DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Gwydir Long Term Water Plan

Part A: Gwydir catchment

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Acknowledgement of Traditional Owners

The NSW Department of Planning, Industry and Environment pays its respect to the Traditional Owners of the Murray-Darling Basin and their Nations. 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 Gwydir catchment, the Department of Planning, Industry and Environment pays its respects to the Traditional Owners – the Kamilaroi/Gomeroi Nation – past, present and emerging, as well as those of other Nations for whom this river is significant. We look forward to developing new partnerships and building upon existing relationships to improve the health of our rivers, wetlands and floodplains, including in recognition of their traditional and ongoing cultural and spiritual significance.

Figure 1 Nardoo at Lynworth, in the West Gingham Wetlands
Photo: T. Cooke

Abbreviations

AHIMS	Aboriginal Heritage Information Management System
ASL	Above Sea Level
Basin Plan	Murray-Darling Basin Plan 2012
BCT	Biodiversity Conservation Trust
BF	Baseflow
BK	Bankfull
BWS	Basin-wide environmental watering strategy
CAG	Customer Advisory Group
CAMBA	China–Australia Migratory Bird Agreement
CEWO	Commonwealth Environmental Water Office
CF	Cease-to-flow
DBH	Diameter at breast height
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DPIE	NSW Department of Planning, Industry and Environment
DPIE–BC	NSW Department of Planning, Industry and Environment – Biodiversity and Conservation Division
DPIE–Water	NSW Department of Planning, Industry and Environment – Water
DPIF	NSW Department of Primary Industries Fisheries
EEC	Endangered ecological community
EWA	Environmental water allowance
EWAG	Environmental Water Advisory Group
EWR	Environmental water requirement
FFDI	Forest Fire Danger Index
GCM	Global Climate Model
GDE	Groundwater-dependent ecosystem
GL/yr	gigalitres per year
ha	hectares
HEW	Held environmental water
JAMBA	Japan–Australia Migratory Bird Agreement
LALC	Local Aboriginal Land Council
LF	Large fresh
LLS	Local Land Services (NSW)
LTWP	Long Term Water Plan
m/s	metres per second
MDBA	Murray-Darling Basin Authority
MER	Monitoring, evaluation and reporting
mg/L	milligrams per litre

ML	megalitre
NPWS	NSW National Parks and Wildlife Services
NRAR	Natural Resources Access Regulator
NSW	New South Wales
OB	Overbank
PCT	Plant community type
PEW	Planned environmental water
PU	Planning unit
RAS	Resource availability scenario
RCM	Regional Climate Model
Risk Assessment	Risk assessment for the Gwydir Surface Water Resource Plan Area
ROKAMBA	Republic of Korea–Australia Migratory Bird Agreement
RRG	River red gum
SDL	Sustainable diversion limit
SF	Small fresh
VF	Very low flow
WL	Wetland inundating flow
WQA	Water quality allowance
WQMP	Water quality management plan
WRP	Water resource plan
WRPA	Water resource plan area
WSP	Water sharing plan

Glossary

Actively managed floodplain	The area of floodplains and wetlands that can be inundated by managed environmental water deliveries alone or in combination with other flows from regulated river systems (see ‘Regulated river’).
Adaptive management	A procedure for implementing management while learning about which management actions are most effective at achieving specified objectives.
Allocation	The volume of water made available to water access licence or environmental water accounts in a given year by DPIE–Water, which is determined within the context of demand, inflows, rainfall forecasts and stored water.
Allochthonous	Organic material (leaf litter, understory plants, trees) derived from outside rivers, including riparian zones, floodplains and wetlands.
Alluvial	Comprised of material deposited by water.
Autochthonous	Organic material derived from photosynthetic organisms (algal and macrophyte growth) within rivers.
Bankfull flow (BK)	River flows at maximum channel capacity with little overflow to adjacent floodplains. These flows engage the riparian zone, anabranches, flood runners and wetlands located within the meander train. They inundate all in-channel habitats including benches, snags and backwaters.
Baseflow (BF)	Reliable background flow levels within a river channel that are generally maintained by seepage from groundwater storage, but also by surface inflows. They typically inundate 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. The movement of blackwater plays an important role in transferring essential nutrients from wetlands into rivers and vice versa. Blackwater carries carbon which is the basic building block of the aquatic food web and an essential part of a healthy river system.
Carryover	Water allocated to water licences or environmental water accounts that remains un-used in storage at the end of the water year which, under some circumstances, may be held over and used in the following water year.
Catch per unit effort (CPUE)	An indirect measure of the abundance of a target species.
Cease-to-flow (CF)	The absence of flowing water in a river channel that leads to 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 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 occurs downstream of dams, particularly during warmer months when stratification is more likely to occur. The impact of cold water pollution can extend for hundreds of kilometres along the river from the point of release.
Constraints	The physical or operational constraints that affect 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, the volume of water that can be carried through the river channel, or scheduling of downstream water deliveries from storage.
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).
Cultural water-dependent asset	A place that has social, spiritual and cultural value based on its cultural significance to Aboriginal people. 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 measurement 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 are food for microscopic animals 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 and ultimately generates a food source for large bodied fish like Murray cod and golden perch and predators such as waterbirds.
Ecological objective	Objective for the protection and/or restoration of an environmental asset or ecosystem function. Objectives are set for all priority environmental assets and priority ecosystem functions and have regard to the outcomes described in the Basin-wide environmental watering strategy.
Ecological target	Level of measured performance that must be met to achieve the defined objective. The targets in this Long Term Water Plan are SMART (Specific/Measurable/Achievable/Realistic/Time-bound) and can demonstrate progress towards the objectives and the outcomes described in the Basin-wide environmental watering strategy.
Ecological value	An object, plant or animal which has value based on its ecological significance.
Ecosystem	A biological community of interacting organisms and their physical environment. It includes all the living things in that community, interacting with their non-living environment (weather, earth, sun, soil, climate and atmosphere) and with each other.
Ecosystem function	The resources and services that sustain human, plant and animal communities and are provided by the processes and interactions occurring within and between ecosystems. Identified ecosystem functions must also meet one or more of the assessment indicators for any of the four criteria specified in Schedule 9 of the Basin Plan.
Environmental asset	The physical features that make up an ecosystem and meet one or more of the assessment indicators for any of the five criteria specified in Schedule 8 of the Basin Plan.
Environmental Contingency Allowance (ECA)	Held water entitlements, in addition to planned environmental water, up to 45,000 ML held in Copeton Dam to be used for environmental purposes.
Environmental water	Water for the environment. It serves a multitude of benefits to not only the environment, but communities, industry and society. It includes

	water held in reservoirs (held environmental water) or protected from extraction from waterways (planned environmental water) for the purpose of meeting the water requirements of water-dependent ecosystems.
Environmental water requirement (EWR)	An environmental water requirement (EWR, singular) describes the characteristics of a flow event (e.g. magnitude, duration, timing, frequency, and maximum dry period) within a particular flow category (e.g. small fresh), that are required for that event to achieve a specified ecological objective or set of objectives (e.g. to support fish spawning and in-channel vegetation). There may be multiple EWRs defined within a flow category, and numerous EWRs across multiple flow categories within a Planning Unit. Achievement of each of the EWRs will be required to achieve the full set of ecological objectives for a Planning Unit. 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. It includes all water in the system including natural inflows, held environmental water and planned environmental water.
Flow category	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 (HEW)	Water available under a water access 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 past 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 fall below the level needed to sustain native fish and other water-dependent species. Bacteria that feed on dissolved organic carbon use oxygen in the water. When they multiply rapidly their rate of oxygen consumption can exceed the rate at which oxygen can be dissolved in the water. As a result, oxygen levels fall and a hypoxic (low oxygen) condition occurs. Dissolved oxygen is measured in milligrams per litre (mg/L). Generally native fish begin to stress when DO levels fall below 4 mg/L. Fish mortality occurs when DO levels are less than 2 mg/L.
Large fresh (LF)	High-magnitude flow pulse that remains in-channel. These flows may engage flood runners with the main channel and inundate low-lying wetlands. They connect most in-channel habitats and provide partial longitudinal connectivity, as some low-level weirs and other in-channel barriers may be drowned out.
Lateral connectivity	The flow linking rivers channels and the floodplain.

Long Term Water Plan (LTWP)	A component of the Murray–Darling Basin Plan. Long Term Water Plans give effect to the Basin-wide environmental watering strategy (MDBA 2014) relevant for each river system and will guide the management of water over the longer term. These plans will identify the environmental assets that are dependent on water for their persistence, and match that need to the water available to be managed for or delivered to them. The plan will set objectives, targets and watering requirements for key plants, waterbirds, fish and ecosystem functions. DPIE is responsible for the development of nine plans for river catchments across NSW, with objectives for five, 10 and 20-year timeframes.
Longitudinal connectivity	The consistent downstream flow along the length of a river.
Montane	Relating to mountainous country.
Overbank flow (OB)	Flows that spill over the riverbank or extend to floodplain surface flows.
Planned environmental water (PEW)	Water that is committed or preserved by the Basin Plan, a water resource plan or a plan made under state water management law to achieving environmental outcomes. This water cannot, to the extent to which it is committed or preserved for such purposes, be taken or used for any other purpose.
Planning Unit	A division of a water resource plan area based on water requirements (in catchment areas in which water is actively managed), or a sub-catchment boundary (all other areas).
Population structure	A healthy population structure has individuals in a range of age and size classes. These populations demonstrate regular recruitment and good numbers of sexually mature individuals.
Priority ecosystem function	Ecosystem functions that meets one or more of the assessment indicators for any of the four criteria specified in Schedule 9 of the Basin Plan and can be managed with environmental water.
Priority environmental asset	A place of particular ecological significance that is water-dependent, meets one or more of the assessment indicators for any of the 5 criteria specified in Schedule 8 in the Basin Plan, and can be managed with environmental water. This includes planned and held environmental water.
Ramsar Convention	An international treaty to maintain the ecological character of key wetlands.
Recruitment	Successful development and growth of offspring; such that they can contribute to the next generation.
Refuge pool	Sections of river channel or waterholes that are deep relative to the rest of the channel which retain water for longer periods of time can provide refuge for aquatic biota during periods of no flow. Refugial waterholes and lakes can also be present in floodplain areas. Not only do these features provide refugial habitat & nursery sites for aquatic life, they are important sinks for nutrients & DOC cycling within the riverine environment.
Refugium	An area in which a population of plants or animals can survive through a period of decreased water availability.
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 brings more reliability to water supplies but has interrupted the natural flow characteristics and regimes required by native fish and other plant and animal to breed, feed and grow.
Riffle	A rocky or shallow part of a river where river flow is rapid and broken.

Riparian	The part of the landscape adjoining rivers and streams that has a direct influence on the water and aquatic ecosystems within them.
Risk management strategy	A plan of management to overcome risks to achieving environmental outcomes.
Small fresh (SF)	Low-magnitude in-channel flow pulse. Unlikely to drown out any significant barriers but can provide limited connectivity and a biological trigger for animal movement.
Stochastic	Relating to or characterised by random chance.
Substrate	A habitat surface such as a stream bed.
Supplementary access	A category of water entitlement where water is made available to licence holder accounts during periods of high river flows that cannot otherwise be controlled by river operations. Water can be taken and debited from licence accounts during a declared period of high flow.
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.
Unregulated river	A waterway where flow is mostly uncontrolled by dams, weirs or other structures.
Very low flow (VF)	Small flow in the very-low flow class that joins river pools, thus providing partial or complete connectivity in a reach. These flows can improve DO saturation and reduce stratification in pools.
Water quality management plan (WQMP)	A document prepared by state authorities and accredited by the Commonwealth under the Basin Plan. It forms part of a water resource plan and aims to provide a framework to protect, enhance and restore water quality in each water resource plan area.
Water resource plan (WRP)	A document prepared by state authorities and accredited by the Commonwealth under the Basin Plan. The document describes how water will be managed and shared between users in an area.
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. It forms part of a water resource plan.
Water-dependent	An ecosystem or species that depends on periodic or sustained inundation, waterlogging or significant inputs of water for natural functioning and survival.
Wetland inundation flow (WL)	Flows that fill wetlands below bankfull or via regulating structures over weeks or sometimes months (i.e. longer than a typical fresh/pulse) or flows that are required to inundate wetlands in areas where there are very shallow channels or no discernible channels exist (e.g. terminal wetlands).

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.

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 Gwydir, the frequency, duration and timing of cease-to-flow periods, low flows and small freshes have experienced the greatest alteration.

The NSW Government’s first Gwydir 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 Gwydir. The Plan identifies water management strategies for maintaining and improving the long-term health of the Gwydir’s 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 delivered in the future, rather it will help water managers and advisory groups, such as the Gwydir Environmental Water Advisory Group, provide advice about where, when and how available water can be managed to achieve agreed long-term ecological objectives. The LTWP looks at all sources of water and how these can be managed to help support environmental outcomes in the catchment. 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 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) and LTWPs are central features of this framework. The BWS establishes long-term ecological outcomes and targets for the Basin and its catchments. LTWPs, which apply to water resource plan areas (catchment-scale), must contribute to the achievement of the BWS by identifying:

- priority environmental assets and functions in a water resource plan area
- ecological objectives and ecological targets for those assets and functions
- environmental watering requirements needed to meet those targets and achieve the objectives.

Water resource plans must have regard to LTWPs.

The Gwydir Long Term Water Plan

The Gwydir LTWP is one of nine plans being developed by the NSW Department of Planning, Industry and Environment (DPIE) 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 Gwydir catchment.
- Determining the **environmental water requirements** (including volume, frequency, timing and duration) needed to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions.
- Identifying potential **management strategies** to meet environmental water requirements
- Identifying **complementary investments** to address **risks and constraints** to meeting the long-term water requirements of priority environmental assets and ecosystem functions.

The LTWP presents this information in 10 chapters in two parts, with accompanying appendices.

Environmental values of the Gwydir catchment

The Gwydir catchment supports a range of water-dependent ecosystems, including instream aquatic habitats, riparian forests, and floodplain watercourses, woodlands and wetlands. Notably, the Gwydir Wetlands are internationally-recognised on the Ramsar Convention List of Important Wetlands. These ecosystems benefit many water-dependent communities and species, including threatened ecological communities, threatened and migratory waterbirds, and threatened native fish species, by providing habitat and food resources.

The ecological condition of the Gwydir's 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, replenish refuge pools to maintain water quality, trigger movement and breeding of native fish and waterbirds, and directly impact vegetation condition, dispersal of propagules and habitat availability.

Extensive local, scientific and, where possible, traditional knowledge about the Gwydir's riverine environmental assets and ecosystem functions underpins this LTWP. This has been collected in partnership with water managers, natural resource managers, environmental water holders, landholders, and community members. Information about the Gwydir's environmental values closely aligns with material in the NSW Department of Planning, Industry and Environment's *Risk assessment for the Gwydir Surface Water Resource Plan Area* (the Risk Assessment) (NSW DPIE-Water 2019c).

Water for the environment

The Gwydir LTWP contains ecological objectives and targets for priority environmental assets and ecosystem functions in the Gwydir 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, frogs and ecosystem functions. Objectives and targets for improving connectivity along the catchment, between rivers and floodplain areas, and with the Barwon-Darling are also included because lateral and longitudinal connectivity is vital to achieving Basin-wide outcomes. As noted in the BWS, each of these themes is a good indicator of river system 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 Gwydir catchment. The targets for each ecological objective provide a transparent means of evaluating the long-term success of management strategies.

Table 1 A summary of the environmental outcomes sought in the Gwydir LTWP

Broad outcomes	Overarching objectives	Example uses of water for the environment to achieve LTWP objectives
To maintain the diversity and improve the population of native fish in the catchment	Increase native fish distribution and abundance, and ensure stable population structures	• Provide improved flow conditions for native fish spawning, recruitment and dispersal in the Gwydir, Mehi and Carole systems • Replenish refuge waterholes for native fish • Provide connection flows between the Gwydir and the Barwon-Darling
To maintain the extent and improve the health of water-dependent native vegetation and wetlands	Maintain and improve the viability and extent of river red gum, black box and coolibah communities, lignum shrublands and non-woody wetland vegetation such water couch and marsh club-rush	• Improve the extent and condition of vegetation in core areas of the Gingham and lower Gwydir wetlands • Improve the extent and condition of vegetation in core areas of the Mallowa system
To maintain the diversity of waterbird species and increase their numbers across the catchment	Restoration of habitat for waterbirds to contribute to recovery of waterbird populations across the Murray-Darling Basin	• Support the successful completion of colonial waterbird breeding • Provide foraging habitat for waterbirds
To maintain and protect a variety of river, wetland and floodplain habitats and support the movement of nutrients throughout the river system	Various objectives relating to instream and floodplain refuge and habitat, supporting productivity and the lifecycles of water-dependent biota, and connecting riverine and floodplain systems.	• Restart flows after cease-to-flow conditions in the lower river to reduce the risk of hypoxic blackwater and fish kills • Contribute to improved flows in the Barwon River
Maintain the number and type of water-dependent species throughout the catchment	Maintain the number and range of water-dependent species including flow-dependent frogs and platypus, and support successful breeding.	• Ensure in-channel flows are within the natural rate of rise and fall to protect platypus burrows and protect feeding and breeding habitats • Maintain wetland habitats where breeding activity of flow-dependent frog species are detected

Management strategies and complementary investments

Complementary measures that are needed to ensure the LTWP's objectives and targets are achieved have been identified in the plan (see chapter 7). These include addressing cold water pollution caused by water releases from Copeton Dam, addressing barriers to fish passage, providing incentives to landholders to conserve riparian, wetland and floodplain vegetation and screening irrigation pumps to protect fish.

A critical complementary measure is the resolution of constraints to the delivery of environmental water in the Gwydir. Murray-Darling Basin Authority (with assistance from NSW Department of Planning, Industry and Environment) has consulted with many wetland and inner floodplain landholders on the implementation of a series of measures that would allow environmental water delivery to be made through critical periods of cropping activity, like planting and harvesting, without impact on these important agricultural activities. While there are many details to be negotiated with landholders, initial consultation indicated a clear willingness to work together to resolve these issues for mutual benefit.

Monitoring and evaluation of the Long Term Water Plan

Over the 20-year duration of this LTWP, NSW and Commonwealth agencies will monitor the health of rivers, wetlands and floodplains within the Gwydir catchment to:

- monitor and demonstrate progress (or otherwise) against 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

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 Gwydir catchment
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit adjustment
- new information arising from evaluating responses to environmental watering
- new knowledge about the ecology of the Gwydir catchment that is relevant to environmental watering
- improved understanding of the effects of climate change and its impacts on the Gwydir 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.

Figure 2 **Whittaker's Lagoon near Mehi River**
Photo: T. Cooke

1. Introduction

The Gwydir is a major catchment of the Murray-Darling Basin. It is in northern New South Wales (NSW) and includes the towns of Moree, Uralla, Guyra, Bingara and Warialda. The Gwydir catchment's boundary extends westward from the Great Dividing Range to the confluence of the Gwydir and Barwon Rivers north of Collarenebri. Major tributaries of the Gwydir River include the Horton River, Myall Creek, Halls Creek, Warialda Creek and Mosquito Creek. The major distributaries of the Gwydir River are the Mehi River system, Carole Creek system, Gingham system and Lower Gwydir (Big Leather) system.

The Gwydir River, its tributaries, distributaries and the region's aquifers are important water resources for agricultural businesses and urban communities. The region also contains a diversity of water-dependent ecosystems that support threatened and iconic native fish (e.g. silver perch, Murray cod), endangered vegetation communities (e.g. marsh club rush sedgeland, coolibah-black box woodland, Darling River endangered ecological community), endangered river snail (*Notopala sublineata*) and migratory waterbirds (e.g. Australasian bittern).

The Gwydir Wetlands, west of Moree, have portions listed on the Ramsar Convention's List of Wetlands of International Importance. The Gwydir Wetlands Ramsar site covers 823 hectares and consists of four sub-sites around the Gingham and Lower Gwydir watercourses. It is the remaining part of a larger wetland area that originally covered 220,000 hectares, which has been substantially reduced because of river regulation and subsequent land use changes (Bowen et al. 2017, Cox et al. 2001, Keith et al. 2009).

River flow in the Gwydir catchment, like many Murray-Darling Basin catchments, has been altered by the construction of a headwater dam, weirs, river and creek modifications, and large-scale irrigation development of the floodplain. 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.

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

1.1 Approach to developing the LTWP

The Gwydir LTWP applies to the Gwydir Surface-water Water Resource Plan area (WRPA) and is one of nine catchment-based plans covering the NSW portion of the Murray-Darling Basin. The LTWP is consistent with the requirements of the Murray-Darling Basin Plan (Basin Plan) (MDBA 2012).

The Gwydir 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 Gwydir LTWP has involved six 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 these key species and functions

- documenting the water required (including volume, frequency, timing and duration) to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions
- identifying the risks and constraints to meeting the long-term water requirements of priority environmental assets and ecosystem functions
- identifying potential management strategies to guide future water management and investment decisions
- complementary measures such as cooperative water management and investment opportunities.

1.2 Implementing the LTWP

Implementation of the LTWP requires strong partnerships and coordination between 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 NSW Department of Planning, Industry and Environment (DPIE), the Commonwealth Environmental Water Office (CEWO) and the Gwydir Environmental Water Advisory Group (EWAG)
- informing planning processes that influence river and wetland health outcomes, including development of water sharing plans and water resource plans
- identifying opportunities for strategic collaboration between river operations and environmental water managers
- informing 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.

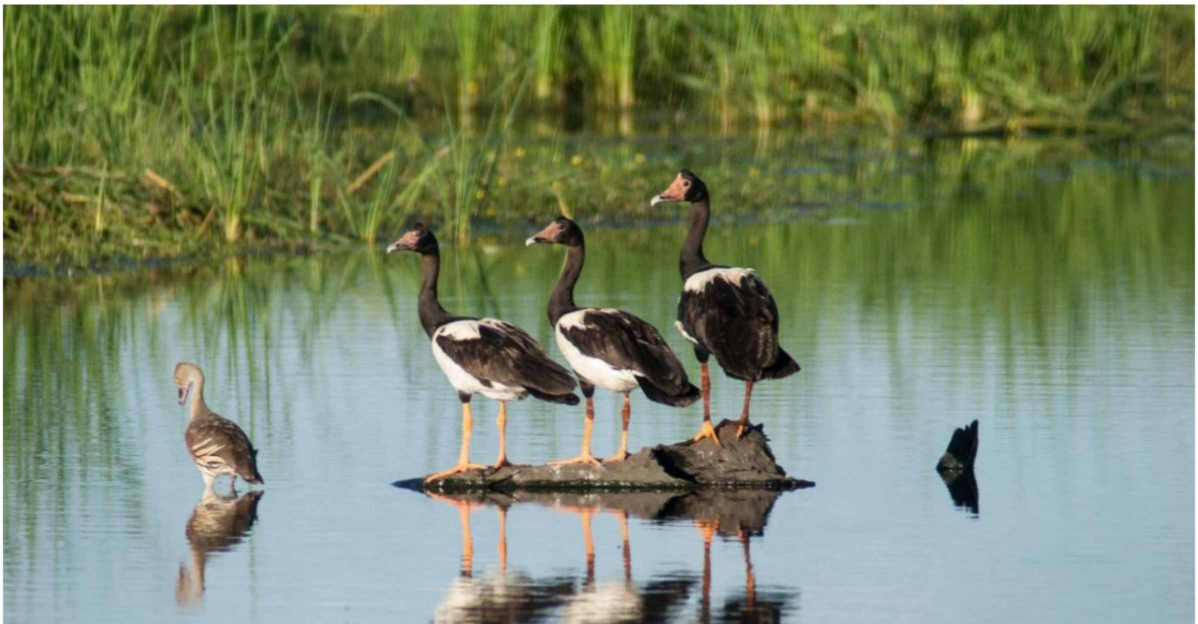


Figure 3 Plumed-whistling duck and three Magpie geese in the Gwydir
Photo: N. Foster

1.3 The LTWP document structure

The Gwydir LTWP is presented in 10 chapters in total with accompanying appendices. It is divided into Part A and Part B.

