DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Namoi Long Term Water Plan

Part A: Namoi catchment

Cover photo: Namoi River below Keepit Dam Wall, Emma Wilson

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Environment, Energy and Science
Department of Planning, Industry and Environment
4 Parramatta Square, 12 Darcy Street, Parramatta NSW 2150
Phone: +61 2 9995 5000 (switchboard)
Phone: 1300 361 967 (Environment, Energy and Science enquiries)
TTY users: phone 133 677, then ask for 1300 361 967
Speak and listen users: phone 1300 555 727, then ask for 1300 361 967
Email: info@environment.nsw.gov.au
Website: www.environment.nsw.gov.au

Report pollution and environmental incidents
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Contents

List of tables

List of figures

Acknowledgement of Traditional Owners

The 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 Namoi catchment, the Department of Planning, Industry and Environment pays its respects to the Traditional Owners – the Kamilaroi/Gamilaraay/Gomeroi people – past, present and future, as well as those of other Nations for whom this river is significant. We look forward to building upon existing relationships to improve the health of our rivers, wetlands and floodplains, including in recognition of their traditional and ongoing cultural and spiritual significance.

Figure 1 Pelicans over the Namoi River
Photo: N Foster

Abbreviations

AHIMS	Aboriginal Heritage Information Management System
Basin Plan	Murray-Darling Basin Plan 2012
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	Department of Planning, Industry and Environment (NSW)
DPIE-BC	Department of Planning, Industry and Environment – Biodiversity and Conservation Division (NSW)
DPIE-Water or DPIE-W	Department of Planning, Industry and Environment – Water (NSW)
DPIF	Department of Primary Industries Fisheries (NSW)
ECA	Environmental Contingency Allowance
EEC	Endangered ecological community
EWAG	Environmental Water Advisory Group
EWR	Environmental water requirement
FFDI	Forest Fire Danger Index
GDE	Groundwater dependent ecosystem
GL	Gigalitres
ha	hectares
HEW	Held environmental water
JAMBA	Japan – Australia Migratory Bird Agreement
LF	Large fresh
LLS	Local Land Services (NSW)
LTWP	Long Term Water Plan
LWH	Large woody habitat
m/s	metres per second
MDBA	Murray-Darling Basin Authority
MER	Monitoring, evaluation and reporting
ML	Megalitre
MLO	Multi-level outtake
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
ROKAMBA	Republic of Korea – Australia Migratory Bird Agreement
RRG	River red gum
SDL	Sustainable diversion limit
SF	Small fresh
VF	Very low flow
WERA	Western Enabling Regional Adaptation
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–W, 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, large woody habitat (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 water 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.
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. In older dams, particularly those with a depth greater than 15 metres, water is typically released from the bottom of the dam where water temperatures can be significantly lower than surface readings. For native fish, that respond to temperature cues to breed, the effects of cold-water pollution can be particularly harmful. Cold water pollution can reduce the availability of food, increase fish mortality and reduce the frequency and success of breeding events. 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).
Duration (with respect to environmental water requirements)	Minimum duration for which flows must be above the specified flow rate for the flow event to achieve the specified ecological objective(s). Longer durations will often be desirable and deliver better ecological outcomes. Ideal and/or maximum durations are included where relevant and, where noted, the duration may also specify the duration for which standing water should be retained within wetland systems.
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 asset	The physical features that make up an ecosystem and meet one or more of the assessment indicators for any of the five criteria specified in Schedule 8 of the Basin Plan

Ecological function	The resources and services that sustain human, plant and animal communities and are provided by the processes and interactions occurring within and between ecosystems. Identified ecosystem functions must also meet one or more of the assessment indicators for any of the four criteria specified in Schedule 9 of the Basin Plan.
Ecological 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 are able to demonstrate progress towards the objectives and the outcomes described in the Basin-wide environmental watering strategy.
Ecological value	An object, plant or animal which has value based on its ecological significance.
Ecosystem	A biological community of interacting organisms and their physical environment. It includes all the living things in that community, interacting with their non-living environment (weather, earth, sun, soil, climate and atmosphere) and with each other.
Environmental water	Water for the environment. It serves a multitude of benefits to not only the environment, but to communities, industry and society. It includes water held in reservoirs (held environmental water) or protected from extraction from waterways (planned environmental water) for meeting the water requirements of water-dependent ecosystems.
Environmental water requirement (EWR)	An environmental water requirement (EWR, singular) describes the characteristics of a flow event (e.g. magnitude, duration, timing, frequency, and maximum dry period) within a particular flow category (e.g. small fresh), that are required for that event to achieve a specified ecological objective or set of objectives (e.g. to support fish spawning and in-channel vegetation). There may be multiple EWRs defined within a flow category, and numerous EWRs across multiple flow categories within a Planning Unit. Achievement of each of the EWRs will be required to achieve the full set of ecological objectives for a planning unit. 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.
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.
EWR Code	The specific code that abbreviates the EWR name (e.g. SF1 for small fresh 1). This code is used to link ecological objectives and EWRs
Flow component/ Flow category	The type of flow in a river defined by its magnitude (e.g. bankfull). The type of flow event in a river defined by its magnitude of flow discharge or height within a watercourse (e.g. baseflow, freshes, bankfull and overbank).

Frequency (Long term average frequency)	The frequency at which the flow event should occur to achieve the ecological objectives, expressed as the number of years that the event should occur within a 10-year period. Where a range is indicated, 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. As such, the minimum long-term average (LTA) target frequency is indicated in parentheses.
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.
Large Woody Habitat	Refers to trees, branches and limbs that fall into waterways and provide a vast array of ecological services to waterways. LWH provides physical habitat diversity for a range of aquatic species.

Lateral connectivity	The flow linking rivers channels and the floodplain.
Longitudinal connectivity	The consistent downstream flow along the length of a river.
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-BC is responsible for the development of nine plans for river catchments across NSW, with objectives for five, 10 and 20-year timeframes.
Maximum 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.
Overbank flow (OB)	Flows that spill over the riverbank or extend to floodplain surface flows.
Planned environmental water (PEW)	Water that is committed by the Basin Plan, a water resource plan or a plan made under state water management law to achieving environmental outcomes.
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 ecological asset	A place of particular ecological significance that is water dependent and can be managed with environmental water. This includes planned and held environmental water (HEW).
Priority ecological function	Ecological functions that can be managed with environmental water.
Perennial stream	A stream or river with continuous flow, during years of normal rainfall.
Ramsar Convention	An international treaty to maintain the ecological character of key wetlands.
Recruitment	Successful development and growth of offspring; such that they have the ability to contribute to the next generation.
Refugium / Refuge habitat	An area in which a population of plants or animals can survive through a period of decreased water availability.
Refuge pools	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 and nursery sites for aquatic life, they are important sinks for nutrients and DOC cycling within the riverine environment.

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.
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 total 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.
Timing (with respect to environmental water requirements)	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 environmental water requirements. 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.
Unregulated river	A waterway where flow is mostly uncontrolled by dams, weirs or other structures.
Valley	The term 'valley' has been used as a substitute for 'catchment' in some cases. Interchangeable terms are the Namoi Catchment and the Namoi WRPA.
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. Where the term 'Namoi Catchment' has been used in this document it refers to the Namoi WRPA.
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 system	An ecosystem or species that depends on periodic or sustained inundation, waterlogging or significant inputs of water for natural functioning and survival.
Western Enabling Regional Adaptation project	The Western Enabling Regional Adaptation project builds on local knowledge to understand climate vulnerabilities in Western NSW and identify opportunities to respond, enabling regional decision-makers to enhance government service delivery and planning at a regional and subregional scale.

Figure 2 Environmental water release at Bugilbone
Photo: N Sloane

Summary

Rivers, creeks, wetlands and floodplains play a vital role in sustaining healthy communities and economies. They are productive systems that connect the landscape for people, plants and animals, with benefits that extend well beyond the river bank.

Over the past 200 years, dams, weirs, floodplain development, water regulation and extraction have disrupted the natural flow regimes of many rivers, wetlands and floodplains in New South Wales (NSW).

The Namoi Long Term Water Plan (LTWP) is an important step to describing the flow regimes that are required to achieve environmental outcomes in the Namoi Water Resource Plan Area (WRPA: “the Namoi catchment"). The LTWP identifies water management strategies for protecting, maintaining and improving the long-term health of the Namoi’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 managed in the future. Rather, it will help water managers and advisory groups make decisions about where, when and how water can be used to achieve agreed long-term ecological objectives.

