environmental watering requirement		Environmental objective		Important flow regime characteristics
SMALL OVERBANK				
OB1	Small overbank or greater (from bankfull to a 1 in 8 year size flood): Frequency is once in 3 years, there is no specified ideal timing however should a small overbank be created with held environmental water a timing between September and February will maximise environmental outcomes, minimum duration is 3 days, and maximum inter-event period is four years.	Maintain the extent and improve the condition of river red gum communities closely fringing river channels	NV3	A small overbank that inundates river red gum on the floodplain 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).
		Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	NV2	A larger flow event will provide greater connection to wetlands and anabranches (Reid, Reid & Thoms 2015).
		No loss of native fish species	NF1	A small overbank flow from September to February for at least 3 days every 3 to 5 years is required for condition and movement/dispersal outcomes. To achieve productivity, overland flows need to return to the main channels (Baldwin et al. 2016).
		Maintain the number and type of waterbird species	WB1	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).
		Increase opportunities for non-colonial waterbird breeding	WB3	
		Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	EF5	Cycles of connection and disconnection create off channel billabong refuges and lentic habitats (Mallen-Cooper & Zampatti 2018). No loss of connection with the floodplain is required to maintain natural wetting and drying cycles, and associated nutrient processes. Achievement of this objective will contribute to achievement of outcomes associated with objectives NF1, NF2, NF3, NF4, NF5, NF6, NF7 and NF8.

Environmental watering requirement		Environmental objective		Important flow regime characteristics
LARGE OVERBANK				
OB2	Above a 1 in 8 year flood level through to 1 in 100 year flood. Frequency is once in every 7 to 10 years, there is no specified ideal seasonal timing, minimum duration is no less than natural, and maximum inter-event period is no more than natural	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands	EF5	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).
		Support groundwater conditions to sustain groundwater-dependent biota	EF6	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 woody vegetation such as Coolibah and Black box.
		Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Black box	NV4 b	Overbank 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 7 years, with a critical spell duration of 10 years (Casanova 2015).
		Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Coolibah woodland	NV4 e	
		Maintain the number and type of waterbird species	WB1	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).
		Increase opportunities for non-colonial waterbird breeding	WB3	

Summary of catchment scale environmental water requirements

It is the combination of the objectives and flows that will improve ecosystem health. Each flow will meet or contribute towards several objectives and an objective may set specific details for a flow, but also require other flows to be achieved. It is assumed that if the most specific requirements are met, then other species with more general or flexible requirements will be covered. The flows required by each of the objectives in Table 9, Table 10 and Table 11 have been defined by:

- the ideal timing, noting that a lesser ecological response may occur outside of this season with some species able to opportunistically use flows;
- minimum durations with longer flows being more beneficial; and
- minimum frequency and maximum inter-flow periods based on lifecycles of biota and known ecosystem tolerances.

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. The catchment scale EWRs are summarised in Table 12 and any planning unit scale specifics are provided in Appendix C. The timing of EWRs associated with productivity is the ideal timing to improve condition of fish prior to spawning, however flows at any time of the year will be beneficial. The flow thresholds associated with each flow component are shown in Table 13, as rounded to the nearest 5, 10 or 100 ML/d.

Table 12 Summary of catchment scale EWRs for the NSW Border Rivers

Flow component		Maximum inter-event period	Timing	Duration	Frequency
Cease-to-flow	CF	Median number of days above cease to flow in each water year 5th percentile of days above cease to flow in each water year			
Very low flow	VF	Median number of days above cease to flow in each water year 5th percentile of days above cease to flow in each water year			
Baseflow	BF1	Median number of days above cease to flow in each water year 5th percentile of days above cease to flow in each water year Deficiency volume in each water year			
	BF2	No more than natural	Sep to Mar	7 days min.	1 in 1–2 years
Small fresh	SF1	1 year	Oct to Apr (but can occur anytime)	10 days min.	Annual
	SF2	2 years	Sep to Apr[8]	14 days min.	1 in 1–2 years
Large fresh	LF1	2 years	Jul to Sep (but can occur anytime)	5 days min.	1 in 1–2 years
	LF2	4 years	Oct to Apr	5 days min.	1 in 2–3 years

[8] September to December for Murray cod.

Flow component		Maximum inter-event period	Timing	Duration	Frequency
	LF3	4 years	Oct to Apr	10 days min.	1 in 1–2 years
Bankfull	BK1	4 years	Any time	3 days min.	1 in 1–2 years
	BK2	4 years	Oct to Apr	No less than natural	2 or more in 1–2 years
Anabranch connection	AC1	Median number of days above commence to flow in each water year 5th percentile of days above commence to flow in each water year			
	AC2	7 years	Any time	No less than natural	No less than natural
Small overbank or greater	OB1	4 years	Any time	3 days min.	1 in 3 years
Large overbank or greater	OB2	No more than natural	Any time	No less than natural	1 in 7–10 years

Table 13 Flow threshold estimates (ML/day) for flow components in planning units in the NSW Border Rivers catchment[9].

Planning unit	Gauge	Low flows			Freshes		Overbank[10]			End of system annualised flow target
		Cease-to-flow	Very low	Baseflow	Small	Large	Bankfull	Small	Large	
TENTERFIELD CREEK										
Tenterfield creek at Clifton	416003	<2 ML/d	N/A	2-20 ML/d	20-450 ML/d	450-10000 ML/d	3100-10000 ML/d	>10000 ML/d	N/A	*
MOLE RIVER										
Mole R at Donaldson	416032	<5 ML/d	<45 ML/d	45-170 ML/d	170-550 ML/d	550-16000 ML/d	7100-16000 ML/d	>16000 ML/d	N/A	*
REEDY CREEK										
Dumaresq R Roseneath	416011	<1 ML/d	<10 ML/d	10-160 ML/d	160-6250 ML/d	6250-19000 ML/d	19000-66600 ML/d	>66600 ML/d	N/A	*
BEARDY RIVER										
Beardy R at Haystack	416008	<1 ML/d	N/A	1-50 ML/d	50-700 ML/d	700-15200 ML/d	4700-15200 ML/d	>15200 ML/d	N/A	*
GLEN INNES										
Severn R at Ducca Marrin	416067	<2 ML/d	<20 ML/d	20-120 ML/d	120-700 ML/d	700-15000 ML/d	5600-15000 ML/d	>15000 ML/d	N/A	*
BONSHAW										
Dumaresq R U/S Bonshaw	416007	<5 ML/d	<40 ML/d	40 -150 ML/d	150-600 ML/d	600-15000 ML/d	10000-15000 ML/d	>15000 ML/d	N/A	*

[9] '*' denotes values which are yet to be determined.

[10] These EWRs also include ideal total event volumes. These values are yet to be determined. Determining these values is part of the workplan described in Chapter 6.