Part A: Gwydir catchment scale information

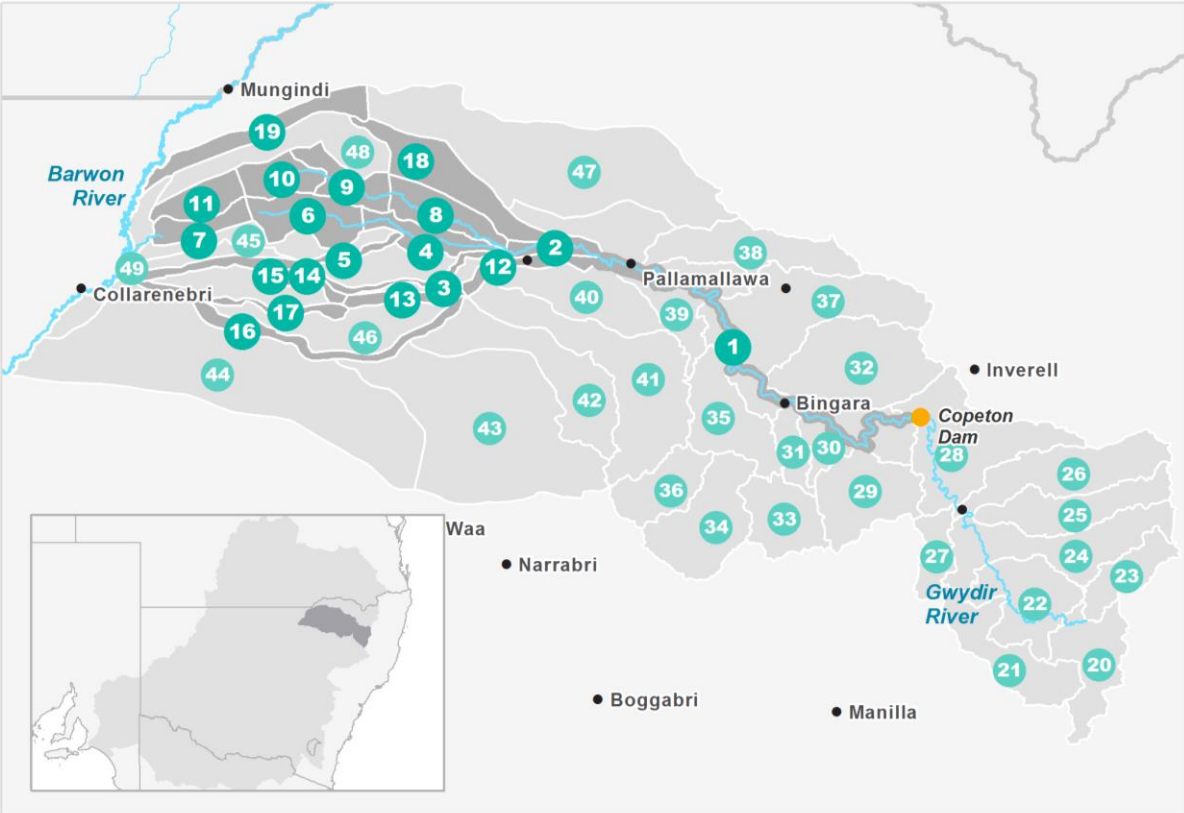
- **Chapter 1** explains the background and purpose of the LTWP.
- **Chapters 2** and **3** identify the Gwydir's priority water-dependent environmental assets and ecosystem functions and articulate the environmental outcomes that are expected from implementation of the LTWP through ecological objectives 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 long-term risks and operational constraints that may limit water managers capacity to achieve the ecological objectives in the Gwydir and recommends management strategies for addressing these.
- **Chapter 6** identifies opportunities for the use of held and planned environmental water, and other system flows to support flow regimes to meet the EWRs of the Gwydir's environmental assets and values under different water resource availability scenarios, extreme events, and critical water quality incidents.
- **Chapter 7** describes potential cooperative arrangements between government agencies and private landholders and prioritised investment opportunities to achieve the ecological objectives described in this LTWP.

Part B: Gwydir planning unit scale information

- **Chapters 1** explains the need and logic for splitting the Gwydir catchment into different planning units
- **Chapter 2** and **3** present the LTWP at the planning unit scale. This includes a summary of the environmental values the planning unit supports, and an evaluation of the impact of water resource development on local hydrology.

1.4 Planning units

The planning units (PUs) shown in Figure 4 are referred to in most chapters. The planning units typically align with the regulated (Zone A) and unregulated (Zone B) river reaches. Planning unit boundaries in Zone A (planning units (1-19) were delineated to reflect how storage and diversion infrastructure can be used to manage water for environmental outcomes. In some instances, Zone A planning unit boundaries include unregulated areas that are downstream regulated areas because they are affected by regulated water deliveries. Planning unit boundaries in Zone B (planning units 20-49) align with the Water Source boundaries in the Gwydir Surface Water Resource Plan (NSW DPIE 2019).



Legend

Zone A Planning Units

Zone B Planning Units

N

0 35 70
Kilometers

Planning Units

1. Gwydir downstream of Copeton
2. Main Gwydir River
3. Tarren Creek
4. Lower Gwydir
5. Goonal Creek
6. Central Lower Gwydir
7. Western Gwydir Floodplain
8. Upper Gingham
9. Central Gingham
10. Lower Gingham
11. Western Gingham Floodplain
12. Upper Mehi
13. Central Mehi
14. Lower Mehi
15. Ballin Boora
16. Moomin Creek
17. Mallowa Creek
18. Carole Creek
19. Gil Gil Creek
20. Rocky River
21. Roumalla Creek
22. Upper Gwydir River
23. Boorolong Creek
24. Laura Creek
25. Georges Creek
26. Moredun Creek
27. Bakers Creek
28. Copeton Darm
29. Keera Creek
30. Mackenzies Flat
31. Halls Creek
32. Myall Creek
33. Cobbodah Creek
34. Upper Horton
35. Lower Horton
36. Rocky Creek
37. Warialda Creek
38. Mosquito Creek
39. Slaughterhouse Creek
40. Moree
41. Tycannah Creek
42. Gurley Creek
43. Millie Creek
44. Thalabah Creek
45. Gwydir water source
46. Mehi water source
47. Gil Gil water source
48. Gingham water source
49. Barwon water source

Figure 4 The Gwydir catchment showing the division of planning units into Zone A and Zone B in the Long Term Water Plan

2. Environmental assets of the Gwydir catchment

The Gwydir catchment supports a variety of water-dependent ecosystems, including instream aquatic habitats, riparian forests, and floodplain woodlands and wetlands. These features are spread throughout the catchment and each has their own water requirements depending on the plants and animal species they support, and ecosystem functions they perform.

Figure 5 Marsh club rush in the Gwydir wetlands (NSW critically endangered community)
Photos: D. Albertson/DPIE

2.1 Priority environmental assets in the Gwydir catchment

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

The Gwydir's water-dependent ecosystems, which are comprised of waterbodies, water-dependent vegetation, and the water-dependent fauna they support were assessed against the Schedule 8 criteria. Significant Aboriginal cultural water-dependent areas that were identified through the Gwydir Floodplain Management Plan, or that are registered in the Aboriginal Heritage Information Management System (AHIMS) were also included as water-dependent assets in the LTWP. This identified areas such as Aboriginal ceremony and dreaming sites, fish traps, scar trees, and water holes throughout the Gwydir catchment. Querying the AHIMS system is not intended to substitute for consultation about sites. However, it is used to demonstrate the presence and variety of sites registered in the Gwydir WRPA. Results of the analysis are presented in Figure 6.

Priority environmental assets in LTWP's are the assets that have been identified using Schedule 8 criteria that can be managed through:

- NSW's planned environmental water (PEW), and/or
- NSW's and CEWO's held environmental water (HEW), and/or
- Implementation of the *Water Sharing Plan for the Gwydir Regulated and Unregulated Rivers Surface water source* rules and compliance with water access licence (WAL) conditions.

Priority environmental assets may be, for example, a reach of river channel and its floodplain features at a geographic location, or a wetland complex or anabranch. Priority environmental assets and values in the Gwydir LTWP are listed in the relevant planning units in Part B, chapters 2 and 3.

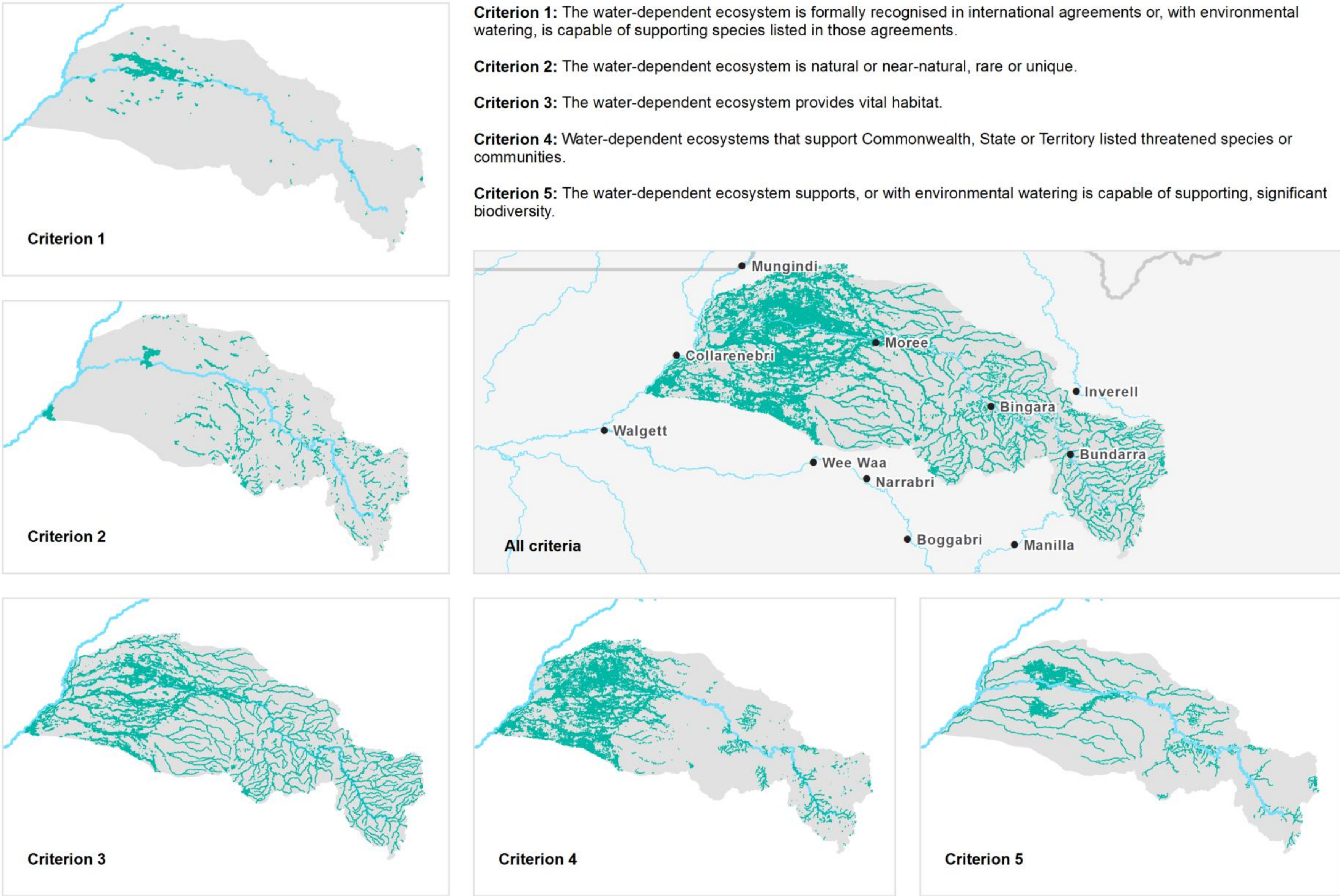


Figure 6 **Five criteria for identification of water-dependent environmental assets applied to the Gwydir catchment**

3. Ecological objectives and targets

Ecological objectives and targets have been established for priority environmental assets and values in the Gwydir catchment (chapters 3.1–3.5). Consistent with the Basin-wide watering strategy (BWS) (with the exception of frogs), the objectives are grouped into five themes: native vegetation, waterbirds, native fish, frogs and ecosystem functions. Each theme is a good indicator of river system health and is responsive to changes in flow patterns. The water requirements of these indicator species, functional groups of species, or ecosystem functions within each theme are representative of those needed by many other water-dependent species, such as turtles, water-dependent bats, and water rats.

The Gwydir's ecological objectives express the environmental outcomes that are expected from implementation of the LTWP. Their achievement will also contribute to the landscape and Basin-scale ecological outcomes sought by the BWS and benefit other water-dependent species.

Five, 10 and 20-year targets for each ecological objective provide a transparent means of evaluating progress and the long-term success of water management strategies and the implementation of strategies to address risks and constraints. The targets will provide an indication of how the environment is responding to environmental water management and inform any refinement to the described flow regime or water management strategies. 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.

Implementation of the LTWP can contribute to Aboriginal cultural objectives (chapter 3.6). Objectives and outcomes[1] for the water-dependent values and uses of the Gomeroi Nation are described in *The Report on culturally appropriate First Nations consultation with Gomeroi Nation* (NSW DPIE-Water 2019b)

The ecological objectives for the Gwydir's priority environmental assets as they relate to individual planning units are listed in Appendix A.

3.1 Native fish values and objectives

The native fish community in the Gwydir catchment consists of 15 native fish species (NSW Department of Primary Industries Aquatic Ecosystem Research Database, from records collected between 1994 and 2017). These species include several listed threatened fish species, including purple spotted gudgeon, silver perch, Murray cod and freshwater catfish, with the endangered olive perchlet also recently detected in Boyanga and Gingham waterholes (Southwell et al. 2015).

Overall, the fish community in the Gwydir is in moderate health (NSW DPI 2015b). The extent and condition of fish populations in the Murray–Darling Basin declined significantly after 2007, largely owing to ongoing drought in the already stressed river systems (NSW DPI 2015b, NSW DPI 2016). The Gwydir River below Copeton Dam and the Mehi River near Moree contain significant reaches of fish communities in good condition. These reaches possess a diverse number of native species and provide important habitat that supports the distribution of many threatened species (NSW DPI 2015b). However, there are some lowland reaches that are in poor or very poor condition.

Objectives and targets for native fish in the Gwydir catchment relate to increasing distribution and abundance and ensuring a stable population structure that includes representation of young-of-year, juvenile and adult-life-history stages (Table 2 and Appendix A). These

[1] as determined during targeted consultation for *The Report on culturally appropriate First Nations consultation with Gomeroi Nation*

objectives require flows across the entire spectrum of the flow regime (from low flows through to bankfull and overbank flow events) to meet the environmental water requirements of all fish species. Improving the condition and increasing the distribution and abundance of native fish populations involves restoring hydrology and physical habitat to expand the extent and carrying capacity of suitable habitat. Fish population structure is closely tied to the frequency of successful breeding events and enhanced recruitment, as well as improved maintenance, condition and movement outcomes for all life-history stages.

The BWS has identified the Gwydir as capable of supporting range extensions for three threatened fish species (MDBA 2014). These are the purple spotted gudgeon, freshwater catfish and olive perchlet. DPI Fisheries (DPIF) have advised the most likely areas to achieve range extensions for these species are in the Gwydir River downstream of Copeton Dam, Halls Creek, Keera Creek and the Gingham Watercourse (Appendix A).

Table 2 Native fish (NF) objectives and targets

Objectives		Target fish species	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
NF1	No loss of native fish species	All recorded fish species	All known species detected annually		
				Fish community status improved by one category compared to 2014 assessment	
NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species	Australian smelt, carp gudgeon, flat-headed 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, flat-headed galaxias			
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		
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	Minimum of 1 significant recruitment event[2] in 5 years	Minimum of 2 significant recruitment events in 10 years	Minimum of 4 significant recruitment events in 20 years
NF6	A 25% increase in abundance of	golden perch	Length-frequency distributions include size classes of legal take size for golden perch and Murray cod		

[2]Significant recruitment event requires young-of-year to comprise more than 30% of the population

Objectives		Target fish species	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
	mature (harvestable sized) golden perch and Murray cod	Murray cod	25% increase in abundance of mature golden perch and Murray cod		
NF7	Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas (within historical range)	olive perchlet	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)		

Figure 7 Purple-spotted gudgeon, freshwater catfish and olive perchlet
Photos: G. Schmida

3.2 Native vegetation values and objectives

The Gwydir catchment supports a diversity of vegetation communities that vary by altitude, climate and soil type. The high-altitude eastern catchment supports a mix of forest and woodlands that are dominated by eucalypts. In the slopes region, vegetation communities are mostly fragmented remnants of forest grading into woodland further west. Vegetation in the western part of the catchment is influenced by the location of floodplains and alluvial fans. The dominant vegetation consists of floodplain woodlands of coolibah and in western most areas black box woodlands, with occasional myall, whitewood and belah vegetation communities. The plains previously supported extensive areas of native grasslands, consisting of Mitchell grass and plains grass. While these vegetation communities have decreased since agricultural development, they can still be found on the plains south-west of Moree.

The Gwydir Wetlands contain several floristic and structurally diverse functional vegetation communities. These communities are distributed across the floodplain in mosaics of both wetland and dryland communities, with the distribution of communities determined on the local inundation regime (e.g. wetting frequency, duration and depth). The Gwydir Wetlands have one of the largest known stands of marsh club-rush sedgeland in NSW. However, only 9% of the marsh club-rush sedgeland that was present in the Gwydir catchment when

Copeton Dam was commissioned in 1978 remained in 2010 (Bowen & Simpson 2010). Marsh club-rush, known locally as sag, is listed as a critically endangered ecological community under the *Biodiversity Conservation Act 2016*.

The core wetland areas are inundated frequently by a range of larger flows through many small channels (McCosker & Duggin 1993). Plant communities are composed of amphibious species such as water couch, spike-rush, and cumbungi. River cooba and lignum shrublands are common in and around the margins of the core wetlands. Coolibah woodlands are an important feature of the floodplain, fringing the semi-permanent wetland areas and forming extensive woodlands on less frequently flooded parts of the floodplain (Bowen & Simpson 2010). These communities have been in decline over the last 30 years due to land clearing (Cox et al. 2001, Keith et al. 2009) and altered flow regimes (CSIRO 2007). Currently, only small fragmented remnants of wetland and floodplain habitat remain (25% and 8%, respectively (Bowen & Simpson 2010). In years of lower than average inflow, the wetland plant communities can be invaded by black roly poly and weeds such as lippia (McCosker & Duggin 1993).

The extent of river red gum, black box and coolibah communities in the Gwydir catchment was approximately 30,099 hectares, 29,799 hectares and 179,389 hectares, respectively (Bowen et al 2017). While it may not be possible to expand the area for many of these communities due to agricultural land development or their location on the floodplain, the long-term objectives of environmental water management is to ensure adequate water is available to maintain their current extent on the actively managed wetlands and floodplains and improve their health. Similarly, catchment-wide objectives for lignum shrublands and non-woody wetland vegetation communities are to maintain extent (4144 hectares of lignum and 7124 hectares of non-woody wetland vegetation on the actively managed wetlands and floodplains) and improve condition. Promoting vegetative growth alone will not support long-term sustainable vegetation communities, particularly those of short-lived species such as marsh club-rush. The objectives for the maintenance of these species include targets for regular seed setting to ensure ongoing population viability.

Specific targets have been set for the main vegetation types described in the BWS (Table 3 and Appendix A). However, rather than focussing on outcomes for single species, objectives have been set for the plant community types (PCTs) to which species belong. Grouping individual species into types simplifies objective setting and reflects both the natural groupings of species with similar water requirements and the management strategies used to sustain them.

Table 3 Native vegetation (NV) objectives and targets

Objectives		Targets		
		5 years (2024)	10 years (2029)	20 years (2039)
NV1	Maintain the extent and viability of non-woody vegetation communities occurring within channels	Increase the cover of non-woody, inundation-dependent vegetation within or closely fringing river channels following inundation events		
NV2	Maintain or increase the extent and maintain the viability of non-woody vegetation communities occurring in wetlands and on floodplains	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 actively managed wetlands and floodplains		
NV3	Maintain the extent and improve the condition of	Maintain the 2016 mapped extent of river red gum woodland and river cooba communities closely fringing river channels		

Objectives			Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
	river red gum communities closely fringing river channels		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		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
NV4b		River red gum woodland	Maintain the 2016 mapped extent of river red gum woodland, black box woodland, and coolibah woodland communities		
NV4c	Maintain or increase the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains	Black box woodland	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		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
NV4d		Coolibah woodland			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
NV4e		Lignum shrubland	Maintain the 2016 mapped extent of lignum shrubland and coolibah wetland woodland communities within the actively managed wetlands and floodplains		Increase the total area of lignum shrublands and coolibah wetland woodlands by 10% occurring within the actively managed wetlands and floodplains
NV4f		Coolibah wetland woodland			

Figure 8 **Water-dependent vegetation at the Gingham channel**
Photo: T. Cooke

3.3 Waterbird values and objectives

The Gwydir Wetlands are one of the most significant semi-permanent wetlands in north-western NSW (Keyte 1994) and provide habitat for many waterbirds and water-dependent woodland birds. Since records began in the 1920s at least 75 waterbird species (50 breeding) have been recorded in the Gingham and Lower Gwydir Wetlands (Spencer 2010) . Heavy rainfall and floodwaters that reach the lower catchment can trigger colonial nesting waterbirds (including straw-necked ibis, intermediate egrets, glossy ibis and nankeen night-herons) to nest in large colonies in the wetlands. Prior to regulation of the Gwydir River in 1976, colonial nesting waterbirds bred regularly in the Gingham and Lower Gwydir Wetlands in about seven years of every decade (Spencer 2010). However, river regulation has reduced the frequency of larger flow events reducing opportunities to breed. Agricultural development has further impacted nesting vegetation, including river cooba and lignum, reducing the habitat available for breeding.

In the 30 years to 2012, annual waterbird surveys revealed a 72% decline in average waterbird abundance in the Murray-Darling Basin. 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).

Colonially-nesting species such as egrets and ibis are particularly sensitive to the duration of wetland inundation and require precisely timed flows of sufficient duration, depth and extent to allow birds to pair up, build nests, lay eggs, and fledge their young successfully (Kingsford & Auld 2005; Scott 1997). They usually nest in dense, mixed species colonies and frequently re-use breeding sites. Historically, large colonial-nesting waterbird breeding sites were in many areas along the Gingham Watercourse and Lower Gwydir. Since river regulation, colonially nesting waterbird colonies have been observed mainly in the central and lower Gingham, with smaller colony areas in the Lower Gwydir. The Mallowa has not seen an active colonial nesting waterbird rookery since the 1970s (Humphries *pers. comm.* 2017), but suitable habitat does remain because of environmental watering. The Mallowa has the potential to support future breeding events if sufficient water continues to be delivered to these areas.

Inundation levels required to trigger large-scale colonial nesting waterbird breeding are typically only achieved through larger natural flood events in the Gwydir. Therefore, the focus of waterbird objectives in this LTWP is to support rather than trigger breeding events. Opportunities for waterbirds to breed will increase through the maintenance and improvement of key waterbird breeding and foraging habitat, and through the delivery of targeted flows to maintain or augment naturally initiated larger flow events from nest building through to post-fledging care.

The Gwydir, in particular the Gwydir Wetlands, has been identified as a catchment where restoration of waterbird habitats can contribute to the recovery of waterbird populations across the Murray-Darling Basin (MDBA 2014). One of the objectives is to maintain the diversity of species and support waterbird population recovery in the Gwydir and contribute to increasing their total abundance across the Basin. Because waterbirds are highly mobile, diversity and abundance records in the Gwydir are highly variable. To account for this variability, baseline diversity and abundance is determined by examining available data collected over multiple years.

Because most waterbird surveys in the Gwydir catchment have occurred in the Gwydir Wetlands, information on waterbird diversity and abundance is more reliable for these areas than throughout the rest of the catchment. The objectives for waterbirds described in this LTWP (Table 4 and Appendix A) are therefore only provided for the wetland areas, where progress toward meeting objectives can be evaluated and contribute the most towards the Basin-scale outcomes of the Basin Plan.

The Gwydir's water-dependent vegetation plays an integral role at various stages of a waterbird's life cycle, being used for nesting materials, as a food resource for some species; and as roosting sites for waterbirds after they have dispersed from natal wetlands. For example:

- river red gum and coolibah are used for roosting and nesting by egrets, herons, cormorants and darters.
- river cooba is used for nesting by cormorants, darters and herons.
- Lignum and cumbungi are used for nesting by ibis, magpie geese and spoonbills (Roberts & Marston 2000).