The LTWP looks at all sources of water and how these can be managed to support environmental outcomes in the catchment.

Background to Long Term Water Plans

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

The Basin-wide environmental watering strategy (BWS) (MDBA 2014) and LTWPs are central features of this framework. The BWS establishes long-term environmental outcomes and targets for the Basin and its catchments (Table 1). LTWPs, which apply to WRPAs, must contribute to the achievement of the BWS by identifying:

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

Water resource plans (WRPs) that describe how water will be managed and shared between users in an area must have regard to LTWPs.

The Namoi Long Term Water Plan

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

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

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

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

Environmental values of the Namoi catchment

The Namoi catchment supports a range of water-dependent ecosystems, including instream aquatic habitats, floodplain watercourses, wetlands, riparian forests and woodlands. These ecosystems benefit many water-dependent species, including migratory waterbirds, threatened native fish species, endangered populations and ecological communities by providing habitat and food resources.

The ecological condition of the Namoi'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, trigger movement and breeding of native fish and waterbirds, and directly impact vegetation condition and habitat availability.

Local, traditional and scientific knowledge about the Namoi's riverine environmental assets and ecosystem functions underpins this plan. This has been collected in partnership with water managers, natural resource managers, environmental water holders and community members. Information about the Namoi's environmental values closely aligns with material in the NSW Department of Planning, Industry and Environment, Water (DPIE–Water) Namoi Water Resource Plan Risk Assessment (DPIE–Water 2019a).

Water for the environment

This Namoi LTWP contains ecological objectives and targets for priority environmental assets and ecosystem functions in the Namoi catchment. The LTWP considers options to achieve environmental outcomes through optimising 'all water'. The objectives and targets have been identified for native fish, native vegetation, waterbirds, river connectivity and ecosystem functions. As noted in the BWS, each of these themes is a good indicator of river system health and is responsive to flow.

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

Coordinated water management

The volume of held environmental water (HEW) in the Namoi catchment is insufficient to meet the range of environmental water requirements needed for a healthy ecosystem. In-channel and overbank environmental water requirements currently met by a combination of consumptive flows, natural events, HEW and planned environmental water (PEW) are expected to continue. There is potential to achieve important environmental water requirements by working with complementary measures and further coordinating PEW and HEW with other flows to maximise environmental outcomes.

Table 1 A summary of environmental outcomes sought in the Namoi LTWP as defined in the BWS

Broad outcomes	Overarching objectives	Example uses of water for the environment to achieve LTWP outcomes and objectives
Maintain the current diversity, extend distributions, improve movement opportunities and improve breeding success and numbers of native fish	Increase native fish distribution and abundance, and ensure stable population structures	• Replenish refuge waterholes for native fish • Provide improved conditions for native fish recruitment in the Namoi River
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	• Improve the extent and condition of vegetation in core areas of the Namoi • Improve the condition of river red gum closely fringing river channels throughout the whole Namoi catchment
Maintain the current species diversity and improve opportunities for breeding success of waterbirds	Restore habitat for waterbirds to contribute to recovery of waterbird populations across the Murray-Darling Basin	• Provide foraging habitat for waterbirds • Improve the condition of waterbird habitats
Improve connections along rivers and between rivers and their floodplains for improved river system health Support the movement of nutrients throughout the river system	Various objectives relating to protecting instream and floodplain refuge habitat, supporting productivity and the lifecycles of water dependent biota, and connecting riverine and floodplain systems.	• Restart flows after cease-to-flow conditions to reduce the risk of hypoxic blackwater and fish kills • Contribute to improved flows into the Barwon River

Management strategies and complementary investments

Complementary measures and investments that may contribute to meeting the LTWPs objectives and targets have been identified in the plan (see Chapter 7). These include establishing an environmental water advisory group to increase community engagement, addressing cold water pollution caused by water releases from Chaffey, Keepit and Split Rock Dams; providing information and support to landholders to conserve riparian, wetland and floodplain vegetation; and screening irrigation pumps to protect fish.

Monitoring and evaluation of the Namoi 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 Namoi catchment to:

- 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 Namoi Long Term Water Plan

To ensure the information in this LTWP remains relevant and up-to-date, DPIE will review and update it no later than five years after it is implemented to capture improved knowledge and evidence of ecological processes in the Namoi catchment.

Additional reviews may also be triggered by:

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

Figure 3 The Namoi River near Wee Waa
Photo: N Foster

1. Introduction

The Namoi catchment is a major Murray–Darling Basin catchment located in northern NSW. It is neighboured by the Gwydir catchment to the north, the Macquarie/Castlereagh to the south and the Barwon Darling to the west.

The Namoi catchment includes the major towns of Tamworth, Gunnedah, Boggabri, Narrabri, Wee Waa and Walgett. The eastern boundary of Namoi catchment starts in the steep gorge country of the Great Dividing Range (GDR) with the Macdonald River and runs approximately 860 kilometres westward to Walgett, where the Namoi River enters the Barwon River (Green and Dunkerley 1992). The catchment has four main water management areas; the Upper Namoi, the Peel, the Namoi Regulated and the Lower Namoi (DPIF 2018 in prep, Figure 4).

The major tributaries in the Upper Namoi management area include the Manilla and Macdonald rivers. The Manilla River flows through the town of Barraba and is regulated by Split Rock Dam, which was built in the 1980s. The Macdonald River starts at around 1330 metres elevation, upstream of Warrabah National Park and flows off the Great Dividing Range, becoming the Namoi River. At Manilla the Namoi and Manilla rivers join at around 300 metres elevation. The Namoi River is regulated by Keepit Dam, completed in 1960 and the primary instream storage facility in the catchment.

The Peel water management area is a major sub-catchment of the Namoi, covering 4700 square kilometres. The Peel River begins upstream from Nundle around 1100 metres elevation and is regulated by Chaffey Dam, which was completed in 1979. Below the dam, the Peel River runs through Dungowan and Piallamore and is joined by the Cockburn River upstream of Tamworth. The Peel River then runs through Tamworth and Somerton, connecting with the Namoi River near Carroll, downstream of Keepit Dam.

The Namoi Regulated water management area includes the extent of the regulated Namoi River, starting downstream of Split Rock Dam, flowing through Gunnedah, Boggabri, Narrabri, Wee Waa and Burren Junction to Walgett. Downstream of Wee Waa a series of effluent creeks split from the Namoi River, including Pian Creek, Gunidgera Creek, Duncan’s Warrambool and Cubbaroo Warrambool. This effluent area is characterised by a network of floodplains, instream benches and anabranches that support important floodplain vegetation communities and irrigated agriculture (CEWO 2012). This area can become inundated for weeks at a time through natural rainfall events that benefit floodplain vegetation of the area including coolibah, black box endangered ecological community (EEC), river red gum, lignum and river cooba (CEWO 2012).

The remaining significant portion of the catchment forms the unregulated Lower Namoi water management area. This area starts downstream of Keepit Dam, excluding the regulated portion of the Namoi River (Figure 4). Key tributaries in this area include Quirindi Creek, Mooki River, Cox’s Creek and Maules Creek. Other tributaries include Bohena, Coghill, Baradine, Etoo and Tullaba creeks, which deliver substantial volumes of water from the Pilliga into the Namoi River. Lake Goran, south of Gunnedah is also within this management area and is listed in the Directory of Important Wetlands in Australia.

The traditional owners, the Kamilaroi/Gamilaraay/Gomeroi people, have longstanding and continuing ties to country and hold the many billabongs along the rivers in this catchment in high regard. Many important sites and artefacts exist across the Namoi catchment, including traditional burial sites, scar trees, Aboriginal ceremony and Dreaming sites.

Remnant water dependent native vegetation in the catchment is diverse and varies from east to west. It includes river red gum woodland and forests, river oak woodlands, coolibah woodlands, tea-tree sedgelands, river coolibah swamp wetlands and lignum shrubland wetlands. EECs found in the catchment include coolibah-black box woodland, brigalow communities, marsh club-rush sedgeland, myall woodland, Pilliga outwash ephemeral wetlands and swamp oak floodplain forest.

The region supports a number of iconic native fish, including the silver perch and Murray cod, with parts of the Namoi catchment forming part of the Lowland Darling River Aquatic Ecological Community. Several threatened birds including the Australasian bittern and Brolga also occur.