Planning unit	Gauge	Low flows			Freshes		Overbank[10]			End of system annualised flow target
		Cease-to-flow	Very low	Baseflow	Small	Large	Bankfull	Small	Large	
KINGS PLAIN										
Severn R at Ashford	416006	<5 ML/d	<40 ML/d	40-170 ML/d	170-2100 ML/d	2100-23300 ML/d	7100-23300 ML/d	>23300 ML/d	N/A	*
INVERELL										
Macintyre River at Ridgelands	416031	<20 ML/d	<210 ML/d	210- 550 ML/d	550-4500 ML/d	4500-50000 ML/d	15000-50000 ML/d	>50000 ML/d	N/A	*
CAMPBELLS CREEK & CAMP CREEK										
Dumaresq R at Glenarbon	416040	<10 ML/d	<80 ML/d	80-150 ML/d	150-1300 ML/d	1300-8500 ML/d	8500 - 53000 ML/d	>53000 ML/d	N/A	*
YETMAN										
Macintyre at Holdfast	416012	<10 ML/d	<80 ML/d	80-100 ML/d	100-1500 ML/d	1500-11300 ML/d	11300-45000 ML/d	>45000 ML/d	N/A	*
CONFLUENCE OF MACINTYRE RIVER AND DUMARESQ RIVER										
Macintyre at Boggabilla	416002	<20 ML/d	<230 ML/d	230-840 ML/d	840-3100 ML/d	3100-21400 ML/d	10900 - 21400 ML/d	>21400 ML/d	>280000 ML/d	*
OTTLEYS CREEK										
Ottleys Creek at Collatai	416020	*	*	*	*	*	*	*	*	*
WHALAN & CROPPA CREEKS										
Whalan at Euraba	416072	*	*	*	*	*	*	*	*	*

Planning unit	Gauge	Low flows			Freshes		Overbank[10]			End of system annualised flow target
		Cease-to-flow	Very low	Baseflow	Small	Large	Bankfull	Small	Large	
MACINTYRE RIVER FLOODPLAIN UPSTREAM OF BOOMI										
Macintyre at Goondiwindi	416201A	<10 ML/d	<120 ML/d	120-260 ML/d	260-1300 ML/d	1300-27000 ML/d	7000-27000 ML/d	>27000 ML/d	>56000 ML/d	*
Macintyre River at Terrewah	416047	<5 ML/d	<40 ML/d	40-110 ML/d	110-1300 ML/d	1300-7900 ML/d	3300-7900 ML/d	>7900[11] ML/d	>114000[11] ML/d	*
Macintyre u/s Boomi	416043	<5 ML/d	<60 ML/d	60-100 ML/d	100-650 ML/d	650-2510 ML/d	1200-2510 ML/d	N/A[11]	N/A[11]	*
Boomi R at Boomi Weir offtake	416037	<5 ML/d	N/A	5-20 ML/d	20-750 ML/d	750-3250 ML/d	1100-3250 ML/d	N/A[11]	N/A[11]	*
Macintyre at Kanowna	416048	<5 ML/d	<40 ML/d	40-90 ML/d	90-900 ML/d	900-4900 ML/d	2500-4900 ML/d	N/A[11]	N/A[11]	*
MACINTYRE RIVER AND BOOMI RIVER FLOODPLAIN										
Barwon River at Mungindi	416001	<30 ML/d	<300 ML/d	300-550 ML/d	550-5400 ML/d	5400-13300 ML/d	7400-13300 ML/d	>13300 ML/d	>18000 ML/d	*

[11] Overbank events for these Planning Units are best measured at the Macintyre at Goondiwindi gauge (416201A) due to gauging limitations.

4.2 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 LTAA inflows) located on the Severn River, the Glenlyon Dam (261,000 ML capacity with 72 GL/y LTAA 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 as high as 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 change the timing and sizes of flows with base flows and small fresh sized flows increased in areas downstream of major dams and upstream of the major extraction points, while larger freshes and bankfull events have been decreased in frequency. Timing of flows has also been moved more 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) and in NSW 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 et al. (2005) report that with water resource development and river operation practices in place at that time, 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. (2008) for the Sustainable Rivers Audit found that hydrological condition at the Border Rivers sites declines from the upland zone upstream of regulation and diversion, through the slopes zone downstream of the storages, to the lowland zone and found that by the time most flows enter the Barwon-Darling downstream of Mungindi that 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 (2012) 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. In the absence of this analysis, it is not possible to suggest targeted actions to address the current gaps in the flow regime. Completion of flow analysis is included within the future workplan, described in Chapter 6.

4.3 Planned and held environmental water in Border Rivers

The following describes the planned and held environmental water arrangements as per the existing 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 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 8,000 ML/y of basic landholder right stock and domestic, 1,205 ML/y domestic and stock alluvial, 620ML/y low WU alluvial, 1,233 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 Catchment 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 10ML/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 8,000 ML. The timing, rate, volume and duration of the stimulus flow released is determined by OEH, in collaboration with other stakeholders such as DOI-W, 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, 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 and 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 across the NSW and QLD Border Rivers the Commonwealth Environmental Water Holder holds 38,933 of entitlements with a long term average annual yield of 14,506 ML (see Table 14). 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 environmental water requirements.

Table 14 Overview of Commonwealth licences held for environmental watering

Type of water licence	Registered entitlements (ML)	Long term average annual yield
Medium security (QLD)	15,540	5,241 ML
Unsupplemented (QLD)	19,358	7,843 ML
General security (NSW)	2,598	1,039 ML
Supplementary (NSW)	1,437	382 ML
Total	**38,933**	**14,506 ML**

Figure 15 Boomi Regulator
Photo: E Wilson

5. Risks, constraints and strategies

The DOI-Water Risk Assessment (DOI-W in prep.) identifies several areas at high risk of insufficient water. There are unmet EWRs and evidence of a degraded aquatic and water-dependent ecosystems.

Understanding the catchment specific environmental assets and experience with using planned and held environmental water in this catchment is still in its infancy, compared to other catchments.

Despite the limited availability and knowledge of the environmental assets and values within the catchment, the NSW Border Rivers LTWP provides crucial baseline information on the environmental water requirements.

This chapter broadly considers risks, constraints and future management strategies to improve water management for this catchment. Further detailed work is required to better understand the impacts of these risks and constraints and identify more targeted watering strategies.

5.1 Cooperative water management

Cooperative use of held 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 the CEWH (see Table 14 for current holdings). Coordinating deliveries of held environmental water with consumptive deliveries can help to achieve greater flow volumes from the smarter 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.

Strategic use of planned environmental water

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 OEH and DOIW. 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.

Cooperative river operations

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. Once this analysis is completed it will be possible to more accurately estimate the volume of HEW required to satisfactorily meet inchannel EWRs.

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 OEH 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.

Complementary land management

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.

5.2 Risks and constraints

The underlying reasons for an EWR no longer occurring as a part of the current water regime may vary. In some cases, these risks and constraints may be relevant to an objective, while in other cases these factors may be relevant to a specific flow component. A brief overview of the types of risks and constraints that may be present is provided below.

Risks and constraints

There are several long-term risks to EWRs. These can be broadly considered as things that need to be managed. The Basin Plan identifies insufficient water, unsuitable water quality and poor condition of water-dependent ecosystems as risks. In addition, within the Border Rivers climate change and inappropriate timing of flows may be impacting on the achievement of EWRs.

There is also risk to the EWRs from potential further development of the tributaries, unregulated water sources and floodplain harvesting. This further development includes changes to pool protection and projected dams and other increases in water capture and storage infrastructure. The EWRs collectively provide an indicator environmental impact, against which any future changes to water management can be assessed.

In addition to risks, there may be operational constraints to the achievement of EWRs. This may be due to operational, structural or channel limitations. Constraints are beyond short-term management and generally require funding of an infrastructure project to mitigate. The Constraints Management Strategy (CMS) does not apply to NSW Border Rivers. Constraints in this LTWP are generic, and outside of those that will be addressed by the CMS.