Figure 9 Straw-necked ibis on lignum in the Lower Gwydir Wetlands
Photo: J. J. Smith

Table 4 Waterbird (WB) objectives and targets

Objectives		Targets		
		5 years (2024)	10 years (2029)	20 years[3] (2039)
WB1	Maintain the number and type of waterbird species	Maintain a 5-year rolling average of 41 or more waterbird species across the 5 functional groups[4] in the Gwydir Wetlands	Identify at least 41 waterbird species in the Gwydir Wetlands in a 10-year period	Identify at least 60 waterbird species in the Gwydir Wetlands in a 20-year period
WB2	Increase total waterbird abundance across all functional groups	Total abundance of the 5 functional groups maintained in the Gwydir Wetlands compared to the 5 years 2012–16 period	Total waterbird abundance increased by 20–25% in the Gwydir Wetlands compared to the 5 years 2012–16 period, with increases in all functional groups	Maintain or increase total waterbird abundance in the Gwydir Wetlands compared to the 10-year target, with increases in all functional groups
WB3	Increase opportunities for non-colonial nesting waterbird breeding	Total abundance of non-colonial waterbirds in the Gwydir Wetlands maintained compared to the 5 years 2012–16 baseline and breeding recorded in at least 17 non-colonial waterbird species	Total abundance of non-colonial waterbirds in the Gwydir Wetlands increased by 20–25% compared to the 5 years 2012–16 baseline with breeding detected in at least 17 non-colonial waterbird species	Maintain or increase total abundance of non-colonial waterbirds in the waterbird area compared to the 10-year target, with breeding detected in at least 17 non-colonial waterbird species
WB4	Increase opportunities for colonial nesting waterbird breeding	Successful[5] completion of all naturally occurring colonial waterbird breeding events active during the 2019-2039 period Maintain the water depth and duration of flooding (as required) to support active waterbird breeding through to completion (from egg laying through to fledging including post-fledgling care) in the Gwydir Wetlands Maintain duration of flooding in key foraging habitats to enhance breeding success and the survival of young		
WB5	Maintain the extent and improve condition of waterbird habitats	Maintain extent and improve condition of nesting vegetation, including lignum, cumbungi, river cooba, river red gum and coolibah, in known colonial breeding locations in the Gwydir Wetlands Maintain or increase extent and improve condition of waterbird foraging and breeding locations[6] in the Gwydir Wetlands (to be evaluated under targets set for native vegetation)		

3.4 Priority ecosystem function values and objectives

The freshwater habitat of the Gwydir catchment is comprised of streams and rivers, and floodplain features such as lagoons and semi-permanent wetlands. Within these broad habitat types, niche habitats such as deep channels, pools and riffles, gravel beds, instream

[3] 20-year targets will be further refined following additional data collection.
[4] Functional groups as described in the *Basin-wide Watering Strategy*
[5] Successful breeding relates to completion of nests where fledglings and juvenile birds are observed at the end of each breeding event.
[6] Includes known, historical and potential breeding locations

benches, snags, aquatic vegetation and riparian vegetation provide a complex mosaic of habitats that support a great diversity of species and perform a range of functions (NBR Fish passage report). Restoring lateral and longitudinal connectivity throughout the catchment is fundamental to supporting many of the priority ecosystem functions in the Gwydir. For example, improved hydrological connectivity along river systems and between rivers and their riparian corridors and floodplain is pivotal to moving nutrients, carbon and sediments, enhancing productivity, allowing organisms to disperse and improving water quality (MDBA 2014).

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 billabongs and anabranches. The refugia can contain different types of habitat, such as logs, wet undercut banks, riffles, sub-surface stream sediments and riparian vegetation (Boulton 2003). 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). Refugia should always be the highest priority for protection, but especially during drought.

Quality instream habitat

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 is 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. 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 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 depend on the flow regime and the nature of the riparian vegetation.

River flow management can be used to increase carbon and nutrient sources in-channel by optimising the frequency of floodplain inundation. Re-wetting patches (e.g. river channels, channel benches, floodplains) following drying provides a pulse of terrestrial carbon available for potential use by consumers (e.g. Lanhans & Tockner 2006) and the flow of water enhances the physical breakdown of leaves, branches and other terrestrial detritus (Mora-Gomez et al. 2015). Furthermore, mimicking the natural flooding and drying regimes in wetlands is likely to conserve and enhance macroinvertebrate assemblages (NOW 2012).

Sediment, carbon and nutrient exchange

The frequency of flows that connect rivers with their floodplain has been substantially reduced in the Gwydir catchment because water volumes released from Copeton Dam typically do not exceed channel capacity. The loss of lateral connectivity between rivers and their floodplains has altered water movement, the flux of sediment, nutrients, carbon, and biota from and to the river (Baldwin et al. 2016). Consequently, the amount of dissolved organic carbon entering the main channels is reduced because of less frequent wetting of benches, flood runners and floodplains (Westhorpe et al. 2010). Longitudinal connectivity is equally important and fulfils the important environmental function of transporting nutrients and sediments between environments (MDBA 2014).

Groundwater-dependent biota

While this LTWP is primarily focused on the management of surface water, the Lower Gwydir Groundwater Source plays an important ecological role in supporting terrestrial and aquatic ecosystems, particularly during extended dry periods where they can be critical for maintaining refuges. The dominant groundwater recharge process for the Lower Gwydir alluvium is leakage from the rivers and watercourses as well as direct rainfall infiltration (Berrett 2009). To continue to support groundwater-dependent ecosystems in the Gwydir, objectives in the LTWP relate to maintaining the mapped extent of groundwater-dependent vegetation communities and groundwater levels within their long-term natural ranges.

Inter-catchment flow contributions

Biological connectivity between key planning units and between the Gwydir catchment and the Barwon River during critical spawning periods will support native fish outcomes and contribute to improved outcomes in the Gwydir and Barwon-Darling catchments. Baseflows in the Gwydir are also important for supporting ecologically significant low flows in the Barwon-Darling. Hydrological connectivity at a planning unit scale is required throughout the catchment to contribute to end of system flows.

Figure 10 Sampling on the Gwydir River downstream of Allambie Bridge
Photo: J. Ocock/NPWS

Table 5 Priority ecosystem function (EF) objectives and targets

Objectives		Description and key contributing processes	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
EF1	Provide and protect a diversity of refugia across the landscape	Water depth and quality in pools (in-channel), core wetlands and lakes Condition of vegetation in core wetlands and riparian zones	Very low flows (VFs), baseflows (BF1) and wetland inundation flows (WL1) are provided at target magnitudes and durations as specified in planning unit EWRs Cease-to-flow periods do not exceed maximum durations as specified in planning unit EWRs Adequate water depth is maintained in key refuge pools during dry times Maintain dissolved oxygen >4 mg/L in key refuge pools		
EF2	Create quality instream, floodplain and wetland habitat	Regulation of dissolved oxygen, salinity and water temperature Flow variability and hydrodynamic diversity Provision of diverse wetted areas Appropriate wetting and drying cycles Geomorphic (erosion/deposition) processes that create and maintain diverse physical habitats Appropriate rates of fall to avoid excessive bank erosion Control of woody-vegetation encroachment into river channels and wetlands	Rates of rise and fall does not fall outside the 5^{th} and 95^{th} percentiles of natural rates during regulated water deliveries Period for which instream freshes are held at constant level (± 5%) does not exceed natural durations At least 1 overbank/wetland inundating event 9 years in 10 in relevant planning units At least 3 fresh events per year to inundate in-channel habitat in relevant planning units		

<table>
<tr><th colspan="3" rowspan="2">Objectives</th><th rowspan="2">Description and key contributing processes</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td>EF3a</td><td rowspan="2">Provide movement and dispersal opportunities for water-dependent biota to complete lifecycles and disperse into new habitats</td><td>within catchments</td><td rowspan="2">Dispersal of eggs, larvae, propagules and seeds downstream and into off-channel habitats
Migration to fulfil life-history requirements
Foraging of aquatic species
Recolonisation following disturbance</td><td colspan="3">Annual detection of species and life stages representative of the whole fish community through key fish passages in specified planning units
The recommended frequency and duration of flows providing lateral connectivity with anabranches, low-lying wetlands and floodplains are met (see EWRs for large freshes and above, and wetland inundating flows)
Provide longitudinal connectivity and integrity of flows to end-of-system, including flow pulses (regulated, natural or augmented natural)</td></tr>
<tr><td>EF3b</td><td>between catchments</td><td colspan="3">Increase dispersal opportunities between catchments for native fish species, with a focus on moderate to long-lived flow pulse specialist native fish species between the Gwydir and the Barwon-Darling a minimum 2-3 years in 10.</td></tr>
<tr><td rowspan="2">EF4</td><td colspan="2" rowspan="2">Support instream and floodplain productivity</td><td rowspan="2">Aquatic primary productivity (algae, macrophytes, biofilms, phytoplankton)
Terrestrial primary productivity (vegetation)
Aquatic secondary productivity (zooplankton, macroinvertebrates, fish larvae, adult fish)
Decomposition of organic matter</td><td colspan="3">Maintain or increase the proportion of wetland and floodplain vegetation that is in good condition over a 5-year rolling period
Maintain native fish population structure that indicates successful transition from young-of-year to juveniles
Enhance riverine productivity to support increased food availability for aquatic food webs by increasing the supply of autochthonous and allochthonous carbon and nutrients</td></tr>
<tr><td>No decline in key native fish species condition metrics
Maintain the abundance and distribution of decapod crustaceans</td><td colspan="2">Improve key native fish species condition metrics
Improve the abundance and distribution of decapod crustaceans</td></tr>
</table>

Objectives		Description and key contributing processes	Targets		
			5 years (2024)	**10 years (2029)**	**20 years (2039)**
EF5	Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands	Sediment delivery to downstream reaches and to/from anabranches, floodplains and wetlands Mobilisation of carbon and nutrients from in-channel surfaces (e.g. benches/banks), floodplains and wetlands and transport to downstream reaches and off-channel habitats Dilution of carbon and nutrients that have returned to rivers	Maintain nutrient and carbon (DOC) pulses at multiple locations along a channel during freshes, bankfull and overbank events Increase lateral connectivity with anabranches, low-lying wetlands and floodplains, as specified in EWRs for large freshes, bankfull events, wetland inundating flows and overbank flows Maintain extent and condition of floodplain vegetation Maintain soil nitrogen, phosphorus and carbon levels at long-term natural levels		
EF6	Support groundwater conditions to sustain groundwater-dependent biota	Groundwater recharge and discharge Dilution of saline/acidic groundwater Salt export from the Murray-Darling Basin	Maintain the 2016 mapped extent of groundwater-dependent vegetation communities Maintain groundwater levels within the natural range of variability over the long term		
EF7	Increase the contribution of flows into the Barwon-Darling from tributaries	Provision of end of system flows to support ecological objectives in downstream catchments	Provide flows from Mehi Creek and Gil Gil Creek to the Barwon-Darling catchment, including baseflows a minimum of 5 to 10 years in 10 and in-channel freshes a minimum of 2 to 3 years in 10 Protect larger flows across the Gwydir catchment that can reach the Barwon-Darling catchment a minimum of 2 to 3 years in 10.		

3.5 Other species values and objectives

The variety of water-dependent ecosystems in the Gwydir catchment supports an equally diverse range of water-dependent species, including water rats, woodland birds, platypus, snakes, turtles, bats, and frogs. While most of these species are supported by the other four objective themes, specific objectives and targets have been developed for frogs because certain species are especially responsive to flows, particularly with regard to breeding opportunities and success (Table 6). Frogs are an important food source for waterbirds, fish and reptiles. Flow-dependent frogs have similar watering requirements to waterbirds for breeding, however, they are not highly mobile, so they require refuge between watering events. As such, the inclusion of flow-dependent frog objectives places greater emphasis on the need to maintain refuge (including permanent waterbodies for some species) in the floodplain.

Historical frog surveys throughout the Gwydir are limited, but more recent surveys over the past 3 years have identified six flow-dependent frog species in the region, which include the eastern sign-bearing froglet, barking marsh frog and salmon striped frog (Ocock and Spencer 2018). While waterholes and dams provide good refuge for frogs generally, the highest levels of observed breeding and recruitment has been observed to be in temporarily inundated wetland and floodplain sites (Ocock and Spencer 2018). Recent surveys in the Gwydir showed that delivery of water for the environment has coincided with higher levels of breeding activity of many flow-responsive frog species in the Gwydir (Ocock and Spencer 2018).

Table 6 Frog and other water-dependent species (OS) objectives and targets

Objectives		Targets		
		5 years (2024)	10 years (2029)	20 years (2039)
OS1	Maintain species richness and distribution of flow-dependent frog communities	Detect all six flow-dependent frog species[7] known from the Gwydir Wetlands based on comprehensive surveys over the 2015-17 period		
OS2	Maintain successful[8] breeding opportunities for flow-dependent frog species	Maintain proportion of wetlands sites where breeding activity[9] of flow-dependent frog species is detected in the Gwydir Wetlands compared to the 2015-17 period		
OS4[10]	Maintain water-dependent species richness	Over the long term (20 years) no reduction in the number and range of water-dependent species that are found throughout the catchment. Platypus present in the Gwydir River downstream of Copeton Dam planning unit and relevant Zone B planning units. Evidence of platypus burrows and successful breeding detected.		

[7] Eastern sign-bearing froglet, barking marsh frog, salmon striped frog, spotted grass frog, broad-palmed frog, and Peron's tree frog

[8] Successful relates to opportunities for species to complete breeding life cycle i.e. laying eggs, to development of tadpoles through to metamorphs (juvenile frogs) which relates to water requirements for minimum duration of inundation

[9] We consider breeding activity to be evidence of male frog callings, frog spawn observed, tadpoles detected and/or recently metamorphosed juvenile frogs as evidence of potential recruitment of new individuals into the breeding population

[10] OS3 refers to objectives relating to southern bell frogs, which are not relevant in Gwydir catchment

Figure 11 Peron's tree frog in Bunnor in the Gwydir Wetlands
Photo: T. Cooke

3.6 Aboriginal cultural values and objectives

NSW LTWPs recognise the importance of rivers and wetlands to Aboriginal culture. For First Nations People, water is a sacred source of life. The natural flow of water sustains aquatic ecosystems that are central to their spirituality, culture and wellbeing. Rivers are described as 'the veins of Country', carrying water to sustain all parts of their sacred landscape, and the wetlands described as the 'kidneys', filtering the water as it passes through the land (National Cultural Flows Research Project, 2019).

Aboriginal cultural values are related to specific places, plants and animals and to the landscape as a whole. There are important linkages between flow events and cultural outcomes. NSW LTWPs acknowledge Aboriginal connection to country and aim to protect Country by maintaining the health of rivers and wetlands, and water-dependent plants and animals that have cultural value.

The floodplain wetlands and waterways of the Gwydir WRPA are central to its Traditional Owners, the Gomeroi/Kamilaroi people, who have longstanding and continuing ties to Country, the waterways and life sustained by it.

Consultation with Aboriginal Nations of the Gwydir WRPA on cultural values and objectives related to water-dependant ecosystems and management of water more broadly is ongoing. This includes the MDBA Aboriginal Partnership Program, and *The Report on culturally appropriate First Nations consultation with Gomeroi Nation* (NSW DPIE-Water 2019b), which presents the objectives and outcomes for the management of water, based on their water-dependent values and uses[11].

[11] As determined during targeted consultation between March and April 2018 as part of the Gwydir WRP development and consultation

In order to achieve these objectives and outcomes, continued collaboration is needed between government and non-government agencies, landholders, and Gomeroi/Kamilaroi people in the Gwydir. DPIE-BC will continue to consult with these Nations during implementation of the LTWP.

Figure 12 Carved trees, Bora grounds, off Watercourse Road
Photo: T. Cooke

4. Environmental water requirements

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

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

Each flow category can provide for a range of ecological functions. For example, a small fresh might inundate river benches that provide access to food for native fish and support in-channel vegetation. Similarly, an overbank flow may support carbon exchange between the river and its floodplain and improve river red gum condition. Flow categories describe the height or level of a flow within a river channel or its extent across a floodplain (Figure 13 and Table 7). Flow rates for flow categories at sites across the Gwydir catchment are shown in Table 9.

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

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

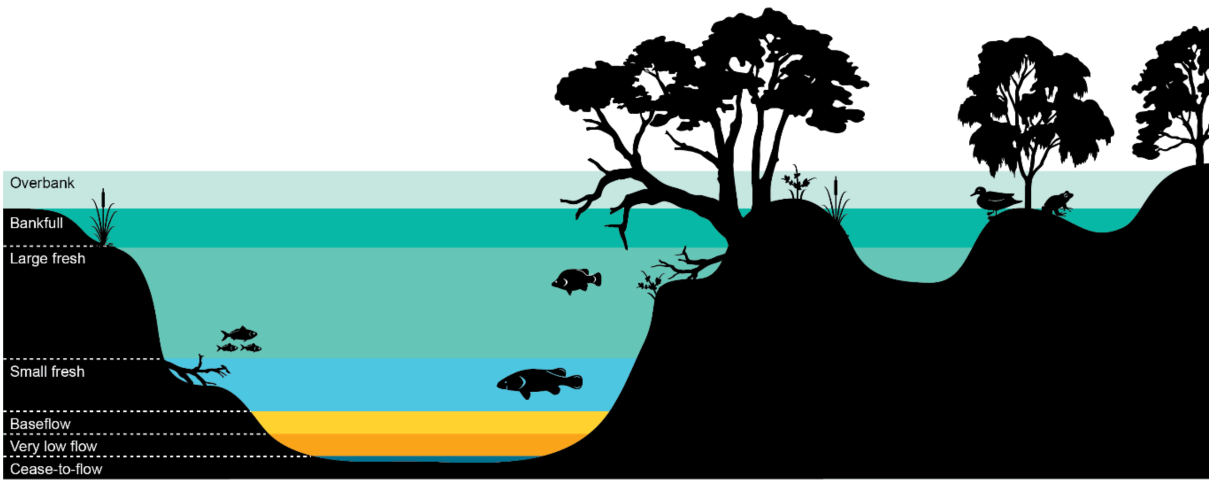


Figure 13 A simplified conceptual model of the role of each flow regime categories

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

Flow category	Description
Overbank / Wetland inundation flow (OB / WL)	Provide lateral connectivity with floodplain and wetlands. They support nutrient, carbon and sediment cycling between the floodplain and channel, and promote large-scale productivity. Overbank flows are used to describe flows when they are above bankfull. Wetland inundation flows (not shown in Figure 13) are used to describe: flows that fill wetlands via regulating structures below bankfull over weeks or sometimes months (i.e. longer than a typical fresh/pulse), or flows that are required to inundate wetlands in areas where there are very shallow channels or no discernible channels exist (e.g. terminal wetlands).
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.

4.1 Developing environmental water requirements to support ecological objectives

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

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

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

A summary of flow rates for flow categories at sites along the Gwydir are shown in Table 9. The timing, duration and frequency components of EWRs, grouped by flow category, for all biota and functions in the Gwydir catchment and the objectives they support, are presented in Table 10. Important flow regime characteristics to meet life-history needs and each of the LTWP objectives are described in Tables 11-15.

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

Term	Definition and guide to interpreting information
EWR code	Each EWR is given a specific code that abbreviates the EWR name (e.g. SF1 for small fresh 1). This code is used to link ecological objectives and EWRs.
Ecological objectives	The LTWP ecological objectives supported by the EWR. Includes reference to codes of all LTWP objectives supported (e.g. NF1 = Objective 1 for Native Fish), and a short description of key objectives and life stages being targeted (e.g. spawning or recruitment). Bold text indicates the primary objectives of each EWR. See Tables 2–8 for full objectives.
Gauge	The flow gauging station that best represents the flow within the planning unit, for the purpose of the respective EWR and associated ecological objective(s). To assess the achievement of the EWR, flow recorded at this gauge should be used.
Flow rate or flow volume	The flow rate (typically ML/d) or flow volume (typically GL over a defined period of time) that is required to achieve the relevant ecological objective(s) for the EWR. Most EWRs are defined using a flow rate, whilst flow volumes are used for EWRs that represent flows into some large wetland systems.
Timing	The required timing (or season, typically expressed as a range of months within the year) for a flow event to achieve the specified ecological objective(s) of the EWR. In some cases, a preferred timing is provided, along with a note that the event may occur at ‘anytime’. This indicates that ecological objectives may be achieved outside the preferred timing window, but perhaps with sub-optimal outcomes. In these instances, for the purposes of managing and delivering environmental water, the preferred timing should be used to give greater confidence in achieving ecological objectives. Natural events may occur at other times and still achieve ecological objectives.
Duration	The number of consecutive days that flows must be above the specified flow rate for the flow event to achieve the EWRs specified ecological objective(s) of the EWR. Typically, this is expressed as a minimum duration. Longer durations will often be desirable and deliver better ecological outcomes. Some species may suffer from extended inundation durations, and where relevant a maximum duration may also be specified. Flows may persist on floodplains and within wetland systems after a flow event has passed. Where relevant, a second duration may also be specified, representing the duration for which water should be retained within floodplain and wetland systems.
Frequency	The frequency at which the flow event should occur to achieve the ecological objective(s) associated with the EWR. Frequency is expressed as the number of years that the event should occur within a 10-year period. In most instances, more frequent events will deliver better outcomes and maximum frequencies may also be specified, where relevant. Clustering of events over successive years can occur in response to climate patterns. Clustering can be ecologically desirable for the recovery and recruitment of native fish, vegetation and waterbirds populations, however extended dry periods between clustered events can be detrimental. Achieving ecological objectives will require a pattern of events over time that achieves both the frequency and maximum inter-flow period, and the two must be considered together when evaluating outcomes or managing systems.

Term	Definition and guide to interpreting information
	Where a range of frequencies is indicated (e.g. 3–5 years in 10), the range reflects factors including the natural variability in population requirements, uncertainty in the knowledge base, and variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences at the lower end of the range, and population improvement and recovery during wet climate sequences at the upper end of the range). The lower end of the frequency range (when applied over the long term) may not be sufficient to maintain populations and is unlikely to achieve any recovery or improvement targets. As such, when evaluating EWR achievement over the long-term through statistical analysis of modelled or observed flow records, the LTWP recommends using a minimum long term average (LTA) target frequency that is at least the average of the recommended frequency range but may be higher than the average where required to achieve objectives. For example, for a recommended frequency range of 3-5 years in 10, the minimum LTA frequency should be at least 40% of years, but may be up to 50% of years at sites where a higher frequency should be targeted over the long term to ensure recovery in certain species/populations. Whilst these higher frequencies may exceed modelled natural event frequency in some cases, recovery in particularly degraded systems will be unlikely should lower (i.e. average) frequencies be targeted. Minimum LTA target frequencies in this LTWP are reported predominantly as the average of the recommended frequency range, however this may be refined during implementation of the LTWP and in future revisions of the LTWP based on the results of ongoing ecological monitoring.
Maximum inter-flow or inter-event period	The maximum time between flow events before a significant decline in the condition, survival or viability of a particular population is likely to occur, as relevant to the ecological objective(s) associated with the EWR. This period should not be exceeded wherever possible. Annual planning of environmental water should consider placing priority on EWRs that are approaching (or have exceeded) the maximum inter-event period, for those EWRs that can be achieved or supported by the use of environmental water or management.
Additional requirements and comments	Other conditions that should occur to assist ecological objectives to be met – for example rates of rise and fall in flows. Also comments regarding limitations on delivering environmental flows and achieving the EWR.

Figure 14 Copeton Dam on the Gwydir River
Photo: T. Cooke

4.2 Flow category thresholds

The flow rates that define each flow category (baseflows, small freshes etc.) and associated EWRs will vary between catchments and river reaches. Table 9 presents the range of flow rates for each flow category at representative gauge sites in the Gwydir catchment (Figure 13). The environmental outcomes associated with each flow category are expected to begin occurring at the bottom end of the flow ranges. Greater and sometimes substantially increased outcomes are likely to occur (e.g. for wetland connecting large freshes and overbank flows) as flows increase in size. While the flow rates for each flow category are expressed as ranges in Table 9, flow rates for the EWRs presented in Part B are expressed as minimum flow rates (i.e. the bottom end of the range) in most cases, meaning that an EWR may also be met by higher flows in other categories (unless otherwise stated).