River flow in the Namoi catchment, like many Murray–Darling Basin catchments, has been altered by the presence of headwater dams, weirs and large-scale development. As a result, all but very low flows have been reduced under the current flow regime, with a greater relative impact downstream (CEWO 2012). The condition of the catchment's riverine and floodplain ecosystems, and the plants and animals they support, have declined considerably because of these developments (CEWO 2012, MDBA 2012).

Water resources are managed under three NSW Water Sharing Plans (WSPs) in the Namoi catchment:

1. *Water Sharing Plan for the Upper Namoi and Lower Namoi Regulated River Water Sources 2016*
2. *Water Sharing Plan for the Peel Valley Regulated, Unregulated, Alluvium and Fractured Rock Water Sources 2010*
3. *Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources 2012*

The NSW Government has developed the Namoi LTWP with the aim of protecting and improving the health of the riverine and floodplain ecosystems in the Namoi catchment. It also recognises the Namoi Rivers' connection and contribution to the environmental health of the Murray–Darling Basin as a significant contributor to flow in the Barwon–Darling River.

1.1 Aboriginal cultural significance

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 Namoi catchment are central to its Traditional Owners, the Kamilaroi/Gamilaraay/Gomeroi people, who have longstanding and continuing ties to Country, the waterways and life sustained by it.

Consultation with Aboriginal Nations of the Namoi catchment 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 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.

1.2 Approach to developing the Namoi Long Term Water Plan

The Namoi LTWP applies to the Namoi 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 Basin Plan.

The Namoi LTWP is the product of best available information and engagement with water managers, natural resource managers, environmental water holders and the community. 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 Namoi LTWP has involved six main steps:

1. undertaking a comprehensive stocktake of water dependent environmental assets and ecosystem functions across the Namoi catchment to identify native fish, water dependent bird, flood-dependent frog species, vegetation species, and river processes that underpin a healthy river system
2. determining specific and quantifiable objectives and targets for the key species and functions in the Namoi catchment
3. determining the water requirements (including volume, frequency, timing and duration) needed to sustain and improve the health and/or extent of priority environmental assets and ecosystem functions
4. identifying the risks and constraints to meeting the long-term water requirements of priority environmental assets and ecosystem functions
5. identifying potential management strategies for guiding water management decisions and investment into the future.
6. complementary measures such as cooperative water management and investment opportunities.

1.3 Implementing the Namoi Long Term Water Plan

Implementation of the LTWP requires strong partnerships, cooperation and coordination between all land and water managers, water users and the community. The LTWP supports future coordination efforts by:

- guiding annual water management deliberations and planning by DPIE-BC and other water managers like the Commonwealth Environmental Water Officer (CEWO)
- informing planning processes that influence river and wetland health outcomes, including development of water sharing plans (WSPs) and water resource plans (WRPs)
- identifying opportunities for more strategic river operations and strengthening collaboration between environmental water holders and other stakeholders
- helping target investment priorities for complementary actions that will contribute to the outcomes sought by this plan
- building broad community understanding of river and wetland health issues.

1.4 The Long Term Water Plan document structure

The Namoi LTWP is presented in nine chapters with accompanying appendices. It is divided into Part A and Part B.

Part A: Namoi catchment scale information

- **Chapter 1** explains the background and purpose of the LTWP.
- **Chapters 2** and **3** identify the Namoi's water dependent environmental assets and ecosystem functions. They also outline the environmental outcomes expected from implementation of the LTWP with ecological objectives and targets.
- **Chapter 4** provides the environmental water requirements (EWRs) that are needed to achieve the ecological objectives over the next five, 10 and 20 years.
- **Chapter 5** describes the long-term risks and operational constraints to achieving the environmental water requirements and ecological objectives in the Namoi LTWP. It also recommends management strategies for addressing these.
- **Chapter 6** identifies the possible ways to use held and planned environmental water (PEW), and other water, to meet the environmental water requirements of the Namoi's environmental assets under different water resource availability scenarios.
- **Chapter 7** describes potential cooperative arrangements between government agencies, state owned corporations, private landholders, local government, community groups, First Nations people and investment opportunities to achieve the environmental outcomes described in this LTWP.

Part B: Namoi catchment management areas and planning unit scale information

- Presents the detail of the LTWP at a finer scale of management areas and planning units. This includes a summary of the priority environmental assets and values each planning unit supports, specific EWRs with flow rates attributed to specific gauges, and an evaluation of the impact of water resource development on local hydrology.

1.5 Planning units

The planning units shown in Figure 4 are referred to in most chapters. They have been grouped in to four management areas which differ in terms of geomorphology, hydrology, management and policy (for example WSPs). The planning unit boundaries typically align with water source boundaries in the *Namoi Water Resource Plan* (NSW Government 2018). However, some of these water sources have been amalgamated or split depending how water management for the environment can be implemented.

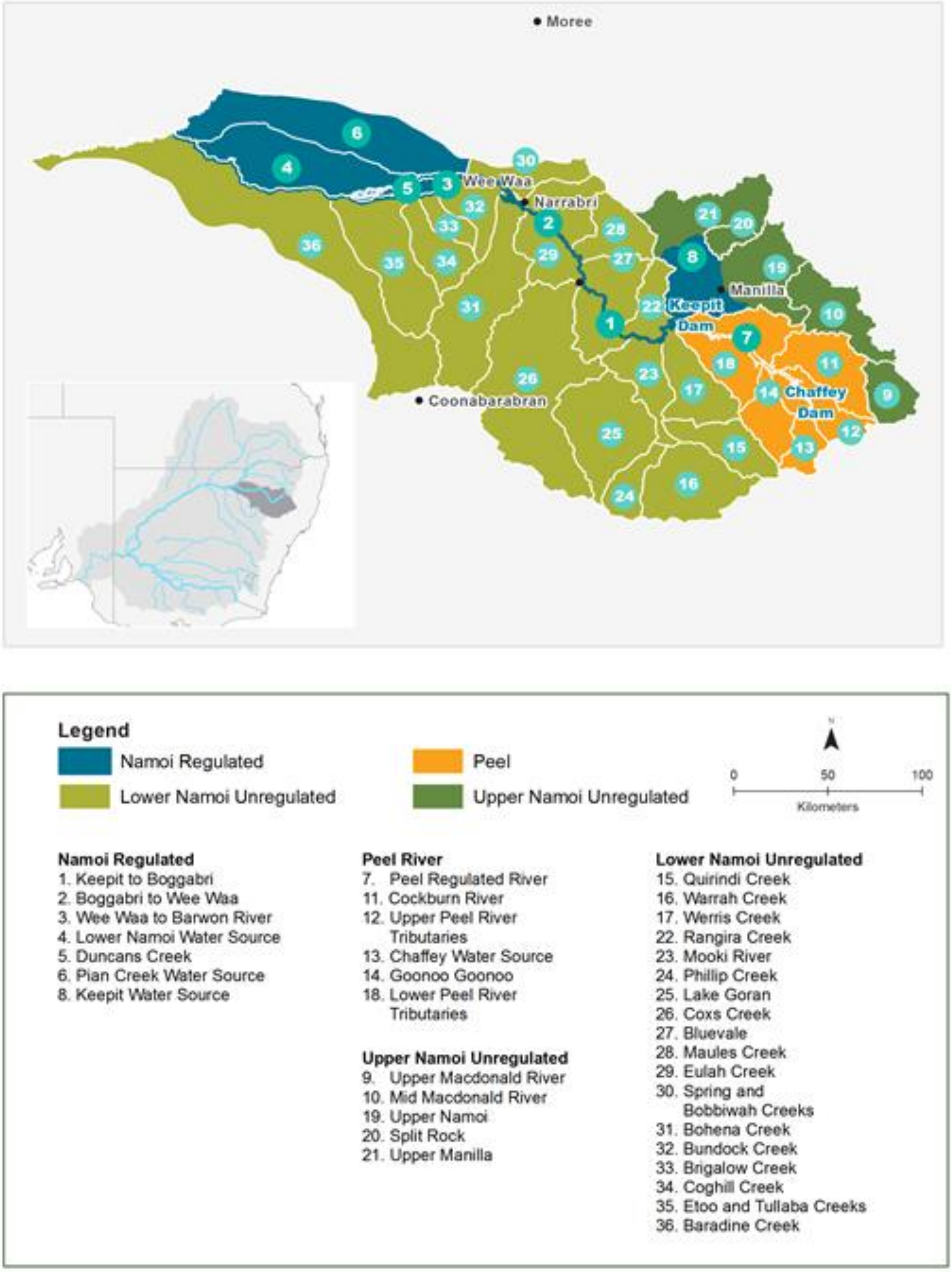

Figure 4 The Namoi catchment showing the division of planning units and management areas in the Long Term Water Plan

2. Environmental assets

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

2.1 Environmental assets in the Namoi catchment

Schedule 8 of the Basin Plan outlines the 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, or can support threatened species, threatened ecological communities or significant biodiversity.