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 2015b); 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 15 Risks to meeting EWRs that may be present in the NSW Border Rivers

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
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.	All EWRs assessed as medium or lower likelihood may not possible to address through 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.	OEH, DOI-W and CEWO
	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.	OEH & DOI-W
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 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.	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 may require constraining to warmer months. Potential direct and indirect impacts on the objectives. Recovery may require increased frequency of environmental flows to encourage	Implement recommendations detailed in the Water Quality Management Plan to promote prevention of water quality incidents. Monitor water quality and if thresholds of ecological tolerance.	OEH and DOI-W

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	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 Severn River downstream of Pindari and the Macintyre River at Boggabilla. Glenlyon Dam is also prone to blue-green algae.	species recruitment and a return to stable populations.	Encourage improvement in land management	LLS with landholders
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
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	OEH, LLS, BCT, DPE
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.	It may become more difficult to meet the minimum durations of environmental water requirements, particularly in unregulated streams.	No further construction of regulating structures on unregulated tributaries. Revision of pumping rules may be required.	DOI-W

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	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.	Frequencies of EWRs in moderate and wet conditions may need to increase to enhance ecosystem recovery and sufficient resilience for dry times.	Monitor changes and adjust use of HEW and PEW in response	OEH
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.	OEH, DPIF
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.	OEH
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	Implement the Border Rivers Floodplain Management Plan and if	DOI-W, OEH

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	floodplain areas. These will be identified by the hotspots project.	and functions objectives associated with overbank environmental water requirements.	funding permits, undertake remedial work	
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 impacts on achievement of the objective “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
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 & DOI-W
Cold water pollution	Cold water pollution was rated as high likelihood for downstream of Pindari Dam, Glenlyon Dam and Coolmunda Dam in DOIW’s Risk assessment (DOI-W in prep.). 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, as associated with metabolic changes 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	DOI-W & WaterNSW
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.	OEH

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
Insufficient release rates from storages	The maximum daily release from storages may not be sufficient to create events that peak in higher flow components, 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.	OEH & CEWO
			Ensure no further development of unregulated tributaries, including no further construction of dams	DOI-W & WaterNSW
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 functions objectives and the durations of EWRs.	Investigate extent of risk and explore options for increasing environmental effectiveness of consumptive water releases.	OEH & WaterNSW
	Inappropriate rate and timing of release can mean that river levels rise and fall rapidly.	This directly impacts on achievement of some functions objectives.		
Dam turnover	Recent turnover 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, OEH & CEWO
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	Potential impacts on the achievement of objectives, through indirect processes. Degradation of water quality and riparian zones may require increased frequency of	Encourage improvement in land management	LLS with landholders

Type of risk	Description or example	Potential impact(s)	Potential management strategies	Responsible organisation(s)
	degradation and erosion can impact the geomorphology of channels. Water runoff and water quality can also be impacted.	environmental flows to enable to the system to compensate.		
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	OEH, 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, OEH, DPIF & 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 significant loss of environmental values and assets.	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, OEH, DPIF & DPI

5.3 Climatic conditions

There are short-term and long-term climatic patterns which can drive changes to environmental assets, rainfall patterns, water held in storages and river flows.

Shorter-term climatic patterns can be highly variable. Water managers are required to adapt to these changes through the flexible delivery of water and the development of responsive strategies to manage the needs of aquatic ecosystems.

Long term climatic changes which result in significant alterations to frequency, timing and duration which exceed the current adaptive limitations of plants and animals will necessitate a review of the LTWP.

The frequency of EWRs anticipates a level of climatic variability, with a lower frequency of events in dry times expected to be countered by a higher frequency in wet times. The maximum interflow period is relevant across all climatic conditions, as it often represents inflexible species life cycle requirements.

Climate change predictions

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[12] (scenario 2), the changes in Table 16 are predicted by 2030 and 2070.

[12] 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.

Table 16 Potential climate-related risks in the New England and NSW North West.

Potential risk due to climate change	Description of risk		NARCLiM projection (scenario 2)	
			2020–39	2060–79
Change in rainfall	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.	Summer	-3.3%	+9.8%
		Autumn	+14.9%	+16.8%
		Winter	-7.6%	-0.7%
		Spring	+2.6%	-0.7%
Change in average temperature	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.	Summer	+0.89C	+2.28C
		Autumn	+0.72C	+2.20C
		Winter	+0.48C	+1.92C
		Spring	+0.80C	+2.33C
Change in number of hot days (max. temp. >35C)	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.	Annual	+7.1	+23.4
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 Glenn 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[13]	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.			

There are uncertainties with these climate change predictions, and the predicted changes will not 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.

[13] 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.

Water management under different water resource availability scenarios

In addition to the longer term climate related risks outlined above, environmental water managers need to 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). 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).

The following section provides an overview the adaptive priorities across different climatic conditions. The following section introduces the broad priorities for each scenario, from very dry to wet conditions, noting that these scenarios point to the climatic conditions, not necessarily the volumes of planned and held environmental water available.

Some of the LTWP objectives are more relevant in certain conditions. For example in very dry and dry conditions, objectives for population expansion take a lesser priority to objectives such as ‘NF1: No loss of native fish species’. There may also be longer term LTWP objectives that include condition improvement or increases in extent, such as or ‘NV2: Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains’ that are refocused to match the shorter term broad priority of a resource availability scenario (RAS).

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 17.

In these conditions management is focused to limiting exceedance of maximum inter-flow periods, as opposed to maintaining the long-term ideal frequency of events. Management strategies for achieving these broad priorities may include:

- 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

Table 17 Priority LTWP objectives and flow components in a very dry RAS

Priority LTWP objective	Flow component								
	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									
NV2: Maintain the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains									
NV3: Maintain the extent of river red gum communities closely fringing river channels									
NV4c: Maintain the extent of native woodland and shrubland communities on floodplains – Lignum shrublands									
WB1: Maintain the number and type of waterbird species									
NF1: No loss of native fish species									
EF1: Provide and protect a diversity of refugia across the landscape									
EF2: Create quality instream, floodplain and wetland habitat									

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 interflow periods. The priority objectives, and if relevant, refocused objectives for dry conditions are shown in Table 18.

Management strategies for achieving these broad priorities may include:

- Explore option for stimulus flow to provide a small fresh through the system

Table 18 Priority objectives and flow components in a dry RAS

Priority LTWP objective	Flow component								
	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									
NV2: Maintain the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains									
NV3: Maintain the extent and the condition of river red gum communities closely fringing river channels									
NV4c: Maintain the extent and maintain the condition of native woodland and shrubland communities on floodplains – Lignum shrublands									
WB1: Maintain the number and type of waterbird species									
WB2: Maintain total waterbird abundance across all functional groups									
WB5: Maintain the extent and condition of waterbird habitats									
NF1: No loss of native fish species									
NF2: Maintain the distribution and abundance of short to moderate-lived generalist native fish species									
NF3: Maintain the distribution and abundance of short to moderate-lived floodplain specialist native fish species									
NF4: Maintain native fish population structure for moderate to long-lived flow pulse specialist native fish species									
NF5: Maintain native fish population structure for moderate to long-lived riverine specialist native fish species									
NF7: Maintain the prevalence of key short to moderate-lived floodplain specialist native fish species in core population areas									
NF8: Maintain the prevalence of key moderate to long-lived riverine specialist native fish species in core population areas									
EF1: Provide and protect a diversity of refugia across the landscape									
EF2: Create quality instream, floodplain and wetland habitat									
EF3a: Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments									
EF4: Support instream and floodplain productivity									
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries									

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, and if relevant, refocused objectives for moderate conditions are shown in Table 19.