Table 9 **Flow threshold estimates (ML/d, unless otherwise stated) for flow categories in Zone A planning units in the Gwydir catchment**

Planning unit	Gauge[12]	Low flows		Freshes			Wetland inundation		Overbank	
		Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small	Large	Small	Large
Gwydir downstream of Copeton	418013	30–170	170–990	990–8,600	8,600–90,000	90,000–100,000				>100,000
Main Gwydir River	418004	20–130	130–540	540–4,860	4,860–50,000	50,000–60,000				>60,000
Lower Gwydir	418053 418063* 418078** 418004***	>10	50–250*	250–800*	800–1,500*	1,500–3,500*			>10,000–60,000 ML event**	>60,000***
Central Lower Gwydir	418078 418004*				>250,000 ML event*	50,000-60,000*	>6,000 ML event* and >36,000–45,000 ML event	>45,000–65,000 ML event		>60,000*
Western Gwydir Floodplain	418004				>250,000 ML event	50,000-60,000				>60,000
Upper Gingham	418074 418004*	10-50	50-250	250-1,000	1,000-50,000	50,000-60,000*	>10,000-45,000 ML event	>45,000-60,000 ML event		>60,000*
Central Gingham	418076 418004*				>250,000 ML event*	50,000-60,000*	>8,000-40,000 ML event	>40,000-50,000 ML event		>60,000*
Lower Gingham	418079 418004				>250,000 ML event*	50,000-60,000*	>3,000-20,000 ML event	>20,000-30,000 ML event		>60,000*

[12] Flow threshold estimates can relate to different gauges within the same planning unit. Gauges with * relate to flow thresholds in that column with the same number of *.

Planning unit	Gauge[12]	Low flows		Freshes			Wetland inundation		Overbank	
		Very low flow	Baseflow	Small fresh	Large fresh	Bankfull	Small	Large	Small	Large
Western Gingham Floodplain	418004				>250,000 ML event	50,000-60,000				>60,000
Tarren Creek	418004				>250-000 ML event	50,000-60,000				>60,000
Goonal Creek	418004				>250-000 ML event	50,000-60,000				>60,000
Upper Mehi	418002	20–130	130–345	345–2,800	2,800–10,000	10,000-20,000				>20,000-30,000
Central Mehi	418037 418002*	10–80	80–220	220–1,500	1,500–8,400	8,400-16,000				>20,000-30,000*
Lower Mehi	418055 418002*		40–90	90–800	800–13,000	13,000-16,000				>20,000-30,000*
	418085		50–100	100–850	850-12,000	12,000-15,000				
Ballin Boora	No gauge 418068* 418002**		600–1,200 ML event						>3,000-21,000 ML event*	>20,000-30,000**
Moomin Creek	418048 418002*		30–80	80–500	500–2,200	2,200–3,000			>3,000	>20,000-30,000*
Mallowa Creek	418049 418002*						>3,000–15,000 ML event	>15,000–22,000 ML event		>20,000-30,000*
Carole Creek	418011* 418052	>20*	70–200	200–900	900–1,500	1,500–2,000			>2,000–6,000	>160,000 ML event*
Gil Gil Creek	416052		25–45	45–750	750–2,000	2,000–2,700				
	416027		60–160	160–1,900	1,900–2,700	2,700–3,700			>3,700–20,000	>20,000

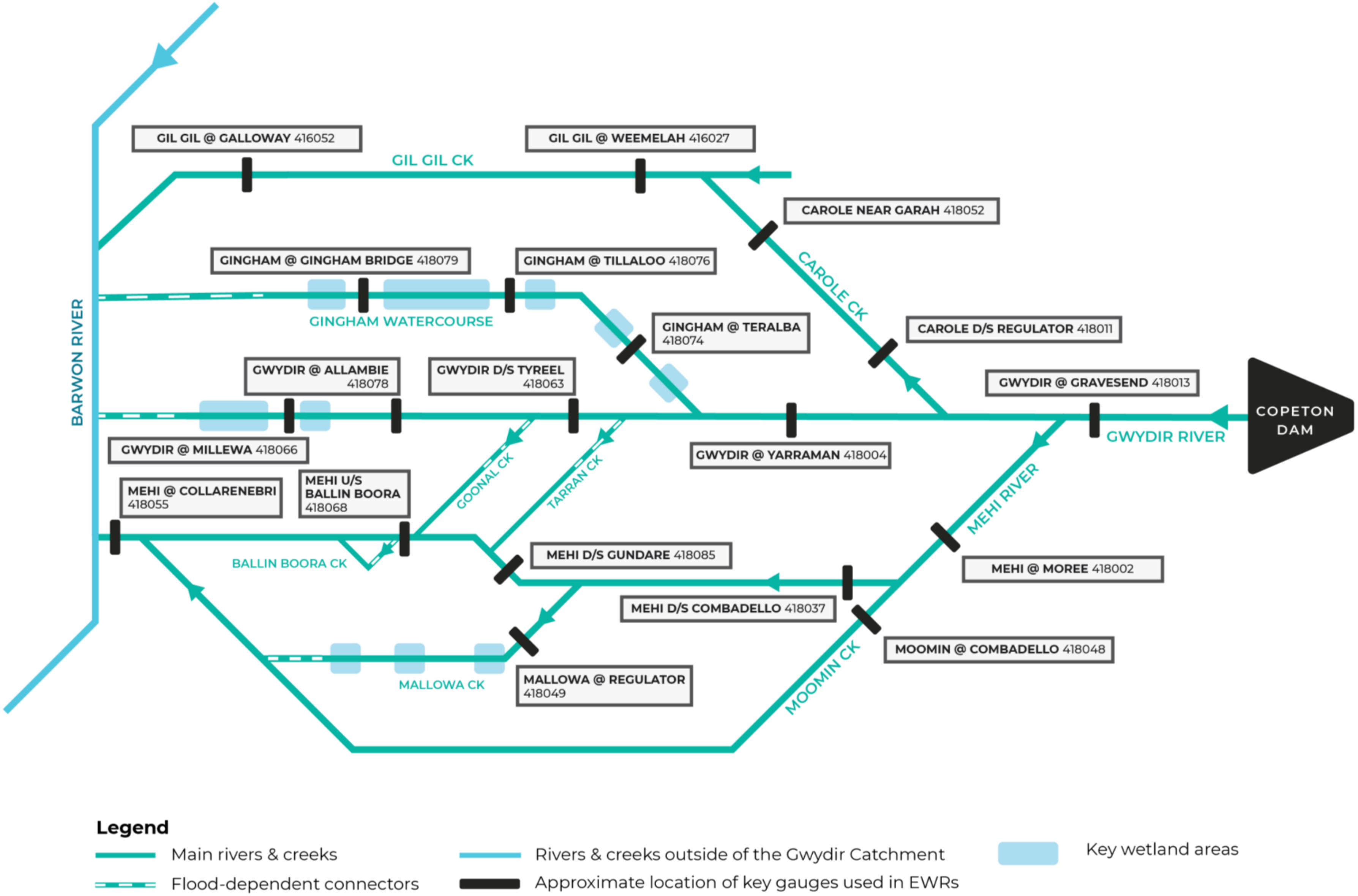


Figure 15 Schematic diagram of the main watercourses in Zone A planning units and the key streamflow gauges used for EWRs in the Gwydir

4.3 Catchment scale environmental water requirements

Table 10 Catchment scale environmental water requirements and the ecological objectives they support[13]

Flow category and EWR code		Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
Cease-to-flow	CF1	Native Fish: NF1 – Survival (all species) Ecosystem Functions: EF1, 2 – refuge habitat	In line with historical low flow season, typically April to June	In line with natural, unless key refuges threatened	No greater than natural	N/A	When restarting flows ensure a slow rate of rise and fall (in line with natural) to reduce the risks of harmful water-quality impacts, such as de-oxygenated refuge pools Ideally there would be no cease-to-flow periods between August to June to accommodate the platypus reproductive cycle, including juvenile dispersal, in known platypus breeding habitat.
Very-low flow	VF1	Native Fish: NF1 – Survival and condition (all species) Ecosystem Functions: EF1, 2 – refuge habitat Other Species: OS4	Any time	In line with natural	No less than natural	1 year	
Baseflow	BF1	Native Fish: NF1, 2, 3, 4, 5, 6, 7, 8 – condition and movement Native Vegetation: NV1, 2 – in-channel and wetland non-woody Ecosystem Functions: EF1, 2, 3a Other Species: OS4 – platypus foraging and movement	Any time	In line with natural	Annual	1 year	Minimum depth of 0.3 meters to allow fish passage Flow magnitude should be varied during event to avoid bank notching (within daily limits for rates of rise and/or fall)
	BF2	Native Fish: NF1, 2, 5, 6, 8 – Recruitment (riverine specialists, generalists) Ecosystem Functions: EF1, 2, 3a, 3b, 7	September to March	In line with natural	5–10 years in 10 (75%)	2 years	

[13] See Table 8 for definitions and explanatory text

Flow category and EWR code		Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
Small fresh	SF1	Native Fish: NF1, 2, 3, 4, 5, 6, 7, 8 – Dispersal/condition (all species) Native Vegetation: NV1 – in-channel Ecosystem Functions: EF1, 2, 3a, 5 Other species: OS4	October to April (but can occur any time)	10 days	Annual	1 year	Minimum depth of 0.5 metres to allow movement of large native fish Ideal foraging habitat for platypus is 1-3 metres >20°C from Oct to April (for native fish); >16°C for river blackfish; Sept to Dec >18°C for Murray cod Flow magnitude should be varied during event to avoid bank notching (within daily limits for rates of rise and/or fall) Rate of fall: No faster than 5th percentile of natural
	SF2	Native Fish: NF1, 2, 5, 6, 8 – Spawning (river specialists, generalists) Native Vegetation: NV1 – in-channel Ecosystem Functions: EF1, 2, 3a, 5 Other Species: OS4	September to April	14 days	5–10 years in 10 (75%)	2 years	
	SF3	Native Fish: NF1, 4, 6 – Dispersal between catchments (flow specialists) Native Vegetation: NV1 – in-channel Ecosystem Functions: EF2, 3a, 3b, 5, 7 – between catchment connectivity	October to April (but can occur any time)	10 days	Within 12 months following LF5	4 years	
Large fresh	LF1	Native Fish: NF1, 2, 4, 5, 6, 8 – dispersal/condition (all species) Native Vegetation: NV1 – in-channel Ecosystem Functions: EF2, 3a, 4, 5, 6 Other Species – OS1, 2, 4	July to September (but can occur any time)	5 days	5–10 years in 10 (75%)	2 years	Minimum depth of 2 metres to cover instream features and trigger response from native fish Ideal foraging habitat for platypus is 1-3 metres Flow ideally 0.3 to 0.4 m/s (depending on channel form) to trigger native fish movement

Flow category and EWR code	Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
LF2	Native Fish: NF1, 4, 6 – spawning (flow pulse specialist fish) Native Vegetation: NV1 – in-channel Ecosystem Functions: EF2, 3a, 4, 5, 6 Other Species – OS1, 2	October to April (Ideally 2-3 weeks before SF1)	5 days	3–5 years in 10 (40%)	4 years	Flow magnitude should be varied during longer duration events to avoid bank notching (within daily limits for rates of rise and/or fall) Rate of rise and fall: No faster than 5th percentile of natural Ideally flow should be complete before the end of August and the upper limit of the flow should be 1 metre below bankfull to support the creation of suitable burrows for platypus breeding in planning units where platypus are present Higher magnitude large fresh flows will often result in overbank flows and wetland inundation in downstream planning units
LF3	Native Vegetation: NV1, 2, 3 – in-channel, fringing, wetland Ecosystem Functions: EF2, 3a, 4, 5, 6 – connectivity with low lying floodplains and anabranches in some upland planning units Other Species – OS1, 2	August to February (but can occur any time)	In line with natural	3–5 years in 10 (40%)	4 years	
LF4	Native Fish: NF1, 4, 6 – dispersal (flow pulse specialist fish) Ecosystem Functions: EF2, 3a, 3b, 4, 5, 6, 7 – between catchment connectivity	July to September (but can occur any time)	5 days	Triggered when LF1 at Barwon @ Collarenebri is detected within 18 months of LF2 at Darling @ Wilcannia	4 years	
LF5	Native Vegetation: NV1, 2, 3 – in-channel, fringing, wetland Ecosystem Functions: EF2, 3a, 4, 5, 6 – connectivity with low lying floodplains and anabranches in some upland planning units	September to May (but can occur any time)	In line with natural	2–3 years in 10 (25%)	5 years	

Flow category and EWR code		Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
	LF6	Native Vegetation: NV4d – coolibah woodland maintenance Waterbirds: WB1, 2, 3, 4, 5 – survival, habitat and breeding (non-colonial and colonial) Ecosystem Functions: EF2, 3a, 5, 6, 7 – connectivity, productivity Other Species: OS1, 2	Any time	1–2 months	1–3 years in 10 (15%)	10 years	
Bankfull	BK1	Native Vegetation: NV1, 2, 3 – in-channel and fringing Ecosystem Functions: EF1, 2, 3a, 4, 5, 6 – channel maintenance, lateral/longitudinal connectivity Other Species: OS4	August to February (but can occur any time)	In line with natural	In line with natural	N/A	Rate of rise and fall: No faster than 5th percentile of natural Ideally flow should be complete before the end of August and the upper limit of the flow should be 1 metre below bankfull to support the creation of suitable burrows for platypus breeding in planning units where platypus are present
Small wetland inundation	WL1	Native Fish: NF1 Native Vegetation: NV1, 2, 3 Waterbirds: WB5 Ecosystem Functions: EF1, 2, 3a, 4, 5, 6 – protection of core wetland areas Other Species: OS1, 2	Any time	In line with natural	9–10 years in 10 (95%)	18 months	Rate of fall: No faster than 5th percentile of natural

Flow category and EWR code		Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
	WL2	Native Fish: NF1, 3, 7 Native Vegetation: NV1, 2, 3 – non-woody wetland maintenance and regeneration Waterbirds: WB1, 2, 5 – survival and habitat Ecosystem Functions: EF2, 3a, 4, 5, 6 – connectivity, productivity Other Species: OS1, 2	September to March (but can occur any time)	2–8 months of asset inundation	7–9 years in 10 (80%)	2 years	Rate of fall: No faster than 5th percentile of natural
Large wetland inundation	WL3	Native Fish: NF1, 3, 7 – Spawning (floodplain specialist fish) Native Vegetation: NV1, 2, 4b, 4e, 4f – lignum regeneration, coolibah wetland regeneration Waterbirds: WB1, 2, 3, 5 – survival, habitat and potential breeding (non-colonial) Ecosystem Functions: EF2, 3a, 4, 5, 6, 7 – connectivity, productivity Other Species: OS1, 2	October to April	10 days, 2–6 months of asset inundation	5–7 years in 10 (60%)	3 years	Rate of fall: No faster than 5th percentile of natural Ideally 2–4 weeks after SF2 or LF2

Flow category and EWR code		Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
	WL4	Native Fish: NF1, 3, 7 – dispersal and condition (all species) Native Vegetation: NV1, 2, 3, 4b, 4e, 4f – lignum maintenance, coolibah wetland maintenance Waterbirds: WB1, 2, 3, 4, 5 – survival, habitat and potential breeding (non-colonial and small scale colonial) Ecosystem Functions: EF2, 3a, 5, 6, 7 – connectivity, productivity Other Species: OS1, 2	August to February (but can occur any time)	5 days, 2–4 months of asset inundation	3–5 years in 10 (40%)	5 years	>22°C Rate of fall: No faster than 5th percentile of natural Ideally 2–4 weeks after SF2 or LF2
Small overbank	OB1	Native Fish: NF1, 3, 7 Native Vegetation: NV3, 4b, 4e – in-channel, fringing, wetland; lignum regeneration; RRG control Waterbirds: WB1, 2, 5 – survival and habitat Ecosystem Functions: EF1, 2, 3a, 4, 5, 6 – connectivity, productivity Other Species: OS1, 2	September to March (but can occur any time)	2–8 months of asset inundation	7–8 years in 10 (75%)	2 years	Rate of fall: No faster than 5th percentile of natural

Flow category and EWR code	Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
OB2	Native Fish: NF1, 3, 7 – Spawning (floodplain specialist fish) Native Vegetation: NV4b, 4c, 4e, 4f – RRG maintenance; black box/lignum/ coolibah regeneration Waterbirds: WB1, 2, 3, 5 – survival, habitat and potential breeding (non-colonial) Ecosystem Functions: EF2, 3a, 4, 5, 6 – connectivity, productivity Other Species: OS1, 2	October to April	10 days, 2–6 months of asset inundation	4–7 years in 10 (55%)	3 years	Rate of fall: No faster than 5th percentile of natural Ideally 2–4 weeks after SF2 or LF2
OB3	Native Fish: NF1, 2, 3, 4, 5, 6, 7, 8 – dispersal and condition (all species) Native Vegetation: NV4b – RRG woodland regeneration Waterbirds: WB1, 2, 5 – habitat Ecosystem Functions: EF2, 3a, 4, 5, 6 – lateral connectivity, productivity Other Species: OS1, 2	August to February (but can occur any time)	5 days, 2–3 months of asset inundation	3–5 years in 10 (40%)	4 years	>22°C Rate of fall: No faster than 5th percentile of natural Ideally 2–4 weeks after SF2 or LF2

Flow category and EWR code		Ecological objectives	Timing	Minimum duration	Frequency (LTA frequency)	Maximum inter-event period	Additional requirements and comments
Large overbank	OB4	Native Fish: NF3, NF5 Native Vegetation: NV4c, 4e – black box and lignum maintenance Waterbirds: WB1, 2, 3, 4, 5 – breeding (colonial and non-colonial) and habitat Ecosystem Functions: EF2, 3a, 3b, 4, 5, 6, 7 – lateral connectivity, productivity, between catchment connectivity Other Species: OS1, 2	September to May (but can occur any time)	3–8 months of asset inundation	2–3 years in 10 (25%)	5 years	Rate of fall: No faster than 5th percentile of natural All large overbank flows in the Gwydir are reliant on the protection of large natural events
	OB5	Native Fish: NF3, NF5 Native Vegetation: NV4d – coolibah maintenance Waterbirds: WB1, 2, 3, 4, 5 – breeding (colonial and non-colonial) and habitat Ecosystem Functions: EF2, 3a, 3b, 4, 5, 6, 7 – lateral connectivity, productivity, between catchment connectivity Other Species: OS1, 2	Any time	1–6 months of asset inundation	1 year in 10 (10%)	10 years	

Table 11 Important flow regime characteristics needed to deliver native fish objectives

NATIVE FISH OBJECTIVES[14]

Ecological objective	EWR code	Important flow regime characteristics
NF1: No loss of native fish species	CF1	Cease-to-flow periods of durations that are not longer than the persistence of water of sufficient volume and quality in key larger river pool refuges is vital for survival of native fish populations.
	VF1; BF1	Very low flows and baseflows are required for the survival and maintenance of native fish condition as these flows maintain adequate water quality (dissolved oxygen, salinity and temperature) and water volumes in refuge pools and sufficient flow depth along the whole channel to allow fish movement (at least 0.3 m above cease-to-flow for small and moderate bodied fish [Gippel 2013; O'Conner et al. 2015] and 0.5 m for large bodied fish [Fairfull & Witheridge 2003; Gippel 2013; O'Conner et al. 2015]). Alternative watering actions (e.g. pumping) may be required to support floodplain habitats under very dry, dry and moderate scenarios to ensure no loss of species (e.g. to prevent wetlands with threatened fish species from drying out).
	BF2	Baseflows, preferably between September and March with an annual or biannual frequency, are required to enhance recruitment outcomes.
	SF1	Small freshes (at least 0.5 m above cease-to-flow) supports movement and dispersal opportunities for large bodied fish (Fairfull & Witheridge 2003; Gippel 2013; O'Conner et al. 2015).
	LF1	A large fresh of at least five days duration and occurring ideally between July and September (but can occur at any time) is required to promote dispersal and pre-spawning condition for all native fish species five to 10 years in 10. The large fresh should trigger some primary productivity that will provide food resources and hence improve fish condition prior to the spring/summer spawning season. Flow velocities of >0.3 m/s are ideal to trigger fish movement.
	WL4	Larger flows that connect low-lying wetlands provide important habitat to support strong survivorship and growth of juveniles.
	OB3	A small overbank and wetland inundating flows, ideally from September to February, for at least five days and occurring two to three years in 10 years (with a maximum inter-event period of five years) is also required to support condition and movement/dispersal outcomes of all native fish groups. Larger flows that inundate off-stream habitat can also promote growth and recruitment through increased floodplain productivity and habitat availability.

[14] Important flow regime characteristics for all native fish objectives are based on NSW DPI 2015b and Ellis et al. 2016.

NATIVE FISH OBJECTIVES[14]

Ecological objective	EWR code	Important flow regime characteristics
NF2: Increase the distribution and abundance of **short to moderate-lived generalist** native fish species	CF1; VF1; BF1; BF2; SF1; LF1; WL4; OB3	In addition to the flows listed above for all native fish species (see NF1 objective), other important aspects of the flow regime for generalists are listed below.
	SF2	Regular (ideally annual) spawning and recruitment events are required for the persistence of short-lived species. Although generalist species can spawn independent of flow events, spawning is enhanced by small freshes during the warmer months of September to April. Events should occur five to 10 years in 10 years with a minimum event duration of 14 days for egg development and hatching. Providing multiple freshes during the spawning season provides flexibility in species response and opportunities for multiple spawning events.
	LF2	Large freshes occurring two to three weeks after spawning will enhance recruitment of larvae and juveniles by aiding dispersal and access to habitat and suitable prey. Larger flows that inundate off-stream habitat can also promote growth and recruitment (i.e. increased floodplain productivity and habitat availability).
NF3: Increase the distribution and abundance of **short to moderate-lived floodplain specialist** native fish species	CF1; VF1; BF1; BF2; SF1; LF1; WL4; OB3	In addition to the flows listed above for all native fish species (NF1), other important aspects of the flow regime for floodplain specialists are listed below.
	WL3; OB2	Overbank and wetland inundating flows during the warmer months of October to April provide spawning habitat and floodplain productivity benefits to support fish growth. Overbank and wetland flows should inundate floodplain habitats for at least 10 days to allow for egg development and be of a long enough duration to support isolated populations. Larger flows should occur at least five years in 10, with a maximum inter-event period of four years. This period will depend on the persistence of floodplain habitats and time between reconnection to mainstem waterways. Water temperatures should be above 22°C.
	LF1-6; BK1; WL1-4; OB1-5	Recruitment is enhanced by subsequent flows events 2–4 weeks after spawning flows. Most floodplain specialist species require spawning and recruitment every one to two years for population survival.

NATIVE FISH OBJECTIVES[14]

Ecological objective	EWR code	Important flow regime characteristics
NF4: Improve native fish population structure for **moderate to long-lived flow pulse specialist** native fish species	CF1; VF1; BF1; BF2; SF1; LF1; WL4; OB3	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for flow pulse specialists are listed below.
	LF2	Spawning of flow pulse specialists is triggered by a rapid rise or fall in flow (relative to natural rates) between spring and summer when temperatures are greater than 17°C. In lowland systems, spawning responses are enhanced by substantial flow depths of at least 2 m to cover instream features and high flow velocities of greater than 0.3 m/s. Large freshes between October to April for a minimum of five days and a rapid rate of rise should meet these spawning requirements. This is needed three to five years in 10 with a maximum inter-event period of four years. Integrity of flow events need to be maintained over long distances (10s to 100s of km) to maximise the capacity for instream spawning, downstream dispersal by drifting eggs and larvae and movements by adults and juveniles.
NF5: Improve native fish population structure for **moderate to long-lived riverine specialist** native fish species	CF1; VF1; BF1; BF2; SF1; LF1; WL4; OB3	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for riverine specialists are listed below.
	SF2	Spawning of riverine specialists usually occurs annually, independent of flow, however spawning may be enhanced by a small fresh between September and April to promote ecosystem productivity and inundate additional spawning habitat. Event duration should be a minimum of 14 days with an average frequency of five to 10 years in 10 and maximum inter-event period of two years. Water temperatures should be >20°C. River blackfish may spawn in lower water temperatures of >16°C and Murray cod in >18°C. Murray cod have a narrower spawning window of September to December. For nesting species (e.g. Murray cod and freshwater catfish) preventing rapid drops water levels (that exceed natural rates of fall) during, and for a minimum of 14 days after, spawning is important for preventing fish nests from drying.