The Namoi catchment's water dependent ecosystems, which are comprised of waterbodies and surrounding water dependent vegetation, have been assessed against Schedule 8.

Significant Aboriginal cultural water dependent sites 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 waterholes throughout the 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 Namoi catchment.

Priority environmental assets in the LTWP are the assets that have been identified using Schedule 8 criteria that can be managed through NSW's planned and/or held environmental water or affected by WSP rules in both the regulated or unregulated streams and floodplains. 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.

Environmental assets in the Namoi catchment have been mapped for this LTWP and results are presented in Figures 5–10[1]. Some key assets are also listed in the relevant planning units in Part B: Namoi planning units.

[1] Analysis used the best available information at the time; however, there may be additional assets not shown in these figures due to data paucity in some areas.

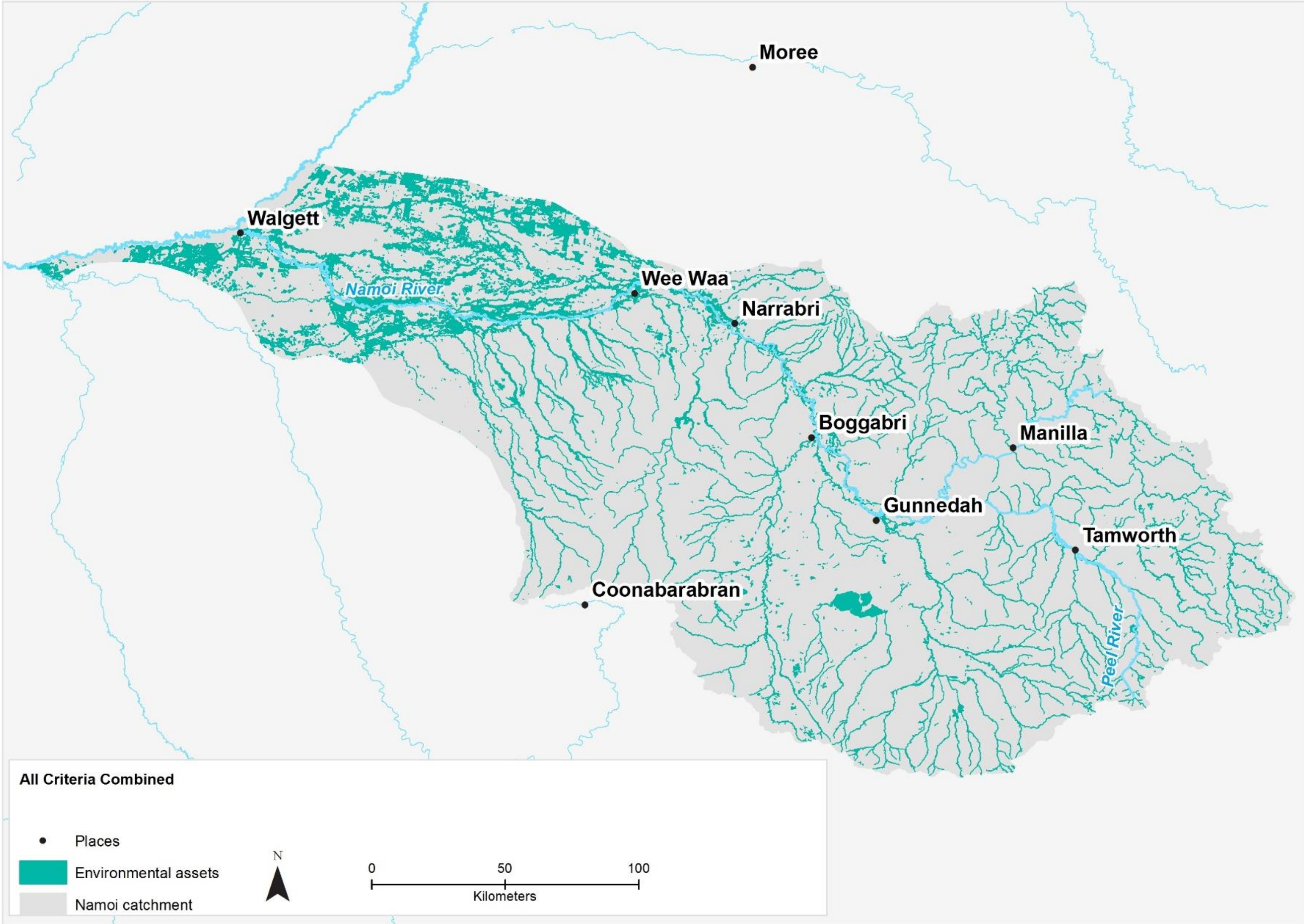

Figure 5 Identification of environmental assets in the Namoi catchment using the Basin Plan's Schedule 8 criteria

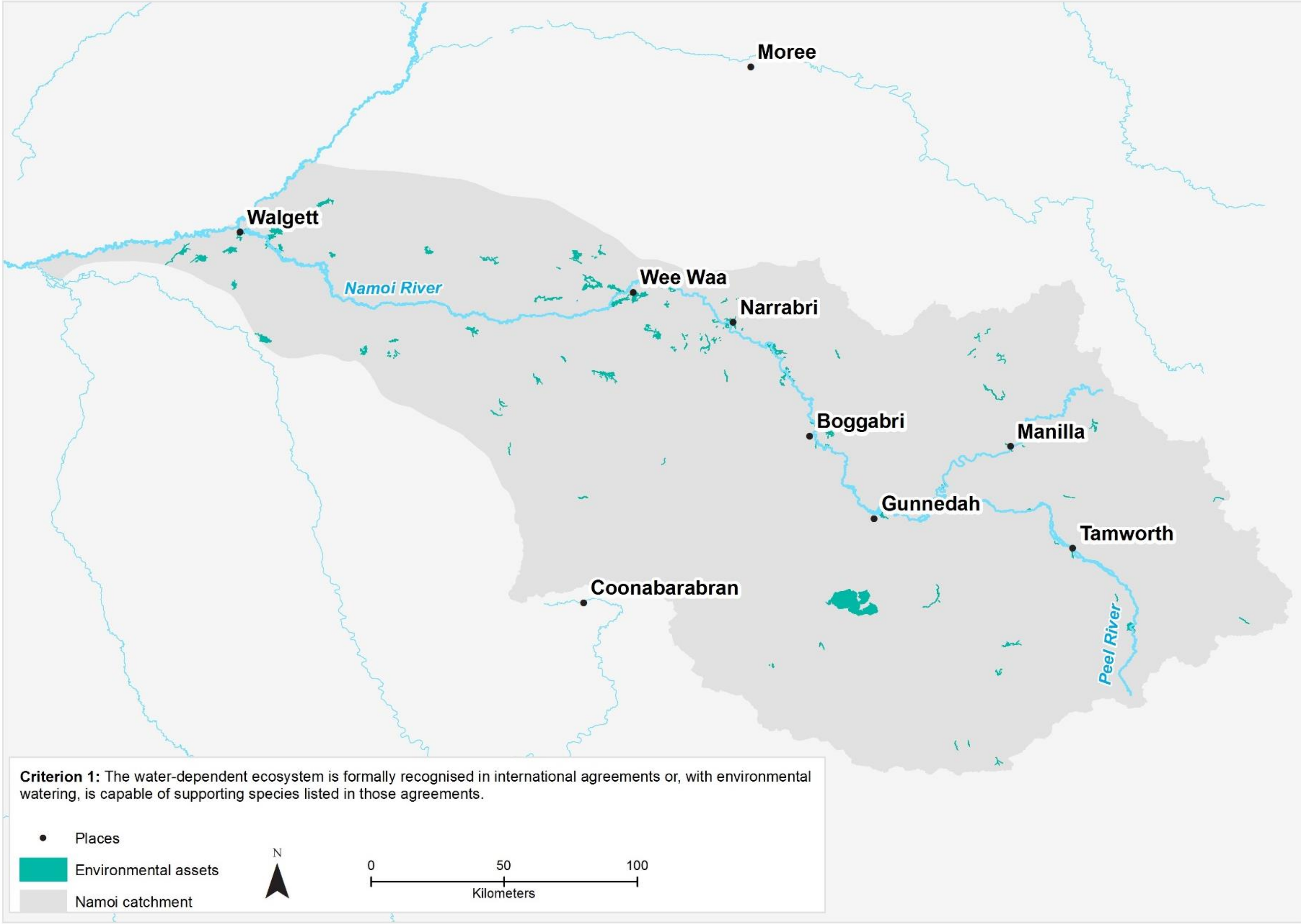

Figure 6 Identification of environmental assets in the Namoi catchment using Criteria 1 in Schedule 8 of the Basin Plan