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 19 Priority objectives and flow components in a moderate RAS

Priority LTWP objective	Flow component								
	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									
NV2: Increase the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains									
NV3: Maintain the extent and improve the condition of river red gum communities closely fringing river channels									
NV4b: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Black box woodland									
NV4c: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Lignum shrublands									
NV4e: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Coolibah woodland									
WB1: Maintain the number and type of waterbird species									
WB2: Increase total waterbird abundance across all functional groups									

Priority LTWP objective	Flow component								
	Cease-to-flow	Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small overbank	Large overbank	Anabranch connection
WB3: Increase opportunities for non-colonial waterbird breeding									
WB5: Maintain the extent and improve condition of waterbird habitats									
NF1: No loss of native fish species									
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish species									
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species									
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species									
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species									
NF6: A 25% increase in abundance of mature (harvestable sized) 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									
NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas									
EF1: Provide and protect a diversity of refugia across the landscape									
EF2: Create quality instream, floodplain and wetland habitat									
EF3a: Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments									
EF3b: Provide movement and dispersal opportunities catchments for water-dependent biota to complete lifecycles and disperse into new habitats – between catchments									
EF4: Support instream and floodplain productivity									
EF5: Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands									
EF6: Support groundwater conditions to sustain groundwater-dependent biota									
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries									

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 20.

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 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 20 Priority objectives and flow components in a wet RAS

Priority LTWP objective		Flow component							
	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									
NV2: Increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains									
NV3: Maintain the extent and improve the condition of river red gum communities closely fringing river channels									
NV4b: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Black box woodland									
NV4c: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Lignum shrublands									
NV4e: Increase the extent and improve the condition of native woodland and shrubland communities on floodplains – Coolibah woodland									
WB1: Maintain the number and type of waterbird species									
WB2: Increase total waterbird abundance across all functional groups									
WB3: Increase opportunities for non-colonial waterbird breeding									
WB5: Maintain the extent and improve condition of waterbird habitats									
NF1: No loss of native fish species									

Priority LTWP objective		**Flow component**							
	Cease-to-flow	**Very low flow**	**Baseflow**	**Small fresh**	**Large fresh**	**Bankfull**	**Small overbank**	**Large overbank**	**Anabranch connection**
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish species									
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species									
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species									
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species									
NF6: A 25% increase in abundance of mature (harvestable sized) golden perch and Murray cod									
NF7: Increase the prevalence and expand the population of key short to moderate-lived floodplain specialist native fish species into new areas									
NF8: Increase the prevalence and expand the population of key moderate to long-lived riverine specialist native fish species into new areas									
EF1: Provide and protect a diversity of refugia across the landscape									
EF2: Create quality instream, floodplain and wetland habitat									
EF3a: Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments									
EF3b: Provide movement and dispersal opportunities catchments for water-dependent biota to complete lifecycles and disperse into new habitats – between catchments									
EF4: Support instream and floodplain productivity									
EF5: Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands									
EF6: Support groundwater conditions to sustain groundwater-dependent biota									
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries									

5.4 Determining watering priorities

Section 2 identifies the water-dependent values and assets of the NSW Border Rivers using the criteria of Schedule 8 of the Basin Plan. The section also provides an overview of the environmental values and assets identified in the BWS and this LTWP. In addition, EWRs have now been determined for the NSW Border Rivers. Assessment of these EWRs will show which are occurring satisfactorily under the current water regime, and which EWRs are unlikely to occur in the future. In combination with the values and assets identified in Section 2, it will be possible for future management to:

- protect EWRs that have a higher likelihood of continuing to occur under a continuation of the current water regime;
- identify EWRs that have not been occurring and have a lower likelihood of occurring in the future if the current water regime continues (i.e. 'missing' EWRs);
- further prioritise these 'missing' EWRs based on objectives and environmental values and assets;
- manage the use of planned and held environmental water to restore priority EWRs and associated environmental values and assets.

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 components (flow thesholds 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 occurrence of EWRs.

Further, implementation of the Northern Basin Amendment may change the volume of held environmental water in the Border Rivers. This will impact on the ability of governments to meet EWRs and the potentially waterable values and assets. Future work in this catchment needs to identify the assets that can be managed using both planned and held environmental water (NSW and Commonwealth).

5.5 Addressing knowledge gaps and measuring progress

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 components, such as the baseflow.

There are other significant knowledge gaps in the NSW Border Rivers that would further benefit the targeting of actions to meet EWRs and the LTWP objectives. These include the identification of high quality habitat drought refugia; expanding habitat mapping, location and watering needs of cultural assets; and flow analysis to determine the underlying reasons for some EWRs that are unlikely to occur in the future (e.g. are flow events not meeting EWRs due to duration or other criteria). Further analysis is also needed to determine appropriate specifics for cease-to-flow and very low flow environmental water requirements. As regionally specific knowledge is gained, revision of the objectives, targets and/or EWRs may be required.

6. Going forward

OEH has been working with local communities over many years to deliver water in five regulated river catchments. In each of these catchments, an Environmental Water Advisory Group (or EWAG) has been established to 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 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.

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 NSW Border Rivers. Any mechanism established will need to recognise the interactions between northern systems and function across catchments. Implementation of the 'toolkit measures' may also be a focus of work at a regional level. Other items that are best addressed with local knowledge and in collaboration with regional stakeholders are outlined in Table 21.

In the short term while the workplan is being completed, it is possible to outline a broad strategy for environmental water management. This strategy is based on the environmental values and assets, objectives, known changes to flow regime and opportunities available through current planned and held environmental water. The key features of this strategy would include the following.

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 in order to create pools in the anabranches and fill low lying wetlands. To achieve the flow heights needed may require coordinated releases of held environmental and consumptive environmental water from Coolmunda, Glenlyon and Pindari Dams. In drier years this 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 wetter 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 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 oensure 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.

Effective and efficient use of all water

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.

Table 21 Forward workplan for the NSW Border Rivers

Item	Actions required
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 environmental water requirements.
Cooperative water management	Ongoing collaboration with CEWO, DOIW, DPI Fisheries and Water NSW to plan and implement releases of held and planned environmental water and monitoring in NSW Border Rivers
	Contribute knowledge to the Border Rivers Commission, as required
	Investigate limitations and barriers to achieving EWRs with consumptive flows
	Identify opportunities to increase achievement of EWRs from refined river operations
	Identify and maintain rules in the WSP and current river operations that are contributing to current achievement of environmental water requirements.
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 stragies.
Risks and constraints	Determine impacts of risks and constraints on specific EWRs and identify targeted management options.

Item	Actions required
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?
Floodplain harvesting	Assess the impacts of floodplain harvesting on EWRs and condition of floodplain ecosystems
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.
Knowledge gaps	Identify any changes to the LTWP required in response to findings from research currently underway.
	Monitor resource condition and impacts of flows to further build an evidence base for watering actions and inform adaptive management of annual EWR priorities.
	Establish a process to identify and incorporate cultural values and assets
Annual environmental water planning	CEWO prepares an environmental water use options report for each valley. Often advisory groups inform the development of these plans which include a list of river and wetland sites that may be targeted under a range of climate and other scenarios. Depending on seasonal conditions, watering events and their objectives may change. Plans must be flexible to accommodate these variations.