NATIVE FISH OBJECTIVES[14]

Ecological objective	EWR code	Important flow regime characteristics
	SF1-2; LF1-2; BK1; WL1-4; OB1-5	Overall, riverine specialists prefer hydraulically complex flowing streams containing submerged structure (snags and benches) that provides cover and spawning habitat. Flow variability through the delivery of small and large freshes, bankfull and overbank flows enhance the availability of diverse habitat, enhances growth and condition of larvae and juveniles and provides connectivity for dispersal between habitats. Recruitment is also enhanced by a larger secondary flow pulse for dispersal and access to nursery habitat in low-lying wetland habitats.
NF6: A 25% increase in abundance of mature (harvestable sized) golden perch and Murray cod	CF1; VF1	The flow requirement of golden perch (flow pulse specialist) and Murray cod (riverine specialist) are outlined above under NF4 and NF5, respectively. An increase in mature (harvestable size) fish is strongly dependant on recruitment success and supporting improved population structure.
	BF1-2	Baseflows support the maintenance of populations.
	SF1-2; LF1; LF2; WL4; OB3	Recruitment for both species benefits from fresh events and larger flows that inundate ephemeral wetlands (bankfull, overbank and in some cases, large freshes). Such large events provide dispersal opportunities and access to sheltered and productive nursery habitat.
NF7: Increase the prevalence and/or expand the population of key **short to moderate-lived floodplain specialist** native fish species into new areas (within historical range)	CF1; VF1; BF1; BF2; SF1; LF1; WL3; WL4; OB2; OB3	Flow requirements of floodplain specialists are outlined for NF3. Expanding populations into new areas will be particularly dependant on dispersal flows, particularly large freshes, overbanks and wetland inundating flows. Complementary actions such as conservation stocking and/or translocation may be required to support these watering actions. Infrastructure based watering actions (e.g. pumping) may also be required to support floodplain habitats under very dry, dry and moderate scenarios to ensure no loss of species for floodplain specialists (e.g. to prevent wetlands with threatened fish species from drying out).
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)	CF1; VF1; BF1; BF2; SF1-2; LF1; WL4; OB3	Flow requirements of riverine specialists are outlined for NF5. Expanding populations into new areas will be particularly dependant on dispersal flows, particularly large freshes, overbank and wetland inundating flows. Complementary actions such as conservation stocking and/or translocation may be required to support these watering actions.

Table 12 Important flow regime characteristics needed to deliver native vegetation objectives

NATIVE VEGETATION OBJECTIVES[15]

Ecological objective	EWR code	Important flow regime characteristics
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within and closely fringing channels	CF1	Non-woody, inundation tolerant plants occurring on the channel bed, banks, bars and benches require regular wetting and drying to complete life cycles. Prolonged submergence of some amphibious species (e.g. especially if there are continuous high flows during the irrigation season) may have detrimental impacts on survival.
	SF1; SF2	Small freshes in summer and autumn are important for replenishing soil moisture in river banks to ensure survival and maintenance.
	LF1-3; LF5; BK1	Inundation of banks during late winter and early spring by freshes and bankfull flows is required to replenish soil moisture to promote growth during spring. Regular inundation will encourage a dominance of native species over exotic species, as the latter tend to be less tolerant of inundation (Catford et al. 2011). Variable size and duration of flows including baseflows, freshes and bankfull flows throughout the year will also promote diverse communities. Increased cover of non-woody, inundation tolerant vegetation on banks is likely to stabilise bank material and therefore reduce the risk of excessive bank erosion.
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	LF3; LF5; LF6; BK1	Large freshes and bankfull flows will support non-woody wetland vegetation in some low-lying wetlands with low commence to flow thresholds (e.g. some upland Gwydir planning units).
	WL1-4; OB1-5	Overbank and wetland inundating flows that inundate wetlands and floodplains for two to eight months between August and April are required to support non-woody, inundation tolerant vegetation.
	WL1; WL2; OB1	Small but frequent overbank and wetland inundating events will be important for maintaining the extent and viability of these species, including Marsh club-rush sedgeland, a critically endangered ecological community occurring in the Gwydir wetlands. The required duration and frequency vary widely by species. Highly water-dependant, amphibious species such as water couch, spike-rush, and cumbungi, which are common in the Gwydir wetlands require inundation for five to eight months, eight to 10 years in 10. The maximum period between events is two years.

[15] Important flow regime characteristics for all native vegetation objectives are based on Bowen, S. pers comms, Cassanova 2015, Roberts & Marston 2011, Roberts & Marston 2000, and Rogers & Ralph 2011.

NATIVE VEGETATION OBJECTIVES[15]

Ecological objective		EWR code	Important flow regime characteristics
		WL4; OB3; OB4	Larger overbank and wetland inundating flows will support amphibious damp species such as floodplain herbs, grasses and sedges that tolerate less frequent (three to 10 years in 10) and shorter duration (2–4 months) inundation.
NV3: Maintain the extent and maintain or improve the condition of river red gum and river cooba communities closely fringing river channels		LF3; LF4; LF5; LF6; BK1	Large freshes and bankfull flows that recharge alluvial aquifers and soil moisture in the riparian zone are also important for maintaining deep rooted vegetation between inundation events. The general condition of riparian vegetation will benefit from inundation or groundwater recharge anytime of the year, with an ideal frequency of inundation of four to 10 years in 10 to maintain good condition.
		BK1; WL3-4; OB1-5	River red gum and river cooba fringing river channels will be supported by a range of flows including, most importantly, bankfull flows, which inundate the tops of banks, overbank flows and larger wetland inundating flows that inundate the fringing riparian zone.
NV4: Maintain the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains	River red gum woodland	WL3; OB2	Maintaining the condition of river red gum woodlands on the floodplain requires overbank flows that inundate vegetation for between two and seven months during September to February. For river red gum communities located on lower parts of the floodplain, inundation needs to occur four to 10 years in 10 with a maximum period between events of three years.
		WL4; OB3	Maintenance of river red gum communities located higher on the floodplain requires larger overbank and wetland inundating events, but these can occur less frequently: on average three to five years in 10 years, with a maximum inter-event period of five years. Regeneration of river red gum communities will require additional, shorter duration (one to two months) inundation during August to November. These events would ideally occur the year following a maintenance flow to support the survival of seedlings from the previous year in areas where recruitment is desired.
	Coolibah wetland woodland and Lignum shrubland	WL3; WL4; OB1; OB2	Maintenance of lignum shrublands and coolibah wetland woodland requires inundation by overbank or wetland inundating flows for three to seven months at a frequency of five to 10 years in 10 and a maximum period between events of five years. Regeneration requires more frequent inundation (ideally annual), for one to 12 months between August and March (September to February for vegetative expansion).
		WL3; OB2	Overbank and wetland inundating events that occur more frequently will support regeneration and maintenance of lignum and coolibah wetland on lower parts of the floodplain.

NATIVE VEGETATION OBJECTIVES[15]

Ecological objective	EWR code	Important flow regime characteristics
	OB4; OB5	Large overbank events will support maintenance of lignum and coolibah wetland located higher on the floodplain.
Black box woodland	OB4; OB5	Large overbank flows are required to maintain and improve condition of black box woodland communities, which tend to be located on higher parts of the floodplain. Maintenance requires inundation for two to six months, at a frequency of two to four years in 10 years and a maximum period between events of five years. Greater than five years interval may result in a reduction in condition.
	OB2	Regeneration and improvement of condition will require additional inundation for one to two months on an annual basis (maximum inter event period of two years). Smaller overbank flows may support regeneration.
Coolibah woodland	OB5	Coolibah woodlands which tend to occur on the higher parts of the floodplain require inundation for up to 1 month, one year in 10 on average. The maximum inter-event period is 10–15 years.

Table 13 Important flow regime characteristics needed to deliver waterbird objectives

WATERBIRD OBJECTIVES[16]

Ecological objective	EWR code	Important flow regime characteristics
WB1: Maintain the number and type of waterbird species	WL1-4; OB1-5	Overbank and wetland inundating flows, preferably delivered in spring-summer, that inundate a mosaic of floodplain habitats including non-woody floodplain vegetation, open shallow waterbodies and deep lakes and lagoons will provide feeding habitat for a range of waterbird species including open water foragers, herbivores, emergent vegetation dependent species, large waders, wetland generalists and small waders (including migratory shorebird species). Where there is gradual draw-down of habitats over late summer-autumn this can extend feeding habitat available for migratory and resident shorebird species (small waders). Maintaining waterbird species richness in the Gwydir wetlands will require a range of small, medium and large overbank and wetland inundating flows to support feeding and breeding habitat (see WB2, 3, 4 objectives) and maintain habitat condition (see WB5 objective).

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

WATERBIRD OBJECTIVES[16]

Ecological objective	EWR code	Important flow regime characteristics
WB2: Increase total waterbird abundance across all functional groups	WL1-4; OB1-5	As in WB1 provide seasonal (spring–summer) flooding with gradual draw-down over summer into autumn to provide feeding habitat for waterbird species and maintain the condition of waterbird breeding and feeding habitats. Where possible to coordinate, overbank and wetland inundating flows should be delivered at the same time as neighbouring catchments to provide benefits to waterbird populations by providing habitat across a larger area of northern Murray-Darling Basin. Increasing total waterbird abundance will also rely on maintaining (and in some cases) improving the condition of key native vegetation types that provide breeding and foraging habitats. In the Gwydir Wetlands, these include colony sites consisting of river red gum, river cooba, coolibah, lignum and cumbungi. Overbank and wetland inundating flows are critical to maintaining the extent and condition of these breeding habitats (see WB5 objective).
	WL1; WL2; WL3; OB1; OB2	Small and medium overbank and wetland inundating events will support survival of waterbirds, provide foraging habitat and may support small scale non-colonial waterbird breeding. Smaller overbank and wetland inundating flows delivered in years following large breeding events in the Gwydir Wetlands and neighbouring catchments in the northern Murray-Darling Basin will also promote the survival of juvenile birds and contribute to increased waterbird populations.
	WL4; OB4; OB5	Increasing waterbird abundance in the Gwydir wetlands area will require increased breeding opportunities for both colonial and non-colonial waterbirds in the Gwydir Wetlands and other wetlands across the Murray-Darling Basin. This can be enhanced through the delivery of large overbank and wetland inundating flows to the Gwydir Wetlands from September to March with inundation duration maintained into May for colonies that commence in March. For active colony sites extend the duration of large overbank and wetland inundating flows to maintain adequate water depths under nesting birds. Overbank events need to be of sufficient duration (3–6 months, species dependant) to ensure successful completion of colonial waterbird breeding (including from egg laying through to fledging including post-fledgling care) and access to key foraging habitats to enhance breeding success and the survival of young.
WB3: Increase opportunities for non-colonial waterbird breeding	OB2; OB4; OB5	Providing opportunities for non-colonial waterbird breeding will include the provision of seasonal flows (September to March) to inundate floodplain habitats for more than 2–3 months. Spring and summer is the ideal season, with opportunistic breeding in autumn and winter.

WATERBIRD OBJECTIVES[16]

Ecological objective	EWR code	Important flow regime characteristics
	WL3; WL4; OB2; OB4; OB5	Habitat availability for non-colonial species will increase with increasing magnitude (both extent and duration of inundation) of overbank and wetland inundating flows. Providing opportunities for breeding in non-colonial species and contributing to increased numbers of non-colonial species will also rely on maintaining (and in some cases) improving the condition of key native vegetation types that provide breeding and foraging habitats (see WB5 objective).
WB4: Increase opportunities for colonial waterbird breeding.	OB4; OB5	Supporting breeding in active waterbird colonies in the Gwydir wetlands requires large overbank flows during September to March. The minimum duration of inundation of active colony sites and surrounding foraging habitat is three to four months to ensure successful completion of colonial waterbird breeding (from egg laying through to fledging including post-fledgling care) and access to key foraging habitats to enhance breeding success and the survival of young. Larger overbank events will support larger colonies and a greater number of breeding species (non-colonial and colonial species) with greater benefit to breeding success and increasing total abundance of waterbirds (see WB2 and WB3 objectives). These large overbank events are required on average two to three years in 10 years, with a maximum inter-event period of five years.
WB5: Maintain the extent and improve condition of waterbird habitats	WL1-4; OB1-5	Waterbirds depend on a wide variety of breeding and foraging habitats, which are maintained through a range of overbank and wetland inundating flows. Colonial waterbird species are dependent on relatively few sites across the major wetlands of the Murray Darling Basin including known sites in the Gwydir wetlands. These include sites provide nesting habitat consisting of river red gum, river cooba, coolibah, belah, lignum and/or cumbungi.
	WL2; WL3; OB1; OB2	Overbank flows of sufficient duration are needed to maintain the extent and condition of these vegetation communities in these discrete wetland sites. This ensures that sites are in event-ready condition when large overbank events initiate large scale colonial waterbird breeding events.
	WL2; WL3; WL4; OB1-5	Overbank and wetland inundating flows will also support a broader range of foraging habitats in the Gwydir Wetlands, including spike-rush sedgelands, marsh grasslands, lignum shrublands, open lagoons and lakes. The required duration and frequency of overbank flows to support these vegetation types are outlined under the native vegetation objectives.

Table 14 Important flow regime characteristics needed to deliver priority ecosystem function objectives

PRIORITY ECOSYSTEM FUNCTIONS OBJECTIVES[17]

Ecological objective	EWR code	Important flow regime characteristics
EF1: Provide and protect a diversity of refugia across the landscape.	CF1	Cease-to-flow periods of durations that are not longer than the persistence of water of sufficient volume and quality in key larger river pool refuges is vital for survival of native plants and animals. When restarting flows after a cease-to-flow event, larger magnitude flows (e.g. small fresh) may be required to prevent detrimental water quality outcomes (as poor-quality water from the bottom of pools is mixed through the water column).
	VF1; BF1; BF2	Very low flows and baseflows are required to maintain in-channel pools as refugia for native fish and other biota. These flows need to be of sufficient magnitude to prevent stratification of pools that can lead to de-oxygenation of the water column and subsequent fish deaths. They are required every year for most of the year (no less than natural) and are especially important during dry times.
	WL1-4; OB1-5	Core wetland areas in the Gwydir wetlands can hold water for many months and provide an important refuge for waterbirds and other aquatic fauna during dry times. Regular overbank and wetland inundating flows are required to maintain the condition of wetland and vegetation in the Gwydir floodplain and wetlands to ensure they can function as refuges during dry times.
EF2: Create quality instream and floodplain habitat	All flows	The full range of in-channel and overbank flows are required to maintain quality instream and floodplain habitat. Variable in-channel flows (baseflows – bankfull flows) will provide a diversity of physical and hydraulic habitats. With increasing magnitude of flows, greater areas of the channel are inundated (e.g. benches, bars, snags and banks at different elevations in the channel). Bank notching can be avoided by varying flows (avoiding holding flows constant for too many consecutive days) and targeting different peak heights for freshes. To protect banks from excessive erosion it is important to maintain rates of fall that do not exceed natural rates of fall for ALL regulated deliveries. Slow rates of fall allow water to drain from the bank slowly, preventing mass failure of the banks.
	BF1; BF2; SF1; SF2; SF3	Baseflows and small freshes provide areas of slackwater (slow flowing) habitat. Small freshes are also important for flushing fine sediment from pools, de-stratifying pools and maintaining geomorphic features such as benches and bars. Maintaining slow rates of fall is particularly important when flows are in the lower third of the channel, to protect the ‘toe’ of the bank, which supports the rest of the bank above.

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

PRIORITY ECOSYSTEM FUNCTIONS OBJECTIVES[17]

Ecological objective		EWR code	Important flow regime characteristics
		LF1-6; BK1	Large freshes provide deeper and faster flowing habitats. Bankfull flows are important for geomorphic maintenance of all channel features. Large freshes are also important for flushing fine sediment from pools, de-stratifying pools and maintaining geomorphic features such as benches and bars.
		WL1-4; OB1-5	Overbank and wetland inundating flows are required to provide essential floodplain and wetland habitat for native fish, waterbirds and other aquatic fauna.
EF3: Provide movement and dispersal opportunities within catchments for water-dependent biota to complete lifecycles.	Within cathcment	BF1; BF2; SF1; SF2	Providing longitudinal connectivity is critical for migration, recolonisation following disturbance events, allowing species to cross shallow areas, and dispersal of larvae to downstream habitats. In-channel flows of adequate depth and duration (baseflows and freshes) are important to allow for the movement of aquatic and riparian fauna and flora along rivers and creeks. For example, flows of at least 0.3 m are needed to allow medium sized native fish to move along a channel.
		LF1-6; BK1; WL1-4; OB1-5	Physical barriers, such as dams and weirs, have introduced additional barriers throughout the Gwydir, making large freshes, bankfull flows, and occasionally small overbank flows important for overcoming these man-made structures where fishways are not present.
	Between catchments	BF2; SF3; LF5	Managed end-of-system flows in the Mehi River and Gil Gil Creek can be coordinated to help improve ecological objectives within the Gwydir catchment and in the Barwon River. Flows of adequate magnitude at the right time of year provide dispersal opportunities for all native fish species, with a focus on moderate to long lived flow pulse specialist native fish, such as silver perch and golden perch, from their spawning habitat into new areas.
EF4: Support instream and floodplain productivity		LF1-6; BK1; WL1	Large freshes bankfull flows and small wetland inundating flows may drive small pulses of productivity.
		WL2-4; OB1-5	Overbank and wetland inundating flows that inundate the floodplain for several months are the most critical flow categories for supporting large scale productivity, which in turns drives aquatic food webs both on the floodplain and instream. Primary productivity includes growth of algae, macrophyte, biofilms and phytoplankton, which in turn drives secondary productivity (zooplankton, macroinvertebrates, fish larvae etc.).
EF5: Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands.		SF1-3; LF1-6; BK1	Freshes and bankfull flows are important for mobilising organic matter and sediment from in-channel surfaces (e.g. leaf litter that has accumulated on bars, benches and banks during low flows). This material is transported downstream or deposited in other parts of the channel where it is utilised, in the case of nutrients and carbon, to drive primary productivity, or in the case of sediment, for channel maintenance (e.g. to replenish banks and benches).
		WL1-4; OB1-5	Overbank and wetland inundating flows are essential for transferring nutrients and carbon from the floodplain to the channel.

PRIORITY ECOSYSTEM FUNCTIONS OBJECTIVES[17]

Ecological objective	EWR code	Important flow regime characteristics
EF6: Support groundwater conditions to sustain groundwater-dependent biota.	LF1-6; BK1; WL1-4; OB1-5	Large freshes, bankfull, overbank, and wetland inundating flows will contribute to recharging shallow groundwater aquifers in areas where there is a surface-groundwater connection. This recharge can reduce the salinity of shallow aquifers and raise water tables, providing critical soil moisture for deep-rooted vegetation in the riparian zone and on low-lying floodplains.
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries.	BF2; SF3; LF5	The coordination of flows in the Gwydir to provide movement and dispersal opportunities between catchments for water-dependent biota to complete lifecycles will also contribute to important environmental water requirements in the Barwon-Darling catchment.
	OB4; OB5	Protecting larger overbank flows will provide important flows and transfer nutrients and carbon from floodplains in the Gwydir to the Barwon River.

Table 15 **Important flow regime characteristics needed to deliver frog and other water-dependent species objectives**

OTHER SPECIES OBJECTIVES

Ecological objective	EWR code	Important flow regime characteristics
OS1: Maintain species richness and distribution of flow-dependent frog communities	CF1	The duration of cease-to-flow events should not persist longer than what occurred naturally to protect sufficient water volumes and quality in key larger river pool refuges.
	VF1; BF1; BF2	Very low flows and baseflows can help maintain adequate water quantity and quality (dissolved oxygen, salinity and temperature) in refuge pools.
	WL1; OB1	Wetland inundating events and small overbanks maintain core wetlands, including off-channel waterholes for refuge.
	WL2-4; OB2-5	larger flows maintain frog condition and habitat, allow dispersal, and support breeding.
OS2: Maintain successful breeding opportunities for flow-dependent frog species.	WL1-4; OB1-5	Wetland inundating events and overbank flows provide opportunities for breeding and recruitment (i.e. laying eggs and tadpole metamorphosis). To support successful breeding opportunities, these flows should ideally occur every one to two years and inundate their habitat for six or more months (with a minimum of four months). Spring–summer breeders require flows ideally from October to March, while species with more flexible breeding are likely to benefit from flows arriving between July to April. A gradual rise and fall is likely to improve recruitment outcomes.

OTHER SPECIES OBJECTIVES

Ecological objective	EWR code	Important flow regime characteristics
OS4: Maintain water-dependent species richness[18]	VF1; BF1; SF1-2	Low flows and riffle areas should be maintained between June to August to support foraging areas and movement between pools, which are their preferred habitat. Platypus prefer to feed in water that is 1-3m deep (Serena & Williams 2010).
	LF1; BK1	Large freshes and bankfull flows should ideally finish before the end of August to encourage female platypus to choose burrows higher on the river bank. If these higher flows occur between September to February or for extended periods they can flood platypus burrows and reduce the availability of benthic invertebrates, therefore reducing breeding success (Scott & Grant 1997).

4.4 Changes to the flow regime

The flow regime in the Gwydir has changed due to regulation and development in the catchment. The degree and type of change varies depending on the location within the catchment. The most impacted flow components are cease-to-flow periods, low flows and small freshes. Larger events are gradually less impacted, mainly because water extraction is a small portion of the larger flows.

Zone A planning units

Flow regimes in the rivers, creeks and wetlands downstream of Copeton Dam (Zone A) are affected by:

- the capture and subsequent active release of water by Copeton Dam at times that support agricultural production
- the redistribution of flows by weir infrastructure
- the extraction or diversion of flows out of rivers and creeks under basic landholder rights or licenced extractions (regulated Stock and Domestic, High Security, General Security, Supplementary)
- water extractions from the floodplain (floodplain harvesting licences and/or unregulated licences)
- river and creek channel works (straightening deepening, increased or decreasing connections) and floodplain works (channels, levees, etc.).

These actions have had the following impacts on flow regimes:

Gwydir River between Copeton Dam and Moree

The Gwydir River management area experiences reduced small freshes in autumn to spring and reduced large freshes and overbank flows because of the portions of events that are captured by Copeton Dam. Reduced periods of zero flow, increased base flows and small freshes over late spring to autumn are also experienced and are associated with irrigation deliveries.

[18] Most of the other flows are able to support the majority of other water-dependent species, however platypus have been found to have a few specific flow requirements to fulfil their life history.

Gwydir River downstream of Moree

Low flows and small freshes have increased during the summer months because of the timing of irrigation deliveries, but overall Copeton Dam has caused a reduction in flows. The increased distribution of irrigation deliveries and parts of natural flow events into the Mehi River and Carole Creek systems has also contributed to a decrease in total volume of water in this planning unit.

Tarren Creek and Goonal Creek

Tarren and Goonal Creek only connect with the Lower Gwydir River during overbank flows, which have reduced in frequency and duration due to the impact of Copeton Dam.

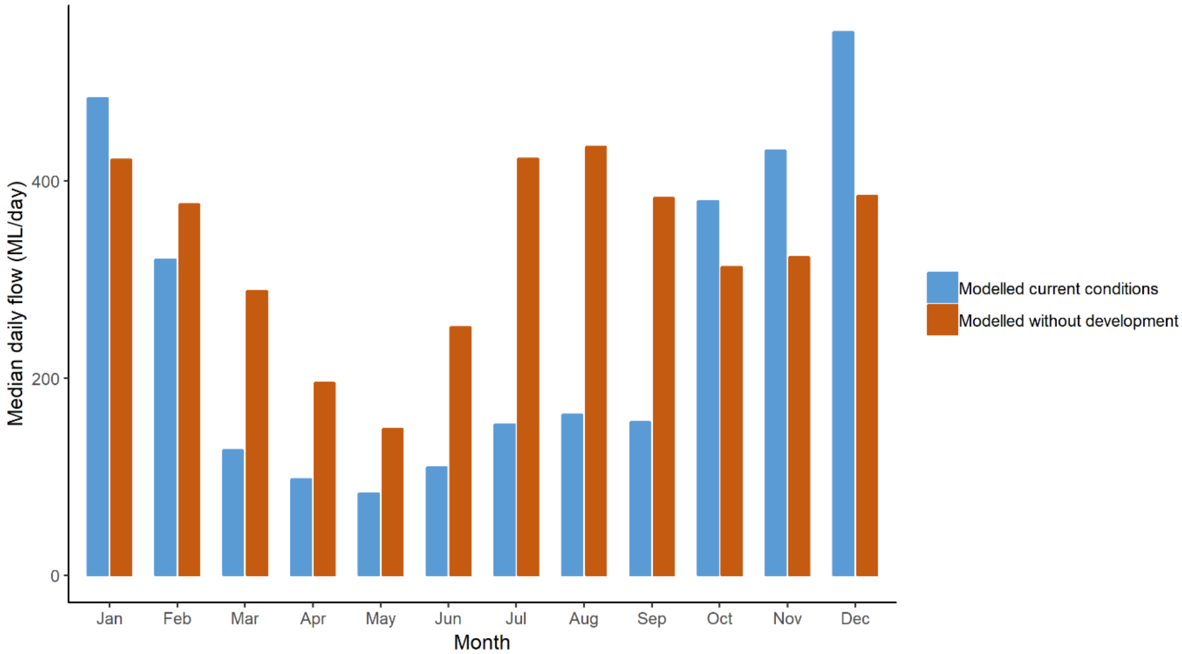


Figure 16 Bar graph showing the median monthly flows (ML/day) at Yarraman Bridge on the Gwydir River showing modelled current conditions and modelled without development.