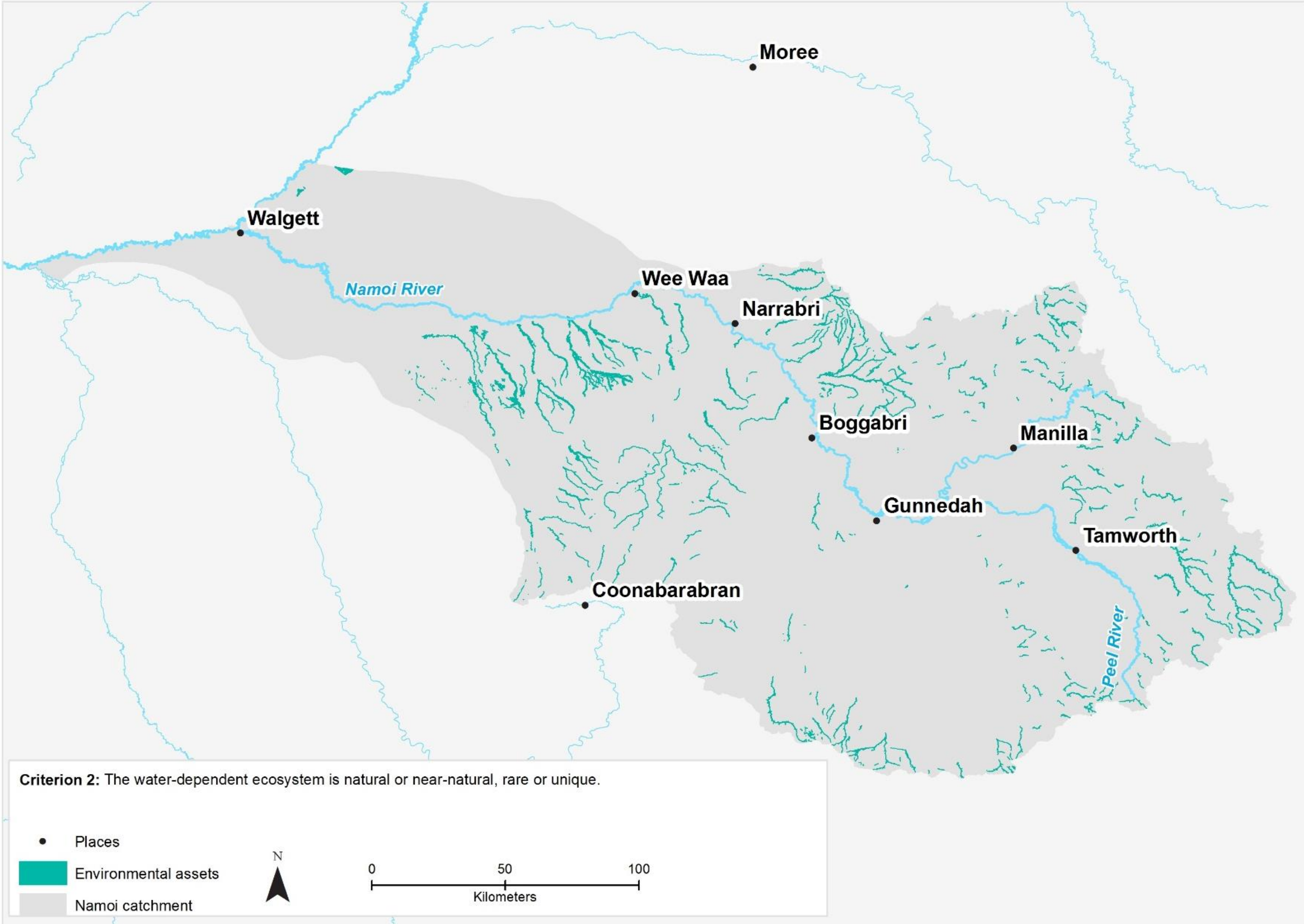

Figure 7 Identification of environmental assets in the Namoi catchment using Criteria 2 in Schedule 8 of the Basin Plan

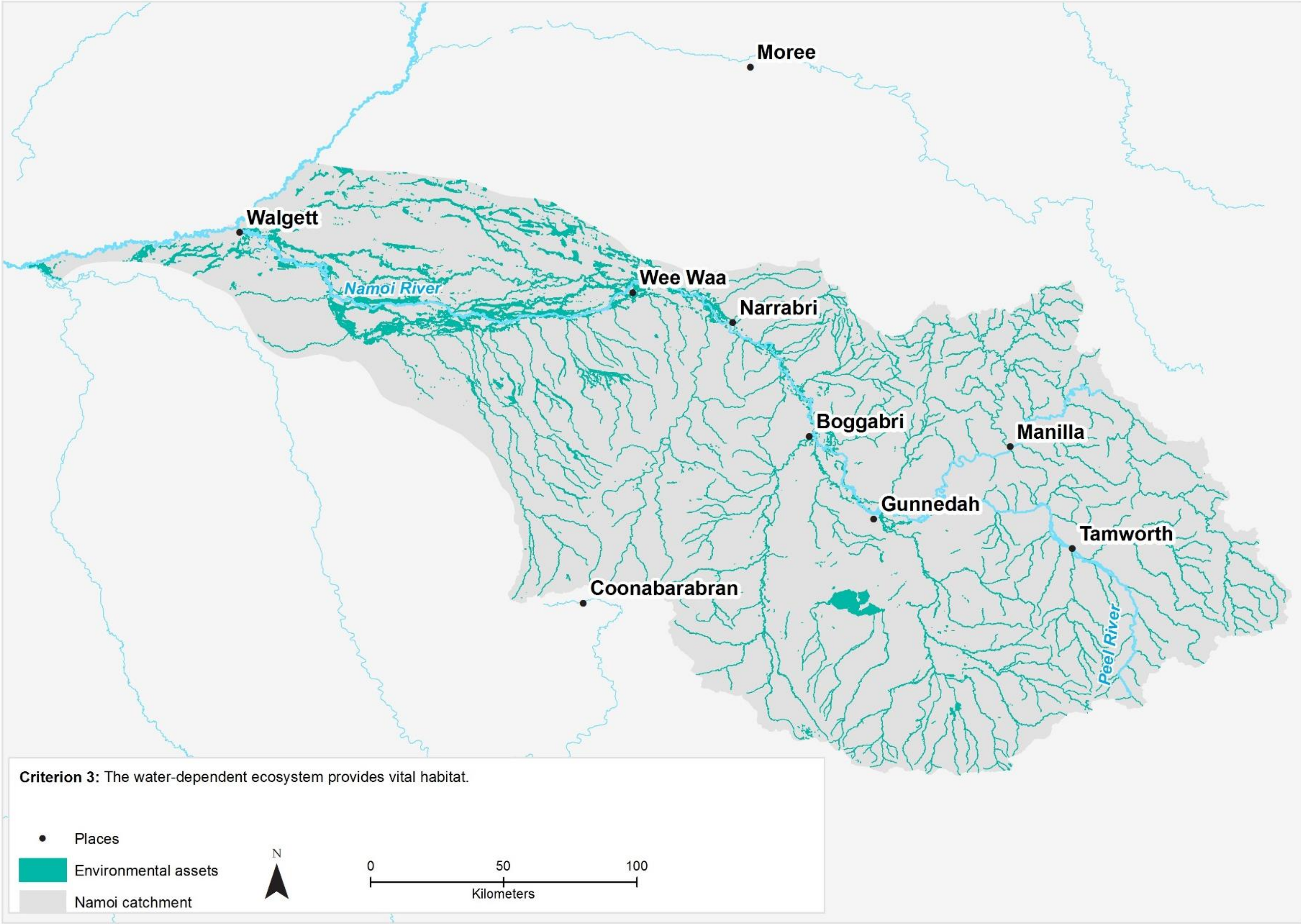

Figure 8 Identification of environmental assets in the Namoi catchment using Criteria 3 in Schedule 8 of the Basin Plan