6.1 Measuring progress

Monitoring, evaluating and reporting (MER) and adaptive management are integral parts of the environmental water management process that inform planning and operational decisions. Monitoring how water moves through the system and how the environment responds to watering events informs ongoing improvements to water management. This information will also assist in progressing adaptive management of environmental water and inform revisions of this LTWP every five years.

Monitoring and evaluating water management draws on contributions from Australian and NSW Government agencies, as well as university and other research institutions.

OEH’s Environmental Water Monitoring and Evaluation Program (MER Program) provides the structure within which the various monitoring activities are brought together to provide a broad evaluation of how the environment is responding to environmental water management. The MER program has three core outcomes: (i) measurement of LTWP outcomes (ii) improved decision making for environmental water planning and delivery, and (iii) improved institutional arrangements. To do this, the OEH MER Program will:

- collate and adopt relevant environmental watering and wetland management objectives, including those within LTWPs
- establish a program that will evaluate progress towards achieving outcomes defined within LTWPs
- meet OEH's obligations for monitoring as stated in high level plans including the Basin Plan
- develop a strategic plan to address information and monitoring gaps or short-falls
- support continual improvement of OEH operations through designing an appropriate monitoring program for the provision of high-quality, scientifically-robust information
- collaborate with water delivery partners (particularly the CEWO), DoI-W, wetland managers, other agencies and researchers to value-add to monitoring outcomes and minimise duplication in monitoring efforts
- create increased government and community confidence, awareness and support for environmental water management through increased transparency, community engagement and improved reporting of environmental water outcomes and management
- streamline reporting requirements under WRPs, LTWPs, Schedule 12 of the Basin Plan and the National Partnership Agreement.

The OEH MER program is also integrated with DoI-W and DPIF MER programs to create a unified approach to delivering Basin Plan and NSW evaluation and reporting requirements. The NSW approach has capitalised on existing MER by retaining the best available scientific knowledge, evidence and analyses to develop this new cohesive program, ensuring credibility, transparency and usefulness of findings. The NSW MER program consists of:

- a NSW MER Framework that describes the principles, types of monitoring, alignment across NSW agencies efforts, knowledge gaps, externalities and constraints, and relationships to the BWS and Basin Plan. It also describes how existing knowledge and programs are built on in a cost-effective and coordinated manner
- OEH's Healthy Inland Wetlands Environmental Water Program that describes the approach to developing LTWP MER objectives, evaluation of management actions, and reporting
- customised MER Plans that summarise the proposed integrated MER activities for surface water monitoring in each catchment
- a monitoring Methods Manuals that describe research themes (e.g. fish, hydrology, vegetation, water quality, macroinvertebrates, waterbirds, etc.). These manuals, when developed, will contain specific information relating to survey, data handling and analysis techniques, conceptual models, the location of survey sites and cooperative research arrangements.

The following principles are used as a foundation for developing this integrated MER program:

- uses 'SMART' (Specific, Measurable, Achievable, Realistic, Time-bound) objectives
- relies on an agreed program logic
- uses best available knowledge and multiple lines of evidence
- emphasis collaboration and builds on existing programs to improve efficiency and reduce duplication in effort
- offers open access to information
- recognises the influence of externalities.

6.2 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 16 Dumaresq River, NSW Border Rivers
Photo L. Cameron and J. St Vincent Welch.

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Appendix A Ecological objectives relevant to each planning unit

Table 22 Ecological objectives for each planning unit in the NSW Border Rivers catchment

		Tenterfield Creek	Mole River	Reedy Creek	Beardy River	Glenn Innes	Bonshaw	Kings Plain	Inverell	Campbells Creek & Camp Creek	Yetman	Ottleys Creek	Confluence of Macintyre & Dumaresq	Macintyre floodplain u/s Boomi	Whalan Creek & Croppa Creek	Macintyre River & Boomi River floodplain
Code	**Ecological objective**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
NATIVE FISH																
NF1	No loss of native fish species	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NF3	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species											•	•	•	•	•
NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

		Tenterfield Creek	Mole River	Reedy Creek	Beardy River	Glenn Innes	Bonshaw	Kings Plain	Inverell	Campbells Creek & Camp Creek	Yetman	Ottleys Creek	Confluence of Macintyre & Dumaresq	Macintyre floodplain u/s Boomi	Whalan Creek & Croppa Creek	Macintyre River & Boomi River floodplain
Code	**Ecological objective**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
NF6	A 25% increase in abundance of mature (harvestable sized) 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)	•	•	•	•	•				•	•	•	•	•	•	•
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)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NATIVE VEGETATION																
NV1	Maintain the extent and viability of non-woody vegetation communities occurring within channels	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NV2	Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains											•	•	•	•	•

		Tenterfield Creek	Mole River	Reedy Creek	Beardy River	Glenn Innes	Bonshaw	Kings Plain	Inverell	Campbells Creek & Camp Creek	Yetman	Ottleys Creek	Confluence of Macintyre & Dumaresq	Macintyre floodplain u/s Boomi	Whalan Creek & Croppa Creek	Macintyre River & Boomi River floodplain
Code	**Ecological objective**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
NV3	Maintain the extent and improve the condition of river red gum communities closely fringing river channels	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
NV4a	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – River red gum woodland											•	•	•	•	•
NV4b	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – Black box woodland															•
NV4c	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – Lignum shrublands												•	•	•	•
NV4e	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains – Coolibah woodland												•	•	•	•

		Tenterfield Creek	Mole River	Reedy Creek	Beardy River	Glenn Innes	Bonshaw	Kings Plain	Inverell	Campbells Creek & Camp Creek	Yetman	Ottleys Creek	Confluence of Macintyre & Dumaresq	Macintyre floodplain u/s Boomi	Whalan Creek & Croppa Creek	Macintyre River & Boomi River floodplain
Code	**Ecological objective**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
WATERBIRDS																
WB1	Maintain the number and type of waterbird species	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
WB2	Increase total waterbird abundance across all functional groups	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
WB3	Increase opportunities for non-colonial waterbird breeding											•	•	•	•	•
WB5	Maintain the extent and improve condition of waterbird habitats											•	•	•	•	•
ECOLOGICAL FUNCTION																
EF1	Provide and protect a diversity of refugia across the landscape	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
EF2	Create quality instream, floodplain and wetland habitat	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
EF3a	Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats – within catchments						•			•			•	•		

		Tenterfield Creek	Mole River	Reedy Creek	Beardy River	Glenn Innes	Bonshaw	Kings Plain	Inverell	Campbells Creek & Camp Creek	Yetman	Ottleys Creek	Confluence of Macintyre & Dumaresq	Macintyre floodplain u/s Boomi	Whalan Creek & Croppa Creek	Macintyre River & Boomi River floodplain
Code	**Ecological objective**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
EF3b	Provide movement and dispersal opportunities catchments for water-dependent biota to complete lifecycles and disperse into new habitats – between catchments													•		•
EF4	Support instream and floodplain productivity	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
EF5	Support nutrient, carbon and sediment transport along channels, and exchange between channels and floodplains/wetlands											•	•	•	•	•
EF6	Support groundwater conditions to sustain groundwater-dependent biota			•	•	•				•		•	•	•		
EF7	Increase the contribution of flows into the Murray and Barwon-Darling from tributaries	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

NSW Border Rivers Long Term Water Plan

Part B: Planning units

7. Introduction to planning units

This section of the LTWP provides further detail of the environmental assets and values at a planning unit scale (Appendix B). It also specifies any planning unit scale tailoring of the catchment scale EWRs (Appendix C).