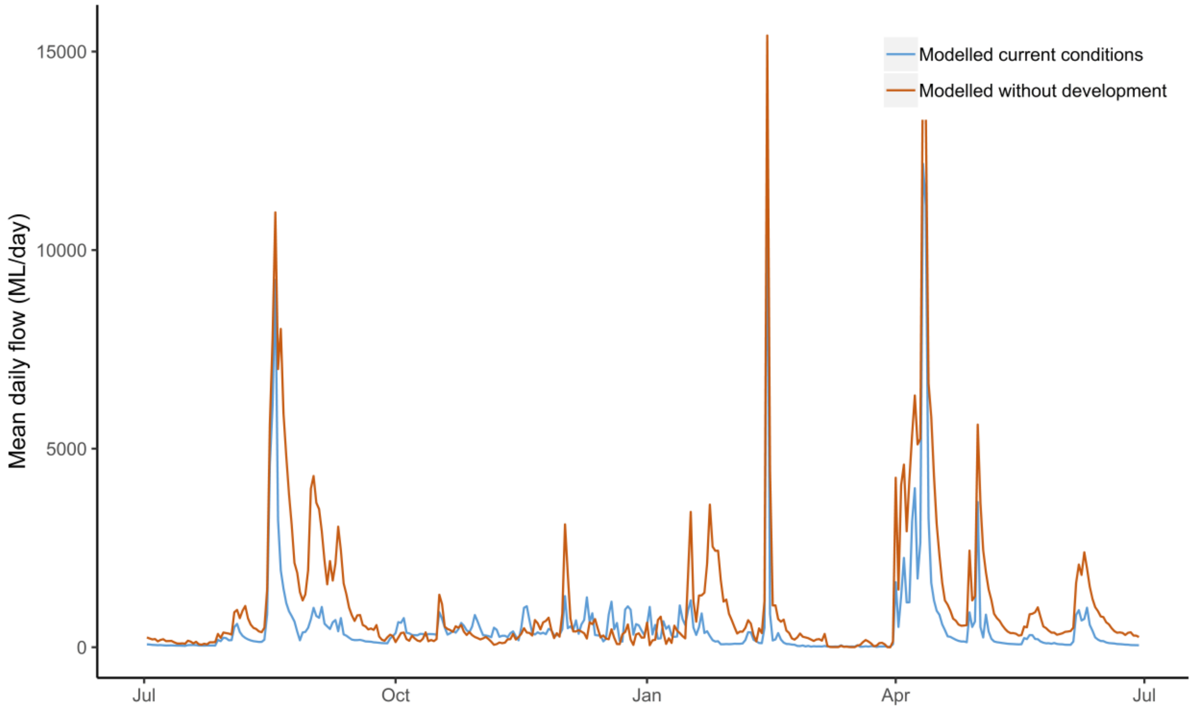


Figure 17 Hydrograph showing the mean daily flow rate (ML/day) at Yarraman Bridge on the Gwydir River showing modelled current conditions and modelled without development.

Lower Gwydir and Gingham watercourse wetlands and floodplains

Overall, this area has experienced a reduction in all flows due to river regulation, the result of Copeton Dam and the redirection of flows into the Mehi River and Carole Creek systems.

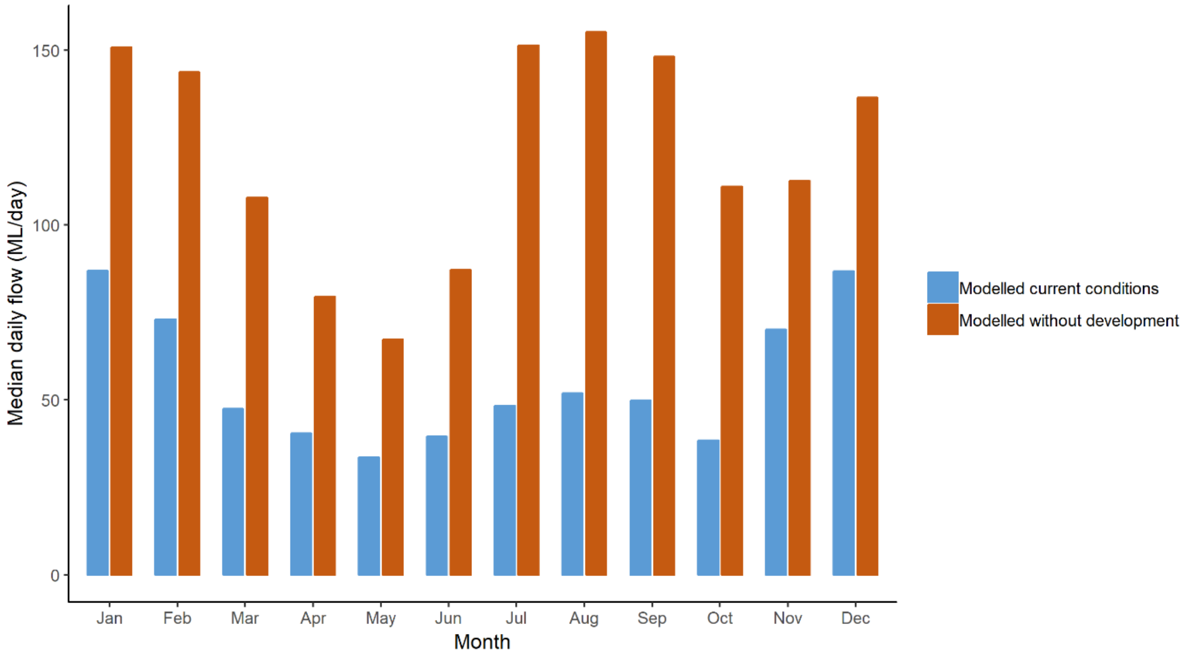


Figure 18 Bar graph showing the median monthly flows (ML/day) at Tillaloo on the Gingham Watercourse showing modelled current conditions and modelled without development.

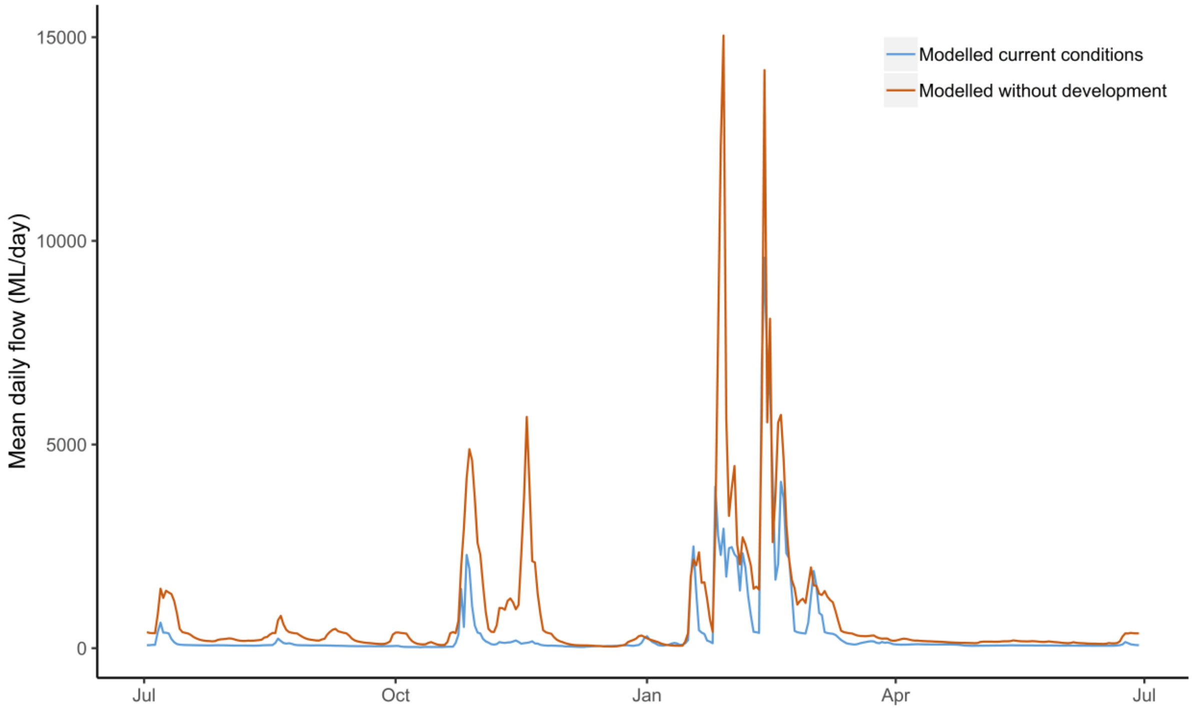


Figure 19 Hydrograph showing the mean daily flow rate (ML/day) at Tillaloo on the Gingham Watercourse showing modelled current conditions and modelled without development.

Mehi River, Moomin Creek and Carole Creek

The portions of events captured by Copeton Dam has reduced small freshes in autumn to spring and reduced large freshes and overbank flows in these areas. However, irrigation deliveries and other managed flow events have reduced periods of zero flow and increased base flows and small freshes over late spring to autumn compared to before regulation.

Mallowa Creek and Ballin Boora Creek

River regulation and other works mean these creeks are now mostly disconnected from all flow categories, except for higher overbank flows or if held environmental water is actively delivered into them using infrastructure.

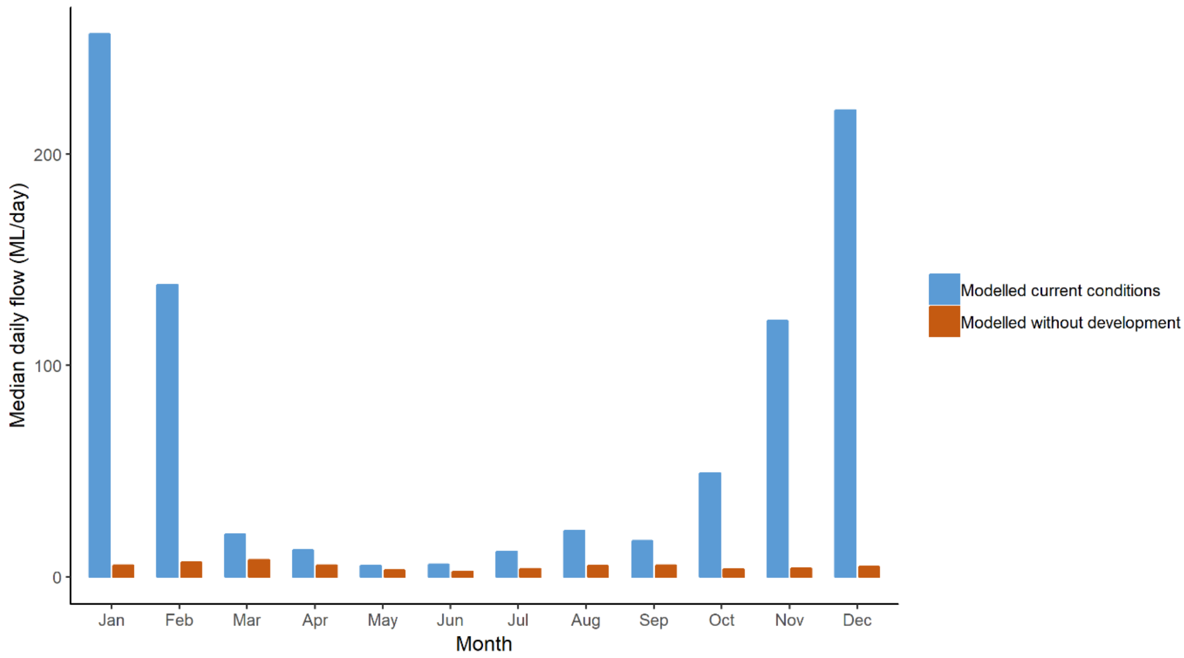


Figure 20 Bar graph showing the median monthly flows (ML/day) downstream of the regulator on Carole Creek showing modelled current conditions and modelled without development.

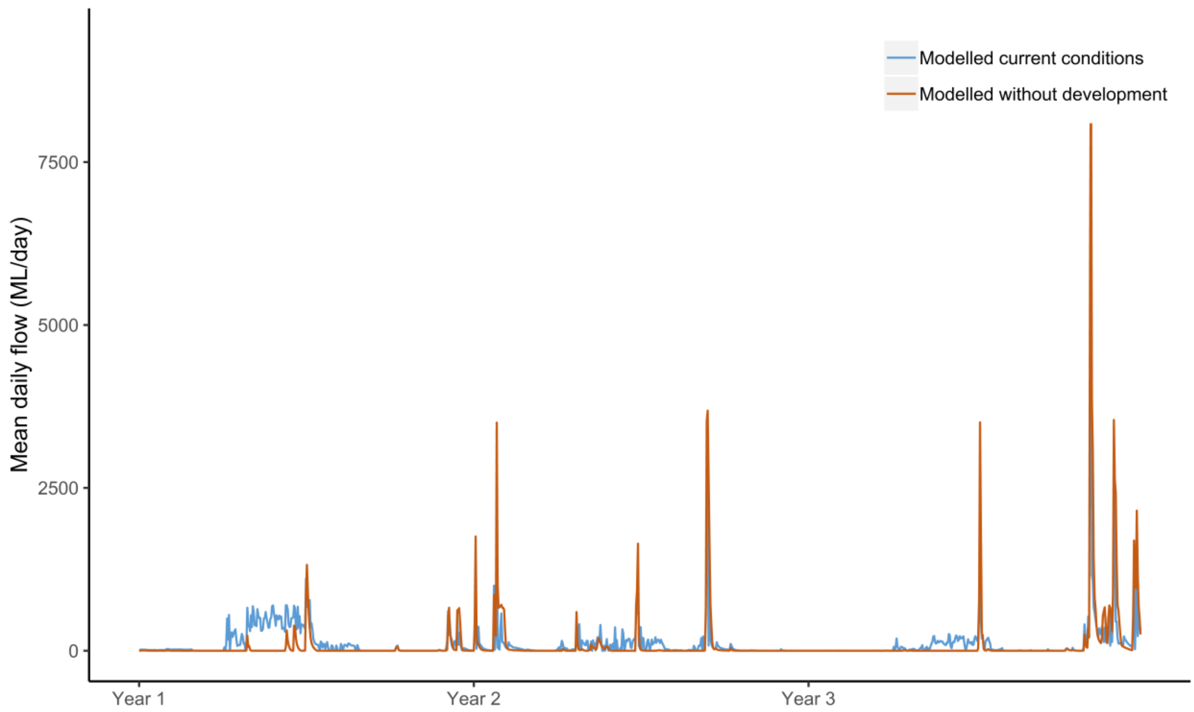


Figure 21 Hydrograph showing the mean daily flow rate (ML/day) downstream of the regulator on Carole Creek showing modelled current conditions and modelled without development.

Zone B planning units

The main impact to flow regimes in Zone B planning units is from extraction for basic landholder rights, unregulated licenced extractions and floodplain harvesting, together with weirs, levees and other works. The impact of this development through most systems in

Zone B has been to increase the duration of cease-to-flow periods, reduce pool persistence duration, and reduce low flows. In some rivers and creeks small fresh flows have also been reduced. While total extractions on these systems are lower, the effects on these parts of the flow regime can be significant.

Flows in these systems are entirely dependent on natural rainfall events and are not manageable except by some small-scale structures such as small weirs and instream (licenced) dams. The main tool available to maintaining or improving flow regimes is through the rules in the WSP, which define when water can be taken, the limits to extraction and on trading into management zones. Management recommendations to support important flows in Zone B are described in Part B, chapter 2.

5. Risks, constraints and strategies

The Gwydir LTWP is focussed on managing environmental water to deliver ecological objectives in a heavily modified landscape. There are several factors that constrain our capacity to deliver HEW to meet environmental water requirements, or how the environment responds to management under this plan.

The *Risk assessment for the Gwydir Water Resource Plan Area* (the Risk Assessment) (NSW DPIE-Water 2019c) was undertaken to inform water resource planning in the Gwydir. It identifies risks to areas of conservation value, based on hydrological change within sub-catchments, and outlines mitigation strategies. This chapter complements the Gwydir Risk Assessment and addresses the specific risks and constraints related to delivering water for the environment.

This chapter focuses on risks to meeting the EWRs of priority environmental assets and functions in the Gwydir catchment (Table 16). It also outlines the risks and constraints that affect our capacity to achieve the ecological objectives of this LTWP (Table 17).

This risk assessment has assisted with identifying investment opportunities for improving the likelihood that EWRs can be achieved in the short and long term (Table 26).

Figure 22 Tareelaroi Weir in the Gwydir catchment
Photo: N. Foster

5.1 Risks and constraints to meeting EWRs

Table 16 Risks and constraints to meeting environmental water requirements in the Gwydir catchment and strategies to address them

Risk	Description	Potential management strategies	Potential project partners[19]
Insufficient water for the environment	Total volume or flow rate of water available for the environment does not meet environmental needs Altered flow regime (timing or duration) does not meet the needs of the environment	**Zone A planning units**	
		Improve the seasonal pattern of freshes through seasonally-cued discretionary water releases for the environment	DPIE–BC and CEWO
		Allow for environmental water delivery to build on natural events	WaterNSW, DPIE–BC and DPIE–Water
		Restrict the trade of supplementary flow access licenses, new supplementary flow access licences, or changes to rules that would result in a net reduction of PEW	DPIE–Water
		Investigate options for the strategic delivery of irrigation orders to mimic natural flow events (requires interagency discussion)	WaterNSW, DPIE–BC, CEWO and DPIE–Water
		Floodplain harvesting access entitlements should support LTWP environmental water requirements and the associated wetland and floodplain priority assets and functions	DPIE–Water and DPIE–BC
		Zone B planning units	
		Implementation of the *Water Sharing Plan for the Gwydir Unregulated Rivers Surface water source* to protect HEW and PEW (active management)	DPIE–Water
		Maintain rules restricting trade into water sources with high or medium risks (as defined by the Risk Assessment)	DPIE–Water
		Consider implementing daily extraction limits or rostering agreements to protect any altered ecologically important flow components	DPIE–Water
		Review low flow access rules where in-channel flows have been impacted since development	DPIE–Water

[19] Implementation may include cooperation with other organisations not listed.

Risk	Description	Potential management strategies	Potential project partners[19]
Water take during environmental water delivery and natural flow events	Losses as discrepancies in volumes of environmental water from all flow deliveries (ordered or natural events)[20]	Refer to the Natural Resources Access Regulator *Water Compliance Policy and Strategy* to ensure compliance with the WSP and licence conditions	NRAR
		Establish an appropriate communication strategy to inform relevant stakeholders of environmental water deliveries	DPIE–BC and WaterNSW
		WSP rules, an effective gauging network and accounting should combat large discrepancies in monitored environmental water	WaterNSW and DPIE–Water
		Implementation of the agreed NSW policy to address constraints in the Gwydir catchment	DPIE–Water and WaterNSW
Floodplain structures and barriers	Unmanaged construction (e.g. levees, diversion channels, sediment blockage of culverts) has diverted flows and caused barriers to delivering water to wetland and floodplain areas	Implement the Floodplain Management Plan *for the Gwydir Valley 2016*	DPIE–Water
		Monitor compliance of infrastructure with the *Floodplain Management Plan* and implement compliance or remediation actions where needed to maximise the benefit of bankfull and overbank flows	NRAR
Insufficient channel capacity	Deliveries to the Gwydir and Gingham Wetlands are limited to 250 megalitres per day, and delivery to the Mallowa Wetlands limited to 150 megalitres per day At these rates, water may take three-to-five months to arrive and only part of the wetland will get inundated in time for vegetation to respond	Investigate increasing the capacities of relevant flow regulators, such as raising the Tyreel weir and Gundare, Moomin and Mallowa Creek regulators, and installing infrastructure at Ballin Boora Creek to increase water for the environment delivery capacities	WaterNSW
		Investigate the potential for the Northern Basin Toolkit and any agreed-on NSW policy measures to address these issues	DPIE–Water
Channel capacity sharing constraint	There is high competition for river channel space, particularly during	Continue to work with WaterNSW and irrigators to share and plan for deliveries when this channel sharing capacity constraint may occur	DPIE–BC, CEWO, WaterNSW and water users

[20] 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

Risk	Description	Potential management strategies	Potential project partners[19]
	December and January in the Lower Gwydir	Investigate implementing a market-based mechanism for sharing channel capacity when there are competing demands	DPIE–Water, DPIE–BC, and WaterNSW
Bulk delivery release periods limiting environmental water deliveries	During years of low irrigation orders and low natural flows (dry conditions) deliveries in rivers and creeks may be constrained to bulk delivery periods This can restrict periods when environmental water deliveries can be made	Proactively plan to deliver environmental water during non-bulk delivery years to maximise environmental outcomes	DPIE–BC and CEWO
Future water demands impacting on amount and availability of water for the environment	A potential increase in extractive industries and/or local developments have the potential to impact on water availability	Consideration of increased consumptive water demand associated with potential future development (extractive industries)	Planning and Environment, Local Government
		Consideration of increased BLR demand associated with potential future development (sub-division of rural land)	Local Governments
Insufficient loss accounts being kept for environmental water deliveries	High irrigation deliveries in the years when accounts are filled can mean delivery loss accounts are depleted, resulting in insufficient volumes in delivery loss accounts to support environmental water deliveries	Plan loss accounts to allow for environmental water deliveries in non-high-irrigation delivery years	DPIE–Water and WaterNSW
		Consider separate loss accounts for irrigation and environmental water deliveries	DPIE–Water and WaterNSW
Inappropriate rate of dam releases	Dam releases occur from Copeton Dam as efficiently as possible, meaning river levels rise and fall rapidly This can increase erosion rates, cause stream banks to collapse and impact on	Investigate gradual declines in water level after flow events to benefit the ecology of the river Adopt more natural flow patterns in releases from Copeton Dam, or allow environmental water to follow deliveries and natural flow events to create a more natural rate of fall, and variability during long delivery periods	DPIE–BC, CEWO, WaterNSW and DPIE–Water

Risk	Description	Potential management strategies	Potential project partners[19]
	the life cycles of native plants and animals	Investigate whether bulk water deliveries can be released from Copeton Dam at flow rates that mimic natural flow conditions[21]	DPIE–BC, CEWO, DPIE–Water, WaterNSW and water users
		Increase weir pool storage capacity through improved water management at Tyreel Weir[22]	DPIE–BC, CEWO, WaterNSW and DPIE–Water
Inappropriate timing of dam releases	Irrigation water is released from Copeton Dam as efficiently as possible and counter to natural seasonal flow patterns This has an impact on the life cycles of native plants and animals	Optimise water releases from Copeton Dam for multiple benefits	DPIE–BC, CEWO, WaterNSW
		Increase weir pool storage capacity through improved water management at Tyreel Weir[22]	DPIE–BC, CEWO, WaterNSW and DPIE–Water
Lack of protection for environmental flows	*Water Sharing Plan for the Gwydir Unregulated River Water Sources* inadequately deals with protection of environmental flows in unregulated reaches Environmental water is ordered to a gauge and there is no protection of environmental water past this point to ensure that it reaches all target assets Environmental water may not be benefiting downstream catchment areas, unregulated systems or contributing to end of system flows	Implement arrangements as determined by the *Gwydir Surface Water Resource Plan* or as otherwise agreed on as a NSW policy	DPIE–Water and DPIE–BC
		Communicating the whole-of-system management approach to communities will help improve understanding of the importance of protecting environmental return flows	DPIE–BC, CEWO and DPIE–Water
		Installation of adequate gauging to more accurately quantify and protect return flows (relates to Moomin, Mallowa and Ballin Boora).	DPIE–Water
		Protection of environmental water deliveries from extraction (including floodplain harvesting), particularly in the Mallowa Gingham, Lower Gwydir and Barwon planning units	DPIE–Water

[21] The ability to implement this strategy will vary between years and seasons and must be consistent with the need for efficient and timely water delivery. Discussions will need to be undertaken between DPIE–BC and other water users at the start of the irrigation planning season, to examine whether delivery patterns can be varied without impacting on water security and efficiency.