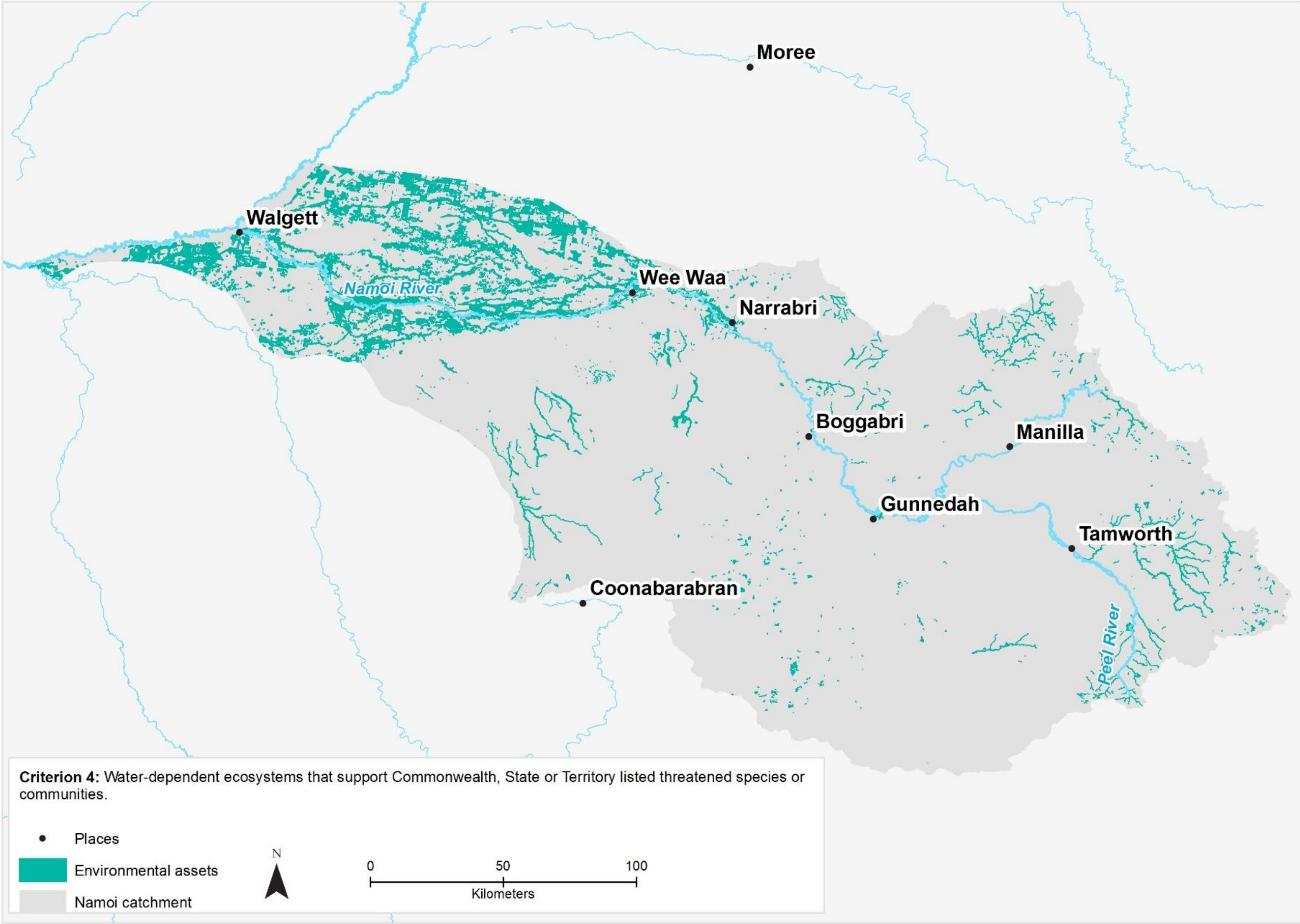

Figure 9 Identification of environmental assets in the Namoi catchment using Criteria 4 in Schedule 8 of the Basin Plan

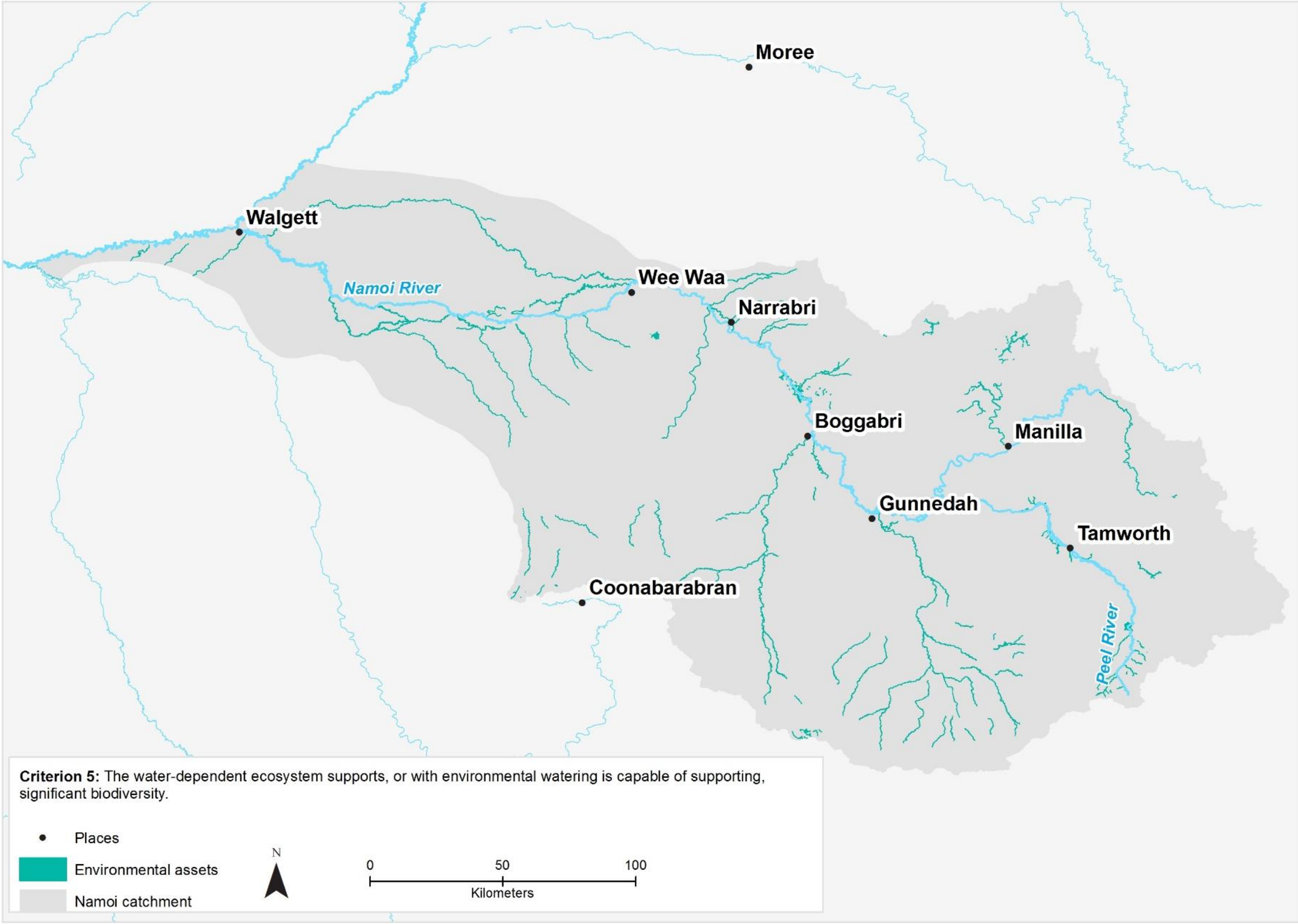

Figure 10 **Identification of environmental assets in the Namoi catchment using Criteria 5 in Schedule 8 of the Basin Plan**

3. Ecological objectives and targets

Ecological objectives and targets have been established for environmental assets in the Namoi catchment (chapters 3.1–3.4). They are grouped into four themes: native vegetation, waterbirds, native fish and ecosystem functions, which are consistent with the Basin-wide environmental watering strategy (BWS) (MDBA 2014). Each theme is a good indicator of river system health and is responsive to flow.