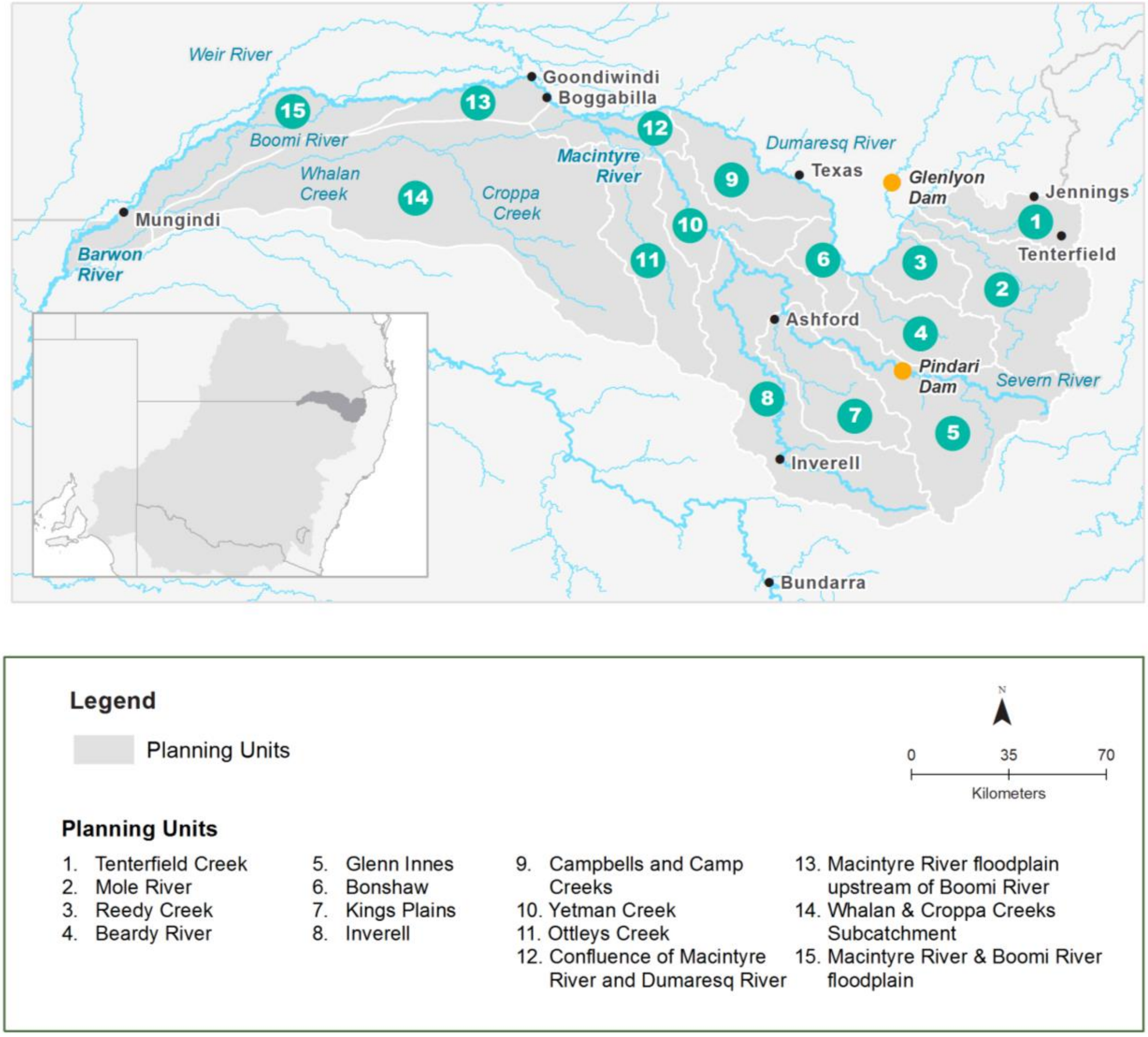

Figure 17 Planning units in the NSW Border Rivers LTWP

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.

Appendix B Assets in each planning unit

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

Table 23 Hectares (ha) of native vegetation in each NSW Border Rivers planning unit

	Tenterfield Creek	Mole River	Reedy Creek	Beardy River	Glenn Innes	Bonshaw	Kings Plain	Inverell	Campbells Creek & Camp Creek	Yetman	Ottleys Creek	Confluence of Macintyre & Dumaresq	Macintyre floodplain u/s Boomi	Whalan Creek & Croppa Creek	Macintyre River & Boomi River floodplain
Vegetation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
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 24 Native fish species catch records (C) and expected distribution (E) in the NSW Border Rivers.

Native fish species by functional group	Threatened species status[14]	Planning units														
		1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glenn 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
Flow pulse specialists																
Golden perch		CE	CE	CE	E	CE	CE	C	CE	CE	CE	E	CE	CE	CE	CE
Silver perch	V					E		CE	CE		CE		E	E	E	E
Spangled perch		C	C	E	CE		CE		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	CE	E	E
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						

[14] E = listed as endangered in FM Act 1994, v = listed as vulnerable in FM Act 1994, V = listed as vulnerable in EPBC Act

Native fish species by functional group	Threatened species status[14]	Planning units														
		1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glenn 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
Floodplain specialists																
Olive perchlet*		CE	CE	E	E		CE		C	CE	CE		CE	CE	E	CE
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																
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							
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 25 Waterbird sightings recorded in each planning unit in the NSW Border Rivers catchment.

Waterbird species by functional group	Threatened species status[15]	Planning units: 1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glenn 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
Ducks																
Australasian grebe		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Australasian shoveler		●				●			●				●	●		
Blue-billed duck	V					●			●							
Buff-banded rail		●							●							
Chestnut teal		●				●							●			
Freckled duck	V												●		●	
Great crested grebe						●			●					●		
Grey teal		●	●	●	●	●		●	●	●	●	●	●	●	●	●
Hardhead		●	●	●	●	●	●	●	●	●	●	●	●	●	●	
Hoary-headed grebe		●				●		●	●			●		●		
Musk duck		●				●			●				●			
Pacific black duck		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Pink-eared duck		●				●			●				●	●	●	

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

Waterbird species by functional group	Threatened species status[15]	Planning units														
		1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glenn 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
Herbivores																
Australian wood duck		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Black-tailed native-hen						●					●		●	●	●	●
Black swan		●			●	●	●	●	●	●	●		●	●	●	●
Dusky moorhen		●	●	●	●	●	●	●	●	●	●		●	●		●
Eurasian coot		●		●	●	●		●	●	●			●	●	●	
Magpie goose	V	●	●													
Plumed whistling-duck													●	●	●	●
Purple swamphen		●	●	●	●	●		●	●	●			●	●		
Large waders																
Black-necked stork	E1					●				●	●			●	●	●
Brolga	V							●						●		●
Piscivore																
Australian gull-billed tern	C													●		
Silver gull									●							
Whiskered tern								●	●				●	●	●	
White-winged black tern	CJ	●														