[22] Increasing the storage capacity of the weir pool in combination with a fishway structure will improve water management in the Lower Gwydir and Gingham systems.

Risk	Description	Potential management strategies	Potential project partners[19]
Unenforced rules in unregulated planning units	Visible flow can be an ambiguous trigger for pump rules and compliance is difficult to enforce Pumping from pools during dry periods impacts on valuable drought refuge Limited gauging and drawdown metering in the unregulated planning units makes it difficult to support these rules and monitor compliance	Consider purchasing water licences in high-risk areas (as determined by the Risk Assessment)	DPIE–BC and CEWO
		Investigate improved metering of pumps	DPIE–Water
		Investigate better gauging to help licence holders and compliance officers determine stream flow	DPIE–Water
		Consider trade out of high-risk areas as a mechanism to ensure that sufficient water is retained for the environment	DPIE–Water
		Investigate pool drawdown rules in the Gwydir WSP to ensure they do not impact on high-value refuge sites	DPIE–BC, CEWO, DPIF and DPIE–Water
Unwanted impacts from environmental water deliveries	As floodplain flow paths are developed for dryland cropping, the risk of crop damage from inundation restricts the use of these flow paths for water delivery. Flooding, disruption to access and inundation of stock and infrastructure can cause water deliveries to be cancelled. Delivery of environmental water during the period July to December (the end of the winter crop harvest) may be reduced to zero or very-low levels because of winter cropping in an along the low flow paths and lower floodplain along the Gingham, Lower Gwydir and Mallowa systems.	Improve stakeholder education and resources to increase understanding of floodplain inundation patterns.	DPIE–BC, CEWO, DPIE–Water, WaterNSW, LLS, water users and landholders
		Implementation of the *Gwydir Valley Floodplain Management Plan*	DPIE–Water
		Monitor natural events and environmental deliveries in relation to channel capacities to determine the risk of third party impacts under a range of flow rates.	DPIE–BC and CEWO
		Communicate with landholders about intended water deliveries and provide regular updated information so they can understand and determine their own flooding risk of farming on the floodplain.	DPIE–BC and CEWO
		Investigate improving crossings and provide access, and programs to reduce cropping land used in lowest flow paths and floodplains	DPIE–Water
Impacts from lack of environmental water deliveries	As decisions are made not to release environmental water there are third party impacts to wetland and floodplain graziers and other implications such as ecotourism and protection of Aboriginal Cultural and environmental values.	Improve stakeholder education and resources to increase understanding and access to information about environmental water management decisions.	DPIE–BC, CEWO, DPIE–Water, WaterNSW, LLS, water users

Risk	Description	Potential management strategies	Potential project partners[19]
Changes to carryover rules	Carryover is vital for managing environmental assets. This is because water regimes span multiple years.	Ensure no reduction in carryover rules for ECA water.	DPIE–Water
		Consistent carryover rules maintained across all licences.	DPIE–Water
Lack of depth variability in weir pools	Irrigators and recreational users expect stable water levels in weirs. Operational limitations also reduce variations to weir height; this impacts on aquatic plants and animals by impairing ecosystem functions and reducing habitat variability for native fish.	Investigate options for optimising management of weir pools, considering environmental benefits and informed by science[23]	DPIE–BC, DPIF, DPIE–Water and WaterNSW
Groundwater extraction reducing surface flows	Where there is high connectivity between surface water and groundwater, overextraction of groundwater can impact on low flows and baseflows, especially during dry times	Ensure groundwater extraction complies with SDL	DPIE–Water, DPIE–BC, CEWO
		Improve monitoring of lower surface water flows and groundwater use in areas known to be highly connected	DPIE–Water, DPIE–BC, CEWO
		Improve understanding of surface water and groundwater relationships in highly connected areas	DPIE–Water, DPIE–BC, CEWO
A reduction of volumes and availability of environmental water (HEW and PEW)	Translucency, carryover, and other environmental water provisions are subject to changes resulting from 5-yearly reviews of the Gwydir WSP	Ensure stakeholders are consulted in any review process for the Gwydir WSP	DOI-W
		Monitoring and evidence of environmental water requirements benefits through implementation of the NSW MER plan.	DPIE–Water, DPIE–BC, CEWO and DPIF

[23] The ecological condition of weir pools will improve if water levels are variable. Changing how weir pools are managed will need to be informed by science to balance potential negative impacts with ecological benefits.

Figure 23 Boyanga Waterhole
Photo: J. Ocock/NPWS

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

The risks and constraints to meeting the ecological objectives include non-flow related external factors that could potentially impact on achieving the objectives outlined in this plan (Table 17). These may be water related, such as cold water pollution downstream of Copeton Dam (NSW DPI 2015a); or consequences of inappropriate land use practices, such as the reduction of groundcover over large areas in upper catchments and the clearing of native vegetation. While managing these risks and constraints is outside the scope of this LTWP, they have been included to draw attention to their influence on river and wetland health, and to highlight the importance of linking this LTWP with natural resource management.

Table 17 Risks and constraints to meeting ecological objectives in the Gwydir catchment

Risk	Description	Potential management strategies	Potential project partners
Poor water quality	Water quality affects the ecology and survival of aquatic organisms	Implement recommendations and strategies detailed in the *Water quality management plan for the Gwydir Water Resource Plan Area*	DPIE–Water
		Manage salinity in accordance with the *Basin Salinity Management Strategy*	DPIE–Water
		Reduce the risk from poor water quality through proposed changes to trade and access rules in the *Water Sharing Plan for the Gwydir Regulated and Unregulated Rivers Surface water source*	DPIE–Water
		Consider use of HEW water to prevent minor water quality issues	DPIE–BC
		Implement land management strategies to improve water quality	LLS with landholders, Landcare, WaterNSW, DPIE–Water and other community groups
Hypoxic events	Hypoxic events can occur with the release of water after dry or low-flow periods, or as a result of algal blooms. This can occur from the build-up of organic material in channels and on floodplains Can lead to low-dissolved oxygen levels and potential fish kills	Map high-risk areas and high-priority refuge areas	DPIE–BC, DPIE–Water, and DPIF
		Consider delivering HEW to avoid high-risk periods, such as warm weather in late spring and summer	DPIE–BC and CEWO
		Monitor dissolved oxygen for active management of water actions	DPIE-BC, DPIE–Water and CEWO
		Provide flow regimes that avoid extended dry or very low-flow periods	DPIE-BC, CEWO and DPIE–Water
		Restart rivers with flow rates that reduce the risk of hypoxic blackwater, informed by water quality monitoring	DPIE–BC, DPIE–Water and WaterNSW

Risk	Description	Potential management strategies	Potential project partners
Cold water pollution	Cold water releases from Copeton Dam can change the range and distribution of species, reduce the opportunity for effective reproduction, reduce body growth and condition, and reduces recruitment success for up to 200km downstream	Identify and implement outcomes of the *New South Wales Cold Water Pollution Strategy*[24]	DPIE–Water and WaterNSW
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	Work with relevant departments and organisations to identify and protect core wetland vegetation communities	DPIE–BC, BCT and CEWO
		Review identification of semi-permanent and ephemeral wetland during dry cycles	DPIE–BC and CEWO
		Map and identify riparian and aquatic habitat condition to inform development of formal agreements in a unified strategy Prioritise reaches for management in partnership with Local Land Services and landholders	DPIE-BC, BCT, CEWO, DPIF and LLS
Grazing pressure and stock access to waterways	Stock trampling and grazing riverbanks can: • reduce native vegetation cover which allows weeds to establish • reduce streambank stability • damage important instream habitat • reduce water quality	Map and identify riparian and aquatic habitat condition to inform development of formal agreements in a unified strategy Prioritise reaches for management in partnership with Local Land Services and landholders	DPIE-BC, CEWO, DPIF and LLS
		Implement grazing strategies that protect, restore and manage wetland vegetation	LLS and landholders
		Investigate incentives to improve management of wetlands on private land	LLS and DPI Agriculture
		Communicate wetland sensitive grazing practices to graziers	LLS

[24] Copeton Dam has been identified as a high-priority in this strategy.

Risk	Description	Potential management strategies	Potential project partners
Spread of pest plant species	There is potential for environmental water to spread weeds like lippia and water hyacinth	Map and identify riparian and aquatic habitat condition to inform development of formal agreements in a unified strategy Prioritise reaches for management in partnership with Local Land Services and landholders	DPIE-BC, DPIE-Water and LLS
		Maintain existing weed control programs including implementing water hyacinth control protocols and maintain spray equipment to be able to respond to outbreaks	DPIE-BC, LLS and Moree Plains Shire Council
		Negotiate and implement easement agreements recognise greater need for weed management to supplement existing weed management on private land.	DPIE-BC and LLS
		Inundate wetlands for enough time to favour native wetland species growth and reduce the extent of lippia	DPIE-BC
Spread of pest animal species	Pest animal populations may benefit from environmental water use	Investigate a carp management plan for the Gwydir catchment	DPIF, WaterNSW and DPIE-BC
		Refer to NSW Department of Primary Industries, DPIF *Fish for the Future: Action in the Northern Basin – NSW proposal for Northern Basin Toolkit* measures to promote native fish health	DPIF
		Coordinate and implement feral pig control	LLS, landholders, DPIE-BC and NPWS
		Investigate the use of regulatory structures to complement water actions[25]	DPIE-BC, CEWO, DPIF and WaterNSW
Excessive erosion	Rapid flow recession can cause excessive erosion and bank slumping	Protect variable flows and ecologically desirable flow recession rates	DPIE-BC, CEWO and WaterNSW
		Map and prioritise riparian habitat and erosion points for rehabilitation at the catchment scale, with a commitment to manage risk and monitor outcomes	DPIE-BC, DPIF and WaterNSW

[25] For example, close regulating structures after watering to allow wetland drying and kill invasive animals.

Risk	Description	Potential management strategies	Potential project partners
	This can increase turbidity and reduce instream habitat quality	Update mapping and prioritise riparian habitat and erosion points for rehabilitation at the catchment scale, with a commitment to manage risk and monitor outcomes	DPIE-BC, DPIE–Water, LLS and DPIF
		Investigate methods for improving the seasonal pattern and variability of water delivery	DPIE-BC, WaterNSW and CEWO
Instream barriers and structures	Instream structures impede natural flow and connectivity which impacts on fish There are over 200 barriers (including weirs, regulators, and road crossings) in the Gwydir catchment, sixty-seven of which have been identified as priority structures for remediation	Refer to NSW Department of Primary Industries, DPIF *Fish for the Future: Action in the Northern Basin—NSW proposal for Northern Basin Toolkit* measures to promote native fish health	DPIF
		Remove priority illegal barriers	NRAR
	Diversion of water can have significant impact on native fish by altering habitat and affecting spawning and recruitment There are over 300 pump offtakes with a diameter greater than 200mm on the Gwydir River, Moomin Creek, Mehi River and Carole Creek	Refer to the *Fisheries management plan* for screens on pumps	DPIF and DPIE–Water
		Develop a Gwydir catchment connectivity plan focussed on improving habitat connectivity, including in the Gwydir, Mehi and Barwon rivers	DPIE-BC, CEWO, DPIF and DPIE–Water

5.3 Climate change

Climate change is a key long-term risk to river, wetland and floodplain health. It will exacerbate the natural seasonal variability that exists in NSW, making it more difficult to manage our landscapes and ecosystems and the human activities that depend on them. Average temperatures have been steadily rising since the 1950s. The decade from 2001 to 2010 was the hottest on record, while 2019 was the hottest year in NSW (DECCW 2010, BOM 2019). As the natural seasonal variability that exists in NSW continues to be altered, climate change will increasingly affect the environment and society in every part of the state.

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 Gwydir catchment and Gwydir wetlands (CSIRO 2007). The project predicts:

- a 10% reduction in average annual runoff to rivers in the Gwydir catchment by 2030
- a 20% reduction in the average annual volume of water reaching the Gwydir wetlands (not considering delivery of held environmental water)
- no significant reduction in the average and maximum period between inundation events (flows exceeding 100 GL/month at Yarraman Bridge) in the Gwydir wetlands.

Best available climate change predictions for the Gwydir catchment indicate a significant change to climatic patterns in the future. According to the NARCLiM model[26] (scenario 2), the changes in Table 18 are predicted by 2030 and 2070.

Figure 24 Cracking clays is the dominant soil type found in many parts of the Gwydir catchment
Photo: T. Cooke

[26] 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 18 Potential climate-related risks in the Gwydir catchment

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 and much of the region during spring. 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	+2.4C
		Autumn	+0.75C	+2.16C
		Winter	+0.48C	+1.92C
		Spring	+0.80C	+2.33C
Change in number of hot days (maximum temperature >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 (minimum temperature <2C)	Cold nights are projected to decrease across the New England North West by an average of 9 days per year by 2030. The greatest decreases are seen in the eastern mountainous region around Glenn Innes, which is projected to experience a 10–20 fewer cold nights per year. Changes in cold nights can have considerable impacts on native ecosystems.	Annual	-8.8	-26.1
Bushfires Changes in number of days a year FFDI>50[27]	Overall, severe fire weather is projected to increase (slightly) across the region by 2030. However, increased severed fire weather is expected in the north-west part of the region during spring (the prescribed burning season) and summer (peak fire risk season). Conversely, declines in severe fire weather are expected in autumn due to increases in rainfall.	Annual	+0.2	+0.9
Hillslope erosion	Changes in erosion can have significant implications for natural assets and water quality.	Mean percent change	4.3%	17.4%
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 Gwydir catchment.

[27] 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.

Strategies for mitigating climate-related risks

Environmental water management and the proactive release of water from Copeton Dam to support improved river and wetland health outcomes has been occurring in the Gwydir catchment since 1996. The climate has been variable during this time, with the region experiencing extreme drought and flooding. Environmental water managers have become experienced in dealing with highly variable conditions, using management practices and responses established over time based on real-world experience and collaboration.

Water managers currently examine the outcomes of climate change research and monitor outcomes against existing objectives and targets using real-time data, such as rainfall, to inform their understanding of the impacts of climate change at the catchment scale. This information assists in answering questions such as:

- How will the volume of water stored in Copeton Dam be affected by climate change?
- How will water quality be affected by climate change?
- Will the flow pathways across the landscape change as our climate changes?
- Will the duration of floodplain inundation decrease due to higher evaporation rates, which will likely come with increased temperatures because of climate change?
- How will changes in rainfall, runoff and evaporation impact soil chemistry in a changing climate?
- How will changes in weather attributed to climate change, including increased air temperatures, flow seasonality due to changes in rainfall or severe weather events, affect the plants and animals of the Gwydir?

Environmental water managers will continue to respond to the environmental demands of rivers, wetlands and floodplains, considering the range of priorities and strategies at their disposal. Climate change will be another important variable in this decision-making process.

6. Water management priorities and strategies

6.1 Prioritisation of ecological objectives and watering in Zone A

Environmental water managers and EWAGs consider a range of factors when determining how discretionary water for the environment should be managed. Some of these considerations include the current condition of the plants and animals, the recent connectivity history 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. They need to accommodate watering activities that range from maximising environmental outcomes from flow events when water is abundant, to managing water to maintain drought refuges when resources become scarce. Appropriate compliance activities to prevent unauthorised extractions is paramount to the success of any water management strategy's ability to contribute to environmental outcomes.

This chapter sets out a framework to help inform annual water management decisions depending on the water resource availability scenario (RAS) in river reaches which are regulated or affected by regulated water. Each of these sections contains three parts:

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

Some of the wording of the LTWP objectives has been adjusted to highlight the most relevant aspect of the objective under the scenario. For example, a LTWP objective that over 20 years seeks 'improvement' may only seek to 'maintain' under a dry scenario[28]. Some of the objectives have been combined for better presentation. The full list of objectives can be found in chapter 3. More information about RAS and how it is defined is outlined in Appendix B.

[28] Some of the objectives have been summarised to assist with presentation. The full set of objectives can be found in chapter 3.

Water resource availability scenario: Very dry – Protect

	Management priorities	Management strategies for achieving priorities
Very dry	Avoid critical loss of species, communities and ecosystems Provide refuges Avoid irretrievable damage or catastrophic events Avoid unnaturally prolonged dry periods Support some targeted longitudinal connectivity for functional processes and a range of flora and fauna	Allow dry down consistent with historical wetting-drying cycles Sustain key in-channel refuge pools, instream habitat and core wetland areas Provide very low flows to relieve severe unnatural prolonged dry periods and support suitable water quality Limit exceedance of maximum inter-event periods for smaller flows as opposed to maintaining the long-term ideal frequency of events If a critical incident restricts the use of water for the environment, then DPIE will work with the Gwydir EWAG to prioritise environmental water needs and DPIE–Water to ensure that these needs are considered, and ensure that there is appropriate DPIE representation on the Critical Water Advisory Panel

Table 19 Priority objectives and flow categories in a very dry RAS

Objectives	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh[29]	Large Fresh	Bankfull	Small overbank/	Large overbank/
NF1: No loss of native fish species	X	X	X	X			X	
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X	X	X			X	
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in core wetlands							X	
WB1: Maintain the number and type of waterbird species							X	
WB2: Maintain total waterbird abundance across all functional groups							X	
WB5: Maintain the extent of waterbird habitats							X	
EF1: Provide and protect a diversity of refugia across the landscape.	X	X	X	X			X	
EF2: Maintain quality instream and core wetland habitat	X	X	X				X	

[29] Small freshes and WL1 flows may be important and achievable in a very dry RAS to protect core wetland habitats and avoid critical habitat loss

EF3: Provide movement and dispersal opportunities within catchments			X				X	
OS1: Maintain species richness and distribution of flow-dependent frog species							X	
OS2: Maintain successful breeding opportunities for flow-dependent frog species							X	

Water resource availability scenario: Dry – Maintain

	Management outcomes	Management strategies
Dry	Support the survival and viability of threatened species and communities Provide refuges Maintain environmental assets and ecosystem functions Avoid unnaturally prolonged dry periods between flow events Support longitudinal connectivity for functional processes and a range of flora and fauna	Allow dry down consistent with historical wetting-drying cycles Sustain key in channel pools, instream habitat and core wetland areas Provide freshes and wetland inundating flows to core wetlands, where possible, at ecologically relevant times Avoid exceeding maximum inter-event periods and provide events which have recently had lower than ideal frequency Provide low flows to relieve severe unnatural prolonged dry periods and support suitable water quality Protect tributary inflows

Table 20 Priority objectives and flow categories in a dry resource availability scenario

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh[30]	Large Fresh	Bankfull	Small overbank/ wetland[17]	Large overbank/ wetland
NF1: No loss of native fish species	X	X	X	X			X	
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish species			X	X				
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species			X	X			X	
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species			X	X				

[30] Small freshes and WL1 flows may be important and achievable in a dry RAS to protect core wetland habitats and avoid critical habitat loss

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh[30]	Large Fresh	Bankfull	Small overbank/ wetland[17]	Large overbank/ wetland
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species			X	X				
NF6: Maintain the abundance of mature (harvestable sized) golden perch and Murray Cod			X	X				
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X	X	X			X	
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in core wetlands							X	
WB1: Maintain the number and type of waterbird species							X	
WB2: Maintain total waterbird abundance across all functional groups							X	
WB5: Maintain the extent and condition of waterbird habitats							X	
EF1: Provide and protect a diversity of refugia across the landscape	X	X	X	X			X	
EF2: Maintain quality instream and core wetland habitat	X	X	X	X			X	
EF3: Provide movement and dispersal opportunities within catchments			X	X			X	
EF5: Support nutrient, carbon and sediment transport along channels				X				
OS1: Maintain species richness and distribution of flow-dependent frog communities							X	
OS2: Maintain successful breeding opportunities for flow-dependent frog species							X	
OS4: Maintain water-dependent species richness			X	X				

Water resource availability scenario: Moderate – Recover

	Management outcomes	Management strategies
Moderate	Enable growth, reproduction and small-scale recruitment for a diverse range of flora and fauna Promote low-lying floodplain-river connectivity Seek to meet ideal event frequencies Support medium flow river and floodplain functional processes Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna Support low flow lateral connectivity and end of system flows Set aside water for use in drier years	Provide freshes, bankfull and wetland inundating flows, where possible, at ecologically relevant times Improve condition of key off channel waterholes Build on natural events to provide wetland and floodplain inundation at ecologically relevant times Provide flows to systems that are otherwise cut off from natural flows Prioritise EWRs that are approaching their maximum inter-event period or lower than ideal frequency Provide low flow connectivity to the Barwon River Consider carrying over water to support water used in drier years

Table 21 Priority objectives and flow categories in a moderate resource availability scenario

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small overbank/ wetland	Large overbank/ wetland
NF1: No loss of native fish species	X	X	X	X	X		X	
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish species			X	X	X		X	
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species			X	X	X		X	
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species			X	X	X		X	
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species			X	X	X		X	
NF6: A 25% increase in abundance of mature (harvestable sized) golden perch and Murray Cod			X	X	X		X	
NF7: Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas			X	X	X		X	

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small overbank/ wetland	Large overbank/ wetland
NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas			X	X	X		X	
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X	X	X	X	X		
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains					X	X	X	
NV3: Maintain the extent and the condition of river red gum communities closely fringing river channels					X	X	X	
NV4b: Maintain the extent and the condition of native woodland and shrubland communities on floodplains							X	
NV4c:							X	
NV4e:							X	
NV4f:							X	
WB1: Maintain the number and type of waterbird species							X	
WB2: Increase total waterbird abundance across all functional groups							X	
WB3: Increase opportunities for small-scale non-colonial waterbird breeding							X	
WB4: Increase opportunities for colonial waterbird breeding							X	
WB5: Maintain the extent and improve the condition of waterbird habitats					X	X	X	
EF1: Provide and protect a diversity of refugia across the landscape	X	X	X	X	X	X	X	
EF2: Create quality instream, floodplain and wetland habitat	X	X	X	X	X	X	X	
EF3: Provide movement and dispersal opportunities within and between catchments			X	X	X	X	X	
EF4: Support instream and wetland productivity					X	X	X	
EF5: Support nutrient, carbon and sediment transport across the catchment				X	X	X	X	
EF6: Support groundwater conditions to sustain groundwater-dependent biota					X	X	X	
EF7: Maintain the contribution of flows into the Barwon-Darling from tributaries			X	X	X	X	X	

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small overbank/ wetland	Large overbank/ wetland
OS1: Maintain species richness and distribution of flow-dependent frog communities							X	
OS2: Maintain successful breeding opportunities for flow-dependent frog species							X	
OS4: Maintain water-dependent species richness			X	X	X	X	X	

Water resource availability scenario: Wet – Improve

	Management outcomes	Management strategies
Wet	Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna Support high flow river and floodplain functional processes Support high flow lateral connectivity and end of system flows Set aside water for use in drier years	Build on natural events to provide wetland and floodplain inundation at ecologically relevant times Provide flows to systems that are otherwise cut off from natural flows Protect naturally occurring floodplain wetland inundating events Build on natural events to provide high flow connectivity to the Barwon River where possible, provide events that are well below their maximum inter-flow event period to improve resilience during dry periods Carry over water to support water use in drier years

Table 22 Priority objectives and flow categories in a wet resource availability scenario

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small overbank/ wetland	Large overbank/ wetland
NF1: No loss of native fish species	X	X	X	X	X		X	X
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish species			X	X	X		X	X
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species			X	X	X		X	X

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small overbank/ wetland	Large overbank/ wetland
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species			X	X	X		X	X
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish species			X	X	X		X	X
NF6: A 25% increase in abundance of mature (harvestable sized) Golden Perch and Murray Cod			X	X	X		X	X
NF7: Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into new areas			X	X	X		X	X
NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas			X	X	X		X	X
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X	X	X	X	X		
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains					X	X	X	X
NV3: Maintain the extent and maintain or improve the condition of river red gum communities closely fringing river channels					X	X	X	
NV4b: Maintain the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains							X	X
NV4c:							X	X
NV4d:							X	X
NV4e:							X	X
NV4f:							X	X
WB1: Maintain the number and type of waterbird species							X	X
WB2: Increase total waterbird abundance across all functional groups							X	X
WB3: Increase opportunities for non-colonial waterbird breeding							X	X

Objective	Flow categories							
	Cease to Flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Small overbank/ wetland	Large overbank/ wetland
WB4: Increase opportunities for colonial waterbird breeding							X	X
WB5: Maintain the extent and improve condition of waterbird habitats					X	X	X	X
EF1: Provide and protect a diversity of refugia across the landscape	X	X	X	X	X	X	X	X
EF2: Create quality instream, floodplain and wetland habitat	X	X	X	X	X	X	X	X
EF3: Provide movement and dispersal opportunities within and between catchments for water-dependent biota to complete lifecycles and disperse into new habitats			X	X	X	X	X	X
EF4: Support instream and floodplain productivity				X	X	X	X	X
EF5: Support nutrient, carbon and sediment transport across the catchment				X	X	X	X	X
EF6: Support groundwater conditions to sustain groundwater-dependent biota				X	X	X	X	X
EF7: Increase the contribution of flows into the Murray and Barwon-Darling from tributaries			X	X	X	X	X	X
OS1: Maintain species richness and distribution of flow-dependent frog communities							X	X
OS2: Maintain successful breeding opportunities for flow-dependent frog species							X	X
OS4: Maintain water-dependent species richness			X	X	X	X	X	X

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

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

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

The effective management of water quality incidents relies on the timely access to monitoring information at key sites and the identification of risk factors. Whilst environmental water may be used in certain instances to provide refuge habitat, there is insufficient environmental water to avoid, mitigate or offset water quality issues in NSW rivers, nor is it the responsibility of environmental water managers to do so.