The Namoi's ecological objectives reflect the environmental outcomes that are expected from implementation of the LTWP. Their achievement will also contribute to the landscape and Basin-scale environmental outcomes sought by the BWS and benefit other water dependent species that have not been specifically addressed, including frog species and platypus.

The five, ten and 20-year targets for each ecological objective provide a transparent means of evaluating progress towards their achievement and the long-term success of the strategies outlined in the LTWP. If the targets are achieved, this will indicate that the environment is responding positively to water management strategies. Failure to meet targets should trigger re-assessment of the flow regime and whether this LTWP is being implemented as intended. It is important to note that the 20-year targets in this Plan assume the relaxation or removal of constraints to allow more flexibility in water delivery and less hindrance to ecological functions.

The ecological objectives that are relevant at the planning unit scale are listed in Appendix A. The ecological objectives recognise the values that the priority environmental asset supports (e.g. native fish species, native vegetation communities, and waterbirds) or the ecosystem function it performs (e.g. provides vital instream habitat).

Figure 11 Golden perch
Photo: Gunther Schmida

3.1 Native fish values and objectives

The Namoi catchment supports 16 native freshwater fish species, several of which are protected by NSW and/or Commonwealth legislation (e.g. silver perch and Murray cod). Each species moves along the Namoi River and its tributaries as part of their lifecycle (Harris et al 1994), with historical records and modelling indicating their widespread presence throughout the area (NSW DPI 2007).

The extent and condition of fish populations in the Murray–Darling Basin, including the Namoi, have declined incrementally since European settlement and significantly since 2007, largely owing to modern development, the introduction of pest species and ongoing drought (Davies et al. 2012; Mallen-Cooper and Zampatti 2015). Multiple factors have played a part in the decline, including changed water regimes, barriers to fish passage such as weirs, degradation of instream habitat and alien fish species (DPIF 2019 in prep).

River flows of specific volume, timing and duration are required to protect and improve the population structure of existing native fish species and increase their spatial distribution throughout the catchment. The fish community in the Namoi catchment was rated poor in the first Sustainable Rivers Audit in 2008, and in very poor condition in the second audit in 2012, demonstrating a decline in the health of the Namoi fish communities (MDBC 2008, MDBA 2012).

The Namoi catchment is identified in the BWS as a target Murray–Darling Basin catchment for expanding the core range of threatened native fish species, including silver perch, freshwater catfish and river blackfish. This LTWP has identified areas in the Namoi catchment that provide the greatest opportunity to achieve this outcome and the EWRs to support fish movement into new habitat, spawning events and recruitment.

Table 2 describes the ecological objectives and targets for native fish in the Namoi catchment. Objectives and targets for native fish in the Namoi catchment focus on increasing distribution and abundance of relevant species. Targeted management should achieve a stable population structure with representation of young-of-year, juvenile and adult-life-history stages. These objectives can be achieved by providing a variety of flows across the entire spectrum (from very low flows through to bankfull and overbank flow events) that meet their water requirements.

Table 2 Native fish (NF) ecological objectives and targets

<table>
<tr><th colspan="2" rowspan="2">Ecological objectives</th><th rowspan="2">Target fish species</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td rowspan="2">NF1</td><td rowspan="2">No loss of native fish species</td><td rowspan="2">All recorded fish species</td><td colspan="3">All known species detected annually</td></tr>
<tr><td>-</td><td colspan="2">Fish community status improved by one category compared to 2014 assessment[2]</td></tr>
<tr><td>NF2</td><td>Increase the distribution and abundance of short to moderate-lived generalist native fish species</td><td>Australian smelt, carp gudgeon, bony herring, Murray–Darling rainbowfish, unspecked hardyhead, mountain galaxias, dwarf flat-headed gudgeon, obscure galaxias</td><td colspan="3" rowspan="2">Increased distribution and abundance of short to moderate-lived species compared to 2014 assessment[2]

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)</td></tr>
<tr><td>NF3</td><td>Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species</td><td>Olive perchlet[3], southern purple-spotted gudgeon[3], flat-headed galaxias</td></tr>
<tr><td>NF4</td><td>Improve native fish population structure for moderate to long-lived flow pulse specialist native fish species</td><td>Golden perch, silver perch, spangled perch</td><td colspan="3">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</td></tr>
</table>

[2] Assessment of fish abundance and distribution pre-2014, aligned with BWS and NSW DPI, 2016

[3] Species are expected to occur based on MaxEnt modelling (NSW DPI 2016)

Ecological objectives		Target fish species	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	Murray cod, river blackfish, freshwater catfish, southern purple-spotted gudgeon[3], olive perchlet[3], Darling River hardyhead	Minimum of 1 significant recruitment event in 5 years[4]	Minimum of 2 significant recruitment events in 10 years[4]	Minimum of 4 significant recruitment events in 20 years[4]
NF6	A 25% increase in abundance of mature (harvestable sized) golden perch and Murray cod	Golden perch, Murray cod	Length-frequency distributions include size classes of legal take size for golden perch and Murray cod 25% increase in abundance of mature golden perch and Murray cod		
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, river blackfish, olive perchlet[3], southern purple-spotted gudgeon[3]	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)		
NF9	Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish species into new areas (within historical range)	Silver perch	-	Increased distribution and abundance in specified planning units	

[4] This should not be interpreted as a maximum, or optimal target. It will be important to maintain the current frequency of recruitment events if it exceeds this minimum target – analysis required.

3.2 Native vegetation values and objectives

Native vegetation is considered an integral component to the health of a riparian ecosystem. A healthy riparian zone provides habitat and feeding opportunities for terrestrial and instream species, corridors for movement and migration of fauna species, stream shading and riverbank stability (MDBA 2012). Remnant stands of riparian vegetation also provide natural seedbanks to assist efforts for regenerating degraded downstream riparian habitat (Thoms et al 2009; O'Donnell et al 2016). The Sustainable Rivers Audit 2 reported the riverine vegetation was rated in poor condition throughout the catchment.

River oaks and river red gums dominate upland reaches of rivers and streams in the Namoi catchment. They are important for shading river banks and the water surface, providing carbon to the river, and as habitat for terrestrial and aquatic biota. They also colonise benches and bars and stabilise banks.

The mid-section of the Namoi River between Gunnedah and Narrabri is characterised by a number of long, narrow lagoons that represent prior channels of the Namoi River, including Barbers lagoon (22km major anabranch) and Gulligal lagoon (4.2km in length) (CEWO 2012). Riverine vegetation in this reach of the Namoi River catchment includes river red gum and coolibah communities (Green and Dunkerley for the MDBC 1992).

The riverine plains in the lower reaches of the Namoi River downstream of Narrabri are characterised by an extensive floodplain environment comprising a complex pattern of tributaries, anabranches, lagoons and effluent channels and are subject to extensive flooding (Thoms and Sheldon 2000). Up to half of this area subject to inundation by 1 in 2-year floods (MDBA 2015). Vegetation in this area is dominated by coolibah, river red gum and river cooba vegetation communities.

Non-woody instream and wetland vegetation is an important component to this riparian ecosystem providing important aquatic habitat for native fish, water birds, frogs and invertebrates. Aquatic plants found in the Namoi include spiny-headed mat rush, spike rushes, tall sedge, nardoo, milfoil, water primrose, wavy marshwort and ribbon weed (Namoi CMA 2008).

Table 3 describes the ecological objectives and targets for native vegetation in the Namoi catchment. Rather than focusing on outcomes for single species, objectives have been set for the plant community types (PCTs) to which the relevant species belong, which aligns to the main vegetation types described in the BWS. The vegetation objectives for the maintenance of these communities include targets for regular seed setting to promote ongoing population viability.