Waterbird species by functional group	Threatened species status[15]	Planning units: 1. Tenterfield Creek	2. Mole River	3. Reedy Creek	4. Beardy River	5. Glenn 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
Shorebirds																
Banded lapwing			●				●	●	●			●	●		●	●
Bar-tailed godwit	CJK	●														
Black-fronted dotterel		●	●	●	●	●		●	●		●	●	●	●	●	●
Black-winged stilt		●		●		●			●				●	●	●	●
Common greenshank	CJK							●								
Latham’s snipe	JK	●	●			●			●				●	●	●	
Marsh sandpiper	CJK					●								●	●	
Masked lapwing		●	●	●	●	●	●	●	●		●	●	●	●	●	●
Pectoral sandpiper	JK					●										
Red-capped plover											●					
Red-kneed dotterel		●				●			●		●		●	●		●
Red-necked avocet						●								●		
Sharp-tailed sandpiper	CJK													●		

Table 26 Key measures of ecosystem function parameters at a PU scale (in stream length and % of total stream length for the PU)

	Tenterfield Creek	Mole River	Reedy Creek	Beardy River	Glenn Innes	Bonshaw	Kings Plain	Inverell	Campbells Creek & Camp Creek	Yetman	Ottleys Creek	Confluence of Macintyre & Dumaresq	Macintyre floodplain u/s Boomi	Whalan Creek & Croppa Creek	Macintyre River & Boomi River floodplain
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
HYDROLOGICAL STRESS															
0.0 – 0.2 Very Low	157 (52%)	321 (64%)	150 (91%)	245 (96%)	451 (71%)	81 (85%)	205 (56%)	597 (69%)	149 (74%)	120 (59%)	222 (72%)	38 (26%)	47 (42%)	520 (67%)	225 (35%)
0.2 – 0.4 Low	9 (3%)	150 (30%)	1 (1%)	2 (1%)	48 (7%)	1 (1%)	55 (15%)	17 (2%)	0	0	0	0	0	0	0
0.4 – 0.6 Moderate	6 (2%)	21 (4%)	0	2 (1%)	31 (5%)	5 (5%)	57 (15%)	37 (4%)	2 (1%)	0	0	0	0	7 (1%)	96 (15%)
0.6 – 0.8 High	1	3 (1%)	0	0	5 (1%)	0	16 (4%)	64 (7%)	0	2 (1%)	54 (17%)	28 (21%)	2 (1%)	0	5 (1%)
0.8 – 1.0 Very High	130 (43%)	4 (1%)	13 (8%)	5 (2%)	100 (15%)	8 (8%)	35 (9%)	150 (17%)	50 (25%)	80 (40%)	32 (10%)	67 (50%)	61 (56%)	247 (32%)	302 (48%)
FRAGILITY															
Low	34 (11%)	88 (18%)	43 (26%)	58 (23%)	87 (14%)	1 (1%)	58 (16%)	81 (9%)	9 (5%)	14 (7%)	13 (4%)	0	33 (30%)	141 (18%)	625 (99%)
Moderate	204 (67%)	343 (69%)	96 (58%)	154 (61%)	477 (75%)	80 (84%)	256 (70%)	704 (81%)	82 (41%)	149 (74%)	212 (69%)	74 (55%)	16 (14%)	260 (34%)	0
High	34 (11%)	69 (14%)	25 (15%)	41 (16%)	71 (11%)	15 (15%)	52 (14%)	80 (9%)	209 (54%)	38 (19%)	83 (27%)	60 (45%)	31 (56%)	374 (48%)	3 (91%)

Appendix C Planning unit scale EWRs

There are relevant landscape differences between planning units. There are other cases where the natural flow provides the best indication of the EWR. Where planning unit scale EWRs have not required refinement, the catchment scale EWRs as shown in Table 12 with the flow thresholds provided in Table 13 apply. The following tables bring together the EWR details provided in Table 12, with the refined planning unit scale details, where relevant, with the flow thresholds provided in Table 13 to provide a complete set of EWRs at the planning unit scale. EWRs that are irrelevant to the planning unit are not shown.

Planning unit:Tenterfield creek – Gauge:Tenterfield creek at Clifton 416003

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<2 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>2 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	Sep to Mar	1 in 1-2 years (75%)	^ Rate of rise and fall
Small fresh	1	>20 ML/d	1 year	10 days	Oct to April	Annual (100%)	^ Rate of rise and fall
	2	20-450 ML/d	2 years	14 days	Sep to April	1 in 1-2 years (75%)	^ Rate of rise and fall
Large fresh	1	>450 ML/d	2 years	3 days	Any time	1 in 1-2 years (75%)	^ Rate of rise and fall
	2		4 years	5 days	Any time	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>3100 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
Overbank	1	>10000 ML/d	10 years		Any time	1 in 7 years (14%)	Average recurrence interval of 6.5 years
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Mole River – Gauge: Mole R at Donaldson 416032

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<5 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<45 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>45 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	^ Rate of rise and fall
Small fresh	1	>170 ML/d	1 year	10 days	October to April	Annual (100%)	^ Rate of rise and fall
	2	170-550 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	^ Rate of rise and fall
Large fresh	1	>550 ML/d	2 years	3 days	Any time	1 in 1-2 years (75%)	^ Rate of rise and fall
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>7100 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
Overbank	1	>16000 ML/d	4 years		Any time	1 in 4 years (25%)	Average recurrence interval of 2 years
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Reedy Creek – Gauge: Dumaresq R at Roseneath 416011

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<1 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<10 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>10 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2		138 days	7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>160 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	160-1050 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>1050 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>6250 ML/d	4 years		Any time	1 in 1-2 years (75%)	
	2		4 years		October to April	2 or more in 1-2 years	
Overbank	1	>19000 ML/d	4 years		Any time	1 in 4 years (25%)	Average recurrence interval of 1 year
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Beardy River – Gauge: Beardy R at Haystack 416008

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<1 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>1 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>50 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	50-700 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>700 ML/d	2 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years	5 days	Any time	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>4700 ML/d	4 years	3 days	Any time	1 in 1-2 years (60%)	
	2		4 years		October to April	2 or more in 1-2 years	
Overbank	1	>15200 ML/d	4 years	3 days	Any time	1 in 4 years (25%)	Average recurrence interval of 2 years
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Glen Innes – Gauge: Severn R at Ducca Marrin 416067

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<2 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<20 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>20 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>120 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	120-700 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>700 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>5600 ML/d	4 years		Any time	1 in 1-2 years (75%)	Note: across the full record of observed flows (from 2002 onwards), median event duration above 5600 ML/d is 3 days, with an average recurrence interval of less than 2 years between peaks.
Overbank	1	>15000 ML/d	4 years		Any time	1 in 3 years (33%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Bonshaw – Gauge: Dumaresq R u/s Bonshaw 416007

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<5 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>150 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	150-600 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>600 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	Any time	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>10000 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
Overbank	1	>15000 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Kings Plain – Gauge: Severn R at Ashford 416006

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<4 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>170 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	170-2100 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>2100 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>7100 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
Overbank	1	>23300 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Inverell – Gauge: Macintyre River at Ridgelands 416031

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<20 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<210 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>210 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>550 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	550-4500 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>4500 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>15000 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		October to April	2 or more in 1-2 years	
Overbank	1	>50000 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Campbells Creek & Camp Creek – Gauge: Dumaresq R at Glenarbon 416040

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<10 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<80 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>80 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>150 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	150-1300 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>1300 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>8500 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
Overbank	1	>53000 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Yetman – Gauge: Macintyre at Holdfast 416012