Tables 23 and 24 describe critical water quality incidents and extreme conditions respectively, and recommended management strategies for environmental water managers. In these two instances, the management priorities of water managers are to:

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

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

Table 23 Priorities and strategies for managing water during critical water quality incidents

Critical water quality incident description	Identifying features	Management strategies for achieving priorities
Water quality does not meet Australian and New Zealand Guidelines for Fresh and Marine Water Quality, and is causing or is likely to cause significant impact on aquatic ecosystems[31]	Weir/refuge pools are stratified Water quality sampling and analysis demonstrates unfavourable conditions: • lack of dissolved oxygen[32] • unnatural change in temperature • unnatural change in pH • unnatural change in salinity • excess suspended particulate matter[33] • elevated levels of nutrients[34] • chemical contamination[35]	DPIE–BC will work with the Gwydir EWAG to prioritise environmental water needs and DPIE–Water and WaterNSW to ensure that these needs are considered in the management of all water Work with WaterNSW to protect, or if possible, provide baseflows and very low flows[36] to support suitable water quality in rivers and critical refuge pools[37] Sustain critical in-channel refuge pools and instream habitat Use infrastructure-assisted delivery, where possible, to create small-scale refuges of good quality water for native biota[37] Limit exceedance of maximum inter-event periods for floodplain inundating flows to reduce the risk of hypoxic blackwater events

[31] Description of the types of water quality degradation, their main causes, and where they are likely to occur in the Gwydir catchment can be found in the *Water quality management plan for the Gwydir Water Resource Plan Area* (DPIE-Water 2019d)
[32] Dissolved oxygen levels should be high enough to prevent the asphyxiation of respiring organisms, typically >4mg/L
[33] Excess particulate matter may be identified through poor optical properties of waterbodies, the smothering of benthic organisms, or the reduction in photosynthesis (which will inhibit primary production)
[34] May lead to nuisance growth of aquatic plants
[35] Diffuse or point source pollutants may have lethal or sub-lethal effects on aquatic biota
[36] As described in the relevant EWRs in the LTWP
[37] Natural flows, operational water, PEW and water quality allowances (where they exist) should be used in the first instance before considering the use of HEW

Table 24 Priorities and strategies for managing water during extreme conditions

Extreme conditions description	Identifying features	Management strategies for achieving priorities
A critical drought and/or water shortage where only restricted town water supply, stock and domestic and other restricted high priority demands can be delivered	Very low to no natural or regulated flows resulting in disconnected pools Limited water held in storages Limited ability to deliver water for critical human needs WSP may be suspended	DPIE-BC will work with the Gwydir EWAG to prioritise environmental water needs and DPIE-Water and WaterNSW to ensure that these needs are considered in the management of all water Sustain critical in-channel refuge pools and core wetland areas Work with WaterNSW to protect, or if possible, provide very low flows or replenishment flows[36] to relieve severe unnatural prolonged dry periods and support suitable water quality in critical refuge pools[37]

6.3 Protection of ecologically important flow categories in Zone B

In areas where water cannot be delivered through a regulating structure (Zone B), the only means of protecting environmentally important flows is through rules in the WSPs for the Gwydir Unregulated Water sources. Table 27 sets out potential management strategies that could be implemented in the WSPs to ensure important flows are protected during very dry through to wet times. Many of these strategies are consistent with the NSW macro planning approach for pools (NOW 2011) which recommends that water access rules for in-river and off-river (wetland) pools be reviewed and alternative rules considered where moderate or high risks to instream environmental values are identified. In order for any of these strategies to be successful, adequate compliance measures need to be in place, and in some areas, improved water metering and gauging is also required.

Part B of the LTWP identifies unregulated planning units where the Risk Assessment has identified one or more flow categories as being at medium to high risk. The LTWP recommends specific management strategies from Table 25 to mitigate these risks in each of these planning units based on the level of risk, which flow categories are at risk and characteristics of extractive water use or hydropower operations.

Table 25 Potential management strategies to protect ecologically important flows in Zone B

Flow categories	Potential management strategies	Most relevant resource availability scenarios
Cease-to-flow	Consider reviewing existing rules to ensure that visible flow is maintained downstream of extraction points. Consider reviewing cease-to-pump rules to reduce the length of cease-to-flow periods Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate Consider implementing Individual and/or Total Daily Extraction Limits (IDELS / TDELS)[38] Consider implementing a commence-to-pump threshold that is higher than cease-to-pump (CtP) threshold to ensure cease-to-flow periods are broken at ecologically relevant times and with events of sufficient magnitude to avoid adverse water quality incidents	Very dry Dry
Low flows and baseflows	Consider reviewing cease-to-pump rules to protect low flows and baseflows, especially during dry times or ecologically important months Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate. Consider implementing Individual and/or Total Daily Extraction Limits (IDELS / TDELS)[38]	Very Dry Dry
Freshes	Consider implementing a commence-to-pump threshold that is higher than cease-to-pump (CtP) threshold to protect freshes at ecologically relevant times. Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate. Consider implementing Individual and/or Total Daily Extraction Limits (IDELS / TDELS)[38]	Very dry Dry Moderate

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

Flow categories	Potential management strategies	Most relevant resource availability scenarios
Entire flow regime, including overbank and wetland inundating flows	Consider targeted water access licence purchases from willing sellers where flows are acutely impacted. Consider installing water level gauges at or near extraction sites, or river flow gauges if none exist in the planning unit. Ensure compliance with water access licence conditions Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate. Consider implementing Individual and/or Total Daily Extraction Limits (IDELS / TDELS)[38] Consider introducing cease-to-pump and commence-to-pump rules (and any associated required amendments to WAL conditions) that protect held environmental water, planned environmental water and water from the EWAs entering unregulated streams and off-channel pools (wetlands)[39] Maintain no trade into water source rules in the WSP Monitor for changes in land use, floodplain harvesting, and water demand and review access rules if current usage is high or if the pattern changes	All weather scenarios

Figure 25 Ibis rookery in the upper Gingham Wetlands
Photo: D. Albertson/DPIE

[39] In-line with the Basin Plan requirement for implementation of *prerequisite policy measures* which provide for delivered environmental water to be protected. It is also recommended by the Matthews reports (2017a,b)

7. Going forward

7.1 Cooperative arrangements

River operations to benefit the environment

All water in the Murray–Darling Basin, including natural events and consumptive water, has the potential to contribute to improving the ecological condition of rivers, wetlands and floodplains (MDBA 2014). Making the best use of all water is a key strategy to achieve the objectives in this LTWP. In some cases, river operating practices need to be revised to provide a mandate to manage rivers so ecological objectives can be achieved. The risks and constraints to achieving EWRs (Table 16) described in this LTWP identifies some river management practices that are currently limiting or impacting on the ability to achieve ecological objectives. The LTWP identifies the following strategies to maximise the benefit of all water in the system:

- investigate options for the delivery of irrigation orders to more closely mimic natural flow events
- establish 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
- optimise water releases from Copeton Dam to mimic natural rates of fall
- consider environmental needs in the management of weir pools.

Despite the advantages of coordinated use of held and planned environmental water, there is insufficient water available from these sources alone to meet the water needs of the environment. 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 should enable larger in-channel and overbank flows that would not be possible with designated environmental water alone.

Similarly, controlled river flows through the system for consumptive deliveries can also meet many environmental water requirements, without any contribution of environmental water. One of the primary recommendations of this LTWP is to investigate the potential to optimise these outcomes, by supporting collaboration between DPIE and WaterNSW to assist in shaping consumptive deliveries to more closely reflect natural flow patterns and strike a balance between operational efficiency and ecological objectives.

Cooperative water management arrangements

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

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

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

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

Complementary natural resource management

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

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

Cooperative investment opportunities

A few significant investment priorities have been identified in the Gwydir catchment (Table 26). Identification of key project partners, funding opportunities and subsequent implementation of projects to address these priorities will contribute significantly to the ecological objectives identified in this plan.

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

Figure 26 Environmental monitoring in the Bungunya Wetland on the Gwydir River
Photo: T. Cooke

Table 26 Investment opportunities and potential project partners to improve environmental outcomes from water management in the Gwydir

Investment opportunity	Description	Potential DPIE project partners
Copeton Dam cold water pollution mitigation	The outlet tower on Copeton Dam is constructed with a fixed level off-take that draws colder water from the bottom of the lake. Cold water impacts have been recorded more than 200km downstream of the dam. Restoration to near natural river water temperatures will provide native fish species the environmental cues they require to spawn and reproduce.	WaterNSW, CEWO
Measures to address flow constraints in the Gwydir catchment	Increasing maximum release capacity in the Lower Gwydir downstream of Tyreel Weir pool, including fish passage, will improve water management at the site. The lower Gwydir wetlands and river system will benefit during natural flow events by the ability to hold back a larger volume in the weir pool, whereby also distributing a larger portion of the event downstream. Investigate infrastructure options to facilitate water delivery to Ballin Boora Creek. In consultation with affected stakeholders, investigate and implement easements or other measures to allow for the passage of managed flows across fringing floodplain as envisaged by the Constraints Management Strategy (including in the Mehi and Ballin Boora systems).	WaterNSW, CEWO, Landholders, water users
Improve protection of important native vegetation communities from clearing	Native vegetation clearing is one of the biggest threats to the Gwydir catchment's resilience besides insufficient water for the environment. The protection of native vegetation requires good knowledge, the cooperation of various stakeholders, and multiple different projects, which include: • habitat mapping to identify riparian and aquatic habitat condition and prioritise reaches for management actions in partnership with LLS and landholders, to develop formal agreements and unified strategies • implement grazing strategies required to protect and restore wetland vegetation, bank stability and adequate water quality. in collaboration with Local Land Services and landholders • provide incentives to landholders to improve management of wetlands on private land • commence wetland restoration activities in the Mallowa in partnership with private landholders.	BCT, LLS, NPWS, CEWO, Landholders
Identifying cultural assets and capacity building for First Nations people	Many of the ecological values across the Gwydir catchment have cultural value and significance to First Nations people and Traditional Owners. Better engagement, opportunities for co-learning and sharing knowledge (including of contemporary water management and cultural values and uses) will provide benefits to local communities and management of water for the environment. Increased engagement with First Nation people will help identify the co-benefits that water for the environment can deliver relative to water dependent cultural uses and values.	First Nations people, CEWO, MDBA, NBAN, LALC

Investment opportunity	Description	Potential DPIE project partners
Increase engagement capacity	By increasing engagement with the people who live and work in the Gwydir catchment, we will increase the communities' understanding, appreciation and involvement in protecting the catchment's freshwater ecosystem. More importantly, we also increase our knowledge and understanding of the catchment, which will ultimately lead to a better LTWP in the future.	NBAN, LALC, Local council, water users, LLS, Landholders, general community, Traditional Owners
Implementation of a native fish restoration project	To assist in improving the aquatic habitat that supports native fish there is an opportunity to implement various instream management activities, including: • assessing and addressing priority barriers to fish passage in the catchment • detailed aquatic habitat mapping • the implementation of pump screening methods to prevent entrainment[40] of native fish and eggs • works to achieve instream habitat improvement including re-snagging and aquatic revegetation • development and implementation of a carp management strategy • reintroduction, translocation and stocking of threatened fish species in key locations	DPIF, LLS, CEWO
Addressing gaps in the water quality network	Currently, there are gaps in the NSW water quality network in the Namoi. A functional water quality monitoring network will help mitigate against future detrimental water quality events.	DPIE-Water, MDBA
Improve measurement of floodplain harvesting take	Accurately measuring floodplain harvesting take is critical understanding the relationship between floodplain harvesting and: • habitats for aquatic organisms • the health of rivers downstream • whether any adjustments are needed to better manage environmental flows Installing automated cameras that generate images of gauge board readings would help to measure floodplain harvesting take.	DPIE-W, MDBA, DPIE-BC

[40] The entrapment of one substance by another substance

Investment opportunity	Description	Potential DPIE project partners
Reduce the spread of pest plant and animal species	There is potential for environmental water to spread weeds like lippia and water hyacinth. Projects should be put in place to increase the re-establishment of native plants. Pest animal populations may benefit from environmental water use and the Gwydir requires the control of various pest species such as pigs and carp. Some strategies are to: • ensure ongoing investment into the control of lippia, water hyacinth and other invasive plant species across the catchment • prioritise reaches for weed management with Local Land Services and landholders • implement priority pest species management actions	LLS, Landholders, Land managers, NPWS

7.2 Measuring progress

Monitoring, evaluating and reporting (MER) to support adaptive management are integral to informing planning and operational decisions. Monitoring how water moves through the system and how the environment responds informs ongoing improvements to water management. This information also assists in informing revisions of this LTWP every five years.

Monitoring and evaluating environmental water management in the Gwydir WRPA draws on contributions from Australian and NSW Government agencies, universities, other research organisations, non-government organisations, individuals and land managers.

The MER program provides a unified approach to delivering Basin Plan and NSW evaluation and reporting requirements. The NSW-wide 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 used to create a cost-effective and coordinated program
- the DPIE-BC-specific parts, called the *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 each WRPA
- monitoring *Methods Manuals* that describe methods for each monitoring theme (e.g. fish, hydrology, vegetation, water quality, macroinvertebrates, waterbirds) considered in broader NSW water monitoring. These manuals, when developed, will contain information relating to survey, data handling and analysis techniques, conceptual models and cooperative research arrangements.

The NSW MER Framework, which includes NSW Fisheries Basin Plan Environmental Outcomes Monitoring program and DPIE MER program, provides the structure within which various NSW-led monitoring activities are brought together for:

- tracking progress towards stated LTWP and WSP outcomes
- improved decision making for environmental water planning and operations (supporting adaptive management).

To do this, the 2018 NSW MER Framework, aim to:

- evaluate progress towards achieving outcomes defined within LTWPs and WSPs
- extend, augment and respect current and historical monitoring
- address information and monitoring gaps or shortfalls
- provide high-quality, scientifically robust information to support both continual improvement of operations and a growing information base for wetland and river conservation generally
- collaborate with water delivery partners (particularly the CEWO), DPIE-Water, wetland managers, other agencies and researchers to value-add to monitoring outcomes and minimise duplication
- provide information that supports community engagement and improved reporting of environmental water outcomes which will increase government and community confidence and awareness of environmental water management
- streamline reporting requirements under WRPs, LTWPs, Schedule 12 of the Basin Plan and the National Partnership Agreement.

The detail of the monitoring to be undertaken under the DPIE MER program is being finalised and is dependent on the level of available funding.

Monitoring progress reports are made available following each watering year.

7.3 Review and update

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

- accreditation or amendment to the WSP or WRP for the Gwydir catchment
- revision of the BWS that materially affects this LTWP
- a sustainable diversion limit adjustment
- new information arising from evaluating responses to environmental watering
- new knowledge about the ecology of the Gwydir catchment that is relevant to environmental watering
- improved understanding of the effects of climate change and its impacts on the Gwydir catchment
- 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 27 Gingham Waterhole in the Gwydir Wetlands
Photo: T. Cooke

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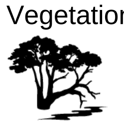
Appendix A Ecological objectives relevant to each planning unit

Table 27 Ecological objectives for priority environmental asset in the Zone A planning units

	Code	Ecological objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Native fish 	NF1	No loss of native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species	X	X		X		X		X	X	X		X	X	X	X			X	X
	NF3	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species	X	X		X		X						X		X	X				
	NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species	X	X		X		X		X	X	X		X	X	X	X			X	X
	NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	X	X		X		X		X	X	X		X	X	X	X			X	X
	NF6	A 25% increase in abundance of mature (harvestable sized) Golden Perch and Murray Cod	X	X		X		X		X	X	X		X	X	X	X			X	X
	NF7	Increase the prevalence and/or expand the population of key short to moderate-lived floodplain specialist native fish species into														X			X		

	Code	Ecological objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		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)	X	X																	
	WB1	Maintain the number and type of waterbird present.				X		X		X	X	X			X	X	X	X			
	WB2	Increase total waterbird abundance.				X		X		X	X	X			X	X	X	X			
Waterbirds 	WB3	Increase breeding activity in non-colonial nesting waterbirds.				X		X		X	X	X			X	X	X	X			
	WB4	Increase opportunities for colonial waterbird breeding events.				X		X		X	X	X			X	X	X	X			
	WB5	Maintain the extent and improve condition of waterbird habitats				X		X		X	X	X			X	X	X	X			
	NV1	Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X		X		X		X	X	X		X	X	X	X	X		X	X
Vegetation 	NV2	Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains						X			X	X		X	X	X	X	X	X	X	X
	NV3	Maintain the extent and maintain or improve the condition of river red gum communities	X	X		X		X		X	X	X	X	X	X	X	X	X	X	X	X

	Code	Ecological objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		closely fringing river channels																			
	NV4a	Maintain or increase the extent and maintain or improve the condition of river red gum woodland	X	X		X		X		X	X	X	X	X	X	X	X	X	X	X	X
	NV4b	Maintain or increase the extent and maintain or improve the condition of black box woodland							X			X		X					X	X	X
	NV4c	Maintain or increase the extent and maintain or improve the condition of lignum shrubland		X		X		X				X	X	X	X	X	X	X		X	X
	NV4d	Maintain or increase the extent and maintain or improve the condition of coolibah wetland woodland		X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X
	NV4e	Maintain or increase the extent and maintain or improve the condition of coolibah woodland	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF1	Provide and protect a diversity of refugia across the landscape.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ecosystem functions ⇅	EF2	Create quality instream, floodplain and wetland habitat.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF3	Provide movement and dispersal opportunities within catchments for water-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

	Code	Ecological objective	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		dependent biota to complete lifecycles.																			
	EF4	Provide movement and dispersal opportunities between catchments for water-dependent biota to complete lifecycles.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF5	Support instream and floodplain productivity.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF6	Support groundwater conditions to sustain groundwater-dependent biota.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF7	Support mobilisation and transport of sediment, carbon and nutrients along channels, between channels and floodplains, and between catchments.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF8	Increase the contribution of flows into the Barwon-Darling tributaries.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Other species 	OS1	Maintain species richness and distribution of flow-dependent frog communities				X		X				X			X		X	X			
	OS2	Maintain successful breeding opportunities for flow-dependent frog species				X		X				X			X		X	X			
	OS4	Maintain water-dependent species richness	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 28 **Ecological objectives for priority environmental asset in the Zone B planning units**

	Code	Ecological objective	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Native fish 	NF1	No loss of native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species			X		X		X								X	X	X					X			X			X		X
	NF3	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species																												X		X
	NF4	Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species					X		X								X	X	X					X			X			X		X
	NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species			X		X		X								X	X	X					X			X			X		X
	NF6	A 25% increase in abundance of mature (harvestable sized) Golden Perch and Murray Cod					X		X																		X					X
	NF7	Increase the prevalence and/or expand the population																														X

	Code	Ecological objective	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
		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)							X		X	X	X	X	X	X		X	X													
	WB1	Maintain the number and type of waterbird present.																														
	WB2	Increase total waterbird abundance.																														
Waterbirds 	WB3	Increase breeding activity in non-colonial nesting waterbirds.																														
	WB4	Increase opportunities for colonial waterbird breeding events.																														
	WB5	Maintain the extent and improve condition of waterbird habitats																														
	NV1	Maintain the extent and viability of	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

	Code	Ecological objective	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
		non-woody vegetation communities occurring within channels																														
	NV2	Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	X	X	X	X	X	X	X	X	X	X	X	X		X		X			X	X	X	X	X	X	X		X	X	X	
	NV3	Maintain the extent and maintain or improve the condition of river red gum communities closely fringing river channels	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X			X			X
Vegetation 	NV4a	Maintain or increase the extent and maintain or improve the condition of river red gum woodland	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X			X			X
	NV4b	Maintain or increase the extent and maintain or improve the condition of black box woodland																									X	X	X	X	X	X
	NV4c	Maintain or increase the extent and maintain or improve the condition of lignum shrubland																								X			X	X		X
	NV4d	Maintain or increase the extent and maintain or improve the condition of																		X	X	X	X	X	X	X	X	X	X	X	X	X

	Code	Ecological objective	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
		coolibah wetland woodland																														
	NV4e	Maintain or increase the extent and maintain or improve the condition of coolibah woodland																			X	X	X	X	X	X	X		X	X	X	X
Ecosystem functions	EF1	Provide and protect a diversity of refugia across the landscape.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF2	Create quality instream, floodplain and wetland habitat.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF3	Provide movement and dispersal opportunities within catchments for water-dependent biota to complete lifecycles.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF4	Provide movement and dispersal opportunities between catchments for water-dependent biota to complete lifecycles.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF5	Support instream and floodplain productivity.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF6	Support groundwater conditions to sustain groundwater-dependent biota.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

	Code	Ecological objective	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
	EF7	Support mobilisation and transport of sediment, carbon and nutrients along channels, between channels and floodplains, and between catchments.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EF8	Increase the contribution of flows into the Murray and Barwon-Darling tributaries.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Other species 	OS1	Maintain species richness and distribution of flow-dependent frog communities																														
	OS2	Maintain successful breeding opportunities for flow-dependent frog species																														
	OS4	Maintain water-dependent species richness	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Appendix B Resource availability scenario

Guidelines for the method to determine priorities for applying environmental water[41]

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

To determine the RAS, the following steps are followed:

a. determine the antecedent conditions for a given water resource plan area by (the 'X' axis of the matrix in Table 29):
   i selecting a representative number of water accounting periods preceding the current water year (e.g. 3–5 years)
   ii assessing the water received by the environment for those years
   iii comparing the amount in (ii) to all the historical data
   iv categorising the antecedent conditions as a percentile relative to all historical water years
b. determine the surface water availability by (the 'Y' axis of the matrix in Table 29):
   i assessing all sources of water available for the environment for a given period
   ii comparing these to all the historical data
   iii categorising the surface water availability as a percentile relative to all historical water years
c. for the relevant water accounting period, determine the surface water availability relative to the antecedent conditions for the water resource plan area using all of the historical climate condition data that are available (in Table 29, this is the surface water availability percentile)
d. using the following matrix below, determine the applicable water RAS.

Table 29 Default matrix for determining the RAS

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

[41] As outlined by the Murray-Darling Basin authority in https://www.mdba.gov.au/publications/policies-guidelines/guidelines-method-determine-priorities-applying-environmental-water