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<10 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<80 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>80 ML/d	N/A	^ Maximum duration	N/A	^ Recurrence interval of events	^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>100 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	100-1500 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>1500 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>11300 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
Overbank	1	>45000 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Ottleys Creek – Gauge: Ottleys Creek at Collatai 416020

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow			^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Large fresh	1		2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
	3		4 years	10 days	October to April	1 in 1-2 years (75%)	
Bankfull	1		4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		October to April	2 or more in 1-2 years	
Anabranch connection	1						^ Number of days below flow threshold: number of days above flow threshold
	2		7 years		Any time		
Overbank	1		4 years	3 days	Any time	1 in 3 years (33%)	
	2				Any time	1 in 7-10 years (12%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Confluence of Macintyre River and Dumaresq River – Gauge: Macintyre at Boggabilla 416002

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<25 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<230 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>230 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	Sep to Mar	1 in 1-2 years (75%)	
Small fresh	1	>840 ML/d	1 year	10 days	Oct to April	Annual (100%)	
	2	840-3100 ML/d	2 years	14 days	Sep to April	1 in 1-2 years (75%)	
Large fresh	1	>3100 ML/d	2 years	5 days	July to Sep	1 in 1-2 years (75%)	
	2		4 years	5 days	Oct to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>10900 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		Oct to April	2 or more in 1-2 years	
Anabranch connection	1						^ Number of days below flow threshold: number of days above flow threshold
	2		7 years		Any time		
Overbank	1	>21400 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
	2	>280000 ML/d			Any time	1 in 7-10 years (12%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Macintyre River floodplain u/s of Boomi – Gauge: Macintyre at Goondiwindi 416201A

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<10 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<120 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>120 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	Sep to March	1 in 1-2 years (75%)	
Small fresh	1	>.260 ML/d	1 year	10 days	Oct to April	Annual (100%)	
	2	260-1300 ML/d	2 years	14 days	Sep to April	1 in 1-2 years (75%)	
Large fresh	1	>1300 ML/d	2 years	5 days	July to Sep	1 in 1-2 years (75%)	
	2		4 years	5 days	Oct to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>7000 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		Oct to April	2 or more in 1-2 years	
Anabranch connection	1	>7000 ML/d					^ Number of days below flow threshold: number of days above flow threshold
	2	>7000 ML/d	7 years		Any time		
Overbank	1	>27000 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
	2	>56000 ML/d			Any time	1 in 7-10 years (12%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Macintyre River floodplain u/s of Boomi – Gauge: Macintyre at Terrewah 416047

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<5 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	Sep to March	1 in 1-2 years (75%)	
Small fresh	1	>110 ML/d	1 year	10 days	Oct to April	Annual (100%)	
	2	110-1300 ML/d	2 years	14 days	Sep to April	1 in 1-2 years (75%)	
Large fresh	1	>1300 ML/d	2 years	5 days	July to Sep	1 in 1-2 years (75%)	
	2		4 years	5 days	Oct to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>3300 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		Oct to April	2 or more in 1-2 years	
Anabranch connection	1	>7000 ML/d					^ Number of days below flow threshold: number of days above flow threshold
	2	>7000 ML/d	7 years		Any time		
Overbank	1	>7900 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
	2	>114000 ML/d			Any time	1 in 7-10 years (12%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Macintyre River floodplain u/s of Boomi – Gauge: Macintyre u/s Boomi 416043

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<5 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<60 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>60 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	September to March	1 in 1-2 years (75%)	
Small fresh	1	>100 ML/d	1 year	10 days	Oct to April	Annual (100%)	
	2	100-650 ML/d	2 years	14 days	September to April	1 in 1-2 years (75%)	
Large fresh	1	>650 ML/d	2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	Oct to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>1200 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		Oct to April	2 or more in 1-2 years	
Anabranch connection	1	>7000 ML/d					^ Number of days below flow threshold: number of days above flow threshold
	2	>7000 ML/d	7 years		Any time		
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Macintyre River floodplain u/s of Boomi – Gauge: Boomi R at Boomi Weir Offtake 416037

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<5 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		N/A					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>5 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	Sep to March	1 in 1-2 years (75%)	
Small fresh	1	>20 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	20-750 ML/d	2 years	14 days	Sep to April	1 in 1-2 years (75%)	
Large fresh	1	>750 ML/d	2 years	5 days	July to Sep	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>1100 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		October to April	2 or more in 1-2 years	
Anabranch connection	1	>7000 ML/d					^ Number of days below flow threshold: number of days above flow threshold
	2	>7000 ML/d	7 years		Any time		
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Macintyre River floodplain u/s of Boomi – Gauge: Macintyre at Kanowna 416048

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<5 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>40 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	Sep to March	1 in 1-2 years (75%)	
Small fresh	1	>90 ML/d	1 year	10 days	October to April	Annual (100%)	
	2	90-900 ML/d	2 years	14 days	Sep to April	1 in 1-2 years (75%)	
Large fresh	1	>900 ML/d	2 years	5 days	July to Sep	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>2500 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		October to April	2 or more in 1-2 years	
Anabranch connection	1	>7000 ML/d					^ Number of days below flow threshold: number of days above flow threshold
	2	>7000 ML/d	7 years		Any time		
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Whalan & Croppa Creeks – Gauge: Whalan at Euraba 416072

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow			^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Large fresh	1		2 years	5 days	July to September	1 in 1-2 years (75%)	
	2		4 years	5 days	October to April	1 in 2-3 years (42%)	Commencing as a rising flow only
	3		4 years	10 days	October to April	1 in 1-2 years (75%)	
Bankfull	1		4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		October to April	2 or more in 1-2 years	
Anabranch connection	1						^ Number of days below flow threshold:number of days above flow threshold
	2		7 years		Any time		
Overbank	1		4 years	3 days	Any time	1 in 3 years (33%)	
	2				Any time	1 in 7-10 years (12%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6

Planning unit: Macintyre River and Boomi River floodplain – Gauge: Barwon River at Mungindi 416001

Flow component	#	Flow threshold	Maximum inter-event period	Minimum duration	Ideal season	Minimum frequency	Other
Cease to flow		<30 ML/d	^ Spell duration	^ Event duration			^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Very low flow		<300 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year
Baseflow	1	>300 ML/d					^ Median number of days above threshold in each water year ^ 5th percentile number of days above threshold in each water year ^ Deficiency volume in each water year
	2			7 days	Sep to March	1 in 1-2 years (75%)	
Small fresh	1	>550 ML/d	1 year	10 days	Oct to April	Annual (100%)	
	2	550-5400 ML/d	2 years	14 days	Sep to April	1 in 1-2 years (75%)	
Large fresh	1	>5400 ML/d	2 years	5 days	July to Sep	1 in 1-2 years (75%)	
	2		4 years	5 days	Oct to April	1 in 2-3 years (42%)	Commencing as a rising flow only
Bankfull	1	>7400 ML/d	4 years	3 days	Any time	1 in 1-2 years (75%)	
	2		4 years		Oct to April	2 or more in 1-2 years	
Anabranch connection	1						^ Number of days below flow threshold: number of days above flow threshold
	2		7 years		Any time		
Overbank	1	>13300 ML/d	4 years	3 days	Any time	1 in 3 years (33%)	
	2	>18000 ML/d			Any time	1 in 7-10 years (12%)	
Hydrological connection							^ End of system annualised flow target

^ to be determined as part of the workplan described in Chapter 6