Table 3 Native vegetation (NV) ecological objectives and targets

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

<table>
<thead>
<tr><th colspan="3" rowspan="2">Ecological objectives</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
</thead>
<tbody>
<tr><td>NV4a</td><td rowspan="5">Maintain or increase the extent and maintain or improve the condition of native forest, woodland and shrubland communities on floodplains</td><td>River red gum forest</td><td colspan="3">Maintain the 2016 extent of river red gum forest</td></tr>
<tr><td>NV4b</td><td>River red gum woodland</td><td colspan="2" rowspan="3">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 river red gum woodlands on the managed floodplain</td><td rowspan="3">Over a 5-year rolling period:
• increase the proportion of woodlands and shrublands in moderate or good condition
• improve the condition score of woodlands and shrublands in poor, degraded or severely degraded condition by at least one condition score
• Support successful recruitment of trees in the long-term by increasing in the abundance of young adult trees (10–30 cm DBH) compared to the previous 10-year period</td></tr>
<tr><td>NV4c</td><td>Black box woodland</td></tr>
<tr><td>NV4d</td><td>Coolibah woodland</td></tr>
<tr><td>NV4e</td><td>Lignum shrublands</td><td colspan="2">Maintain the 2016 extent of lignum shrubland communities</td><td>Increase the total area of lignum shrublands by 10% occurring within actively managed flow paths</td></tr>
</tbody>
</table>

3.3 Waterbird values and objectives

Water resource development has had a substantial impact on the distribution and composition of waterbird assemblages at the whole-of-Basin scale (Reid et al 2013). River regulation has reduced the frequency of larger flow events and reduced the quantity and quality of available habitat for waterbirds and opportunities to breed. Agricultural development has further decreased the available habitat (Spencer et al 2017).

Long-term trends in populations of waterbirds in the Murray–Darling Basin have shown the waterbird populations are declining (Kingsford et al. 2013), placing more importance on the provision of breeding opportunities to slow population declines (Brandis and Bino 2016).

Within the Namoi catchment, the long-running Eastern Australian Waterbird Survey (UNSW, Centre for Ecosystem Science 2018) has recorded 40 waterbird species since annual aerial-based monitoring commenced in 1983. This includes the brolga listed as threatened under NSW legislation and Caspian tern listed under the Japan – Australia Migratory Bird Agreement (JAMBA). This survey has shown that some waterbird functional groups have declined significantly in the Namoi catchment between 1983 and 2016, for example:

- duck numbers have declined by 23%
- herbivore numbers have declined by 61%
- large wader numbers have declined by 71%.

The Namoi's water-dependent vegetation underpins all elements of the lifecycle of waterbirds, being used for nesting materials, as a food resource for some species, and as roosting sites for other species. For example, river red gum is used for roosting and nesting by egrets, herons, cormorants and darters; river cooba is used for nesting by cormorants, darters and herons; and tangled lignum is used for nesting by ibis and spoonbills (Roberts and Marston 2011). Riparian vegetation also provides important habitat for aquatic invertebrates, juvenile fish, and small bodied fish that form part of some waterbird diets.

The total number of waterbird species and total number of individuals can change rapidly in response to flows, specifically increases in total wetland area and the diversity of wetland habitats inundated. When inundated, floodplain habitats can provide feeding and breeding habitat for a range of waterbird species. For example, Lake Goran is a wetland of national importance that provides important bird habitat, especially when full. There are also numerous other wetland communities in the catchment that provide a range of aquatic habitats, and important refugia during drought (Australian Government 2018).

Key objectives of the Namoi LTWP (Table 4) are to maintain the number of waterbird species and support waterbird population recovery, to contribute to increasing waterbird total abundance within the catchment and more broadly across the Basin.

Table 4 Waterbird (WB) ecological objectives and targets

Ecological objectives		Targets		
		5 years (2024)	10 years (2029)	20 years[5] (2039)
WB1	Maintain the number and type of waterbird species	Maintain a 5-year rolling average[6] of 16[7] or more waterbird species in the Namoi catchment		
			Identify at least 29 waterbird species in the Namoi WPRA in a 10-year period[6]	Identify at least 38 waterbird species in the Namoi WPRA in a 20-year period[6]
WB2	Increase total waterbird abundance across all functional groups	Total abundance of the 5 functional groups maintained in the Namoi catchment compared to the 5 years 2012–16 period		
WB5	Maintain the extent and improve condition of waterbird habitats	Maintain or increase extent and improve condition of waterbird foraging and breeding habitat (to be evaluated under targets set for native vegetation.		

3.4 Priority ecosystem function values and objectives

The freshwater environment of the Namoi 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 benches, large woody habitat, aquatic and riparian vegetation are available to the catchment's aquatic species.

Restoring lateral and longitudinal connectivity throughout the catchment is fundamental to supporting many of the priority ecosystem functions in the Namoi (Table 5). 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

Instream pools and floodplain lagoons are critical refugia for the survival of many aquatic species during dry spells and drought, and act as source populations for subsequent recolonisation and population growth (Adams and Warren 2005; Arthington et al. 2010). Refugia should be the highest priority for protection, especially during drought.

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

[6] Rolling average is based on aerial (and ground where available) spring surveys with the baseline being 2012–16 period. Total species records for 10 and 20-year targets are based on all available records including public databases. 2012–16 period represents complete survey coverage (ground and aerial) for many sites and also 5 years post implementation of the Basin Plan. The 1992–2012 period is 20 years pre-Basin Plan and using all sources of data allows for the capture of information on uncommon (cryptic and/or rare) species.

[7] There is limited waterbird survey coverage for the Namoi catchment and this value represents an absolute minimum target.

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. For example, fresh and bankfull flows with sufficient velocity are required to maintain pool depth and riffles by scouring out bed material and initiating material transportation downstream. Other types of instream refugia include large woody habitat (LWH), wet undercut banks, riffles, sub-surface stream sediments and riparian vegetation (Boulton 2003).

Movement and dispersal opportunities for aquatic biota

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

Instream and floodplain productivity, sediment, carbon and nutrient exchange

The supply of organic material underpins all river food webs by providing the food energy needed to drive life. In riverine environments, carbon in the form of leaves, branches and other terrestrial detritus (the organic material) are the building block for food-webs. ‘Productivity’ of a river, creek or wetland is influenced by the type of organic material, how much, and how often waterways connect with parts of the channel, river bank and floodplain that store organic material. The sources of organic material, the timing of its delivery and how long it remains in a section of river depend closely on the flow regime and the nature of the riparian and floodplain vegetation.

River flow management can be used to increase productivity by increasing the frequency of flows that connect and inundate river channels, benches, banks and floodplains. This provides a pulse of terrestrial carbon available for potential use by consumers (Langhans and Tockner 2006). The flow of water enhances the physical breakdown of leaves, branches and other terrestrial detritus to support micro-organisms (e.g. protozoa, copepods) and biofilms that in turn support invertebrates such as shrimp, juvenile fish, large fish and water birds (Mora-Gomez et al. 2015).

The reduction of lateral connectivity between rivers and floodplains has affected the transport of sediment, nutrients, carbon, and biota to and from 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, both the Upper and Lower Namoi Groundwater Sources play an important ecological role in supporting terrestrial and aquatic ecosystems. The Namoi River’s alluvium is important in providing water for stock, domestic, irrigation and industry, and also plays an important ecological role in supporting terrestrial and aquatic ecosystems, particularly during extended dry periods where groundwater can be critical for maintaining refuges (Green et al. 2011).

The Namoi is comprised of a complicated groundwater system of inland alluvial, porous rock and fractured rock groundwater aquifer types (Green et al. 2011). In the Upper Namoi, the shallow aquifers are highly connected to the river system and are highly dependent on surface water flows for recharge.

Groundwater development is high in the Namoi catchment. In 2007, groundwater use equated to nearly half of all water use in the region and is higher in dry years (CSIRO 2007). Surface water naturally recharges groundwater systems at certain points in the catchment. Annually around 22 GL of surface water is 'lost' to groundwater recharge, affecting surface water availability and the ecological health of assets in the catchment (CSIRO 2007).

Inter-catchment flow contributions

Biological connectivity between key planning units and between the Namoi catchment and the Barwon River during critical spawning periods will support native fish outcomes and contribute to improved outcomes in the Namoi and Barwon-Darling catchments. Baseflows in the Namoi 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 12 Namoi River below Keepit Dam
Photo: T. Cooke

Table 5 Priority ecosystem function (EF) objectives and targets

Ecological objectives		Description and key contributing processes	Targets		
			5 years (2024)	10 years (2029)	20 years (2039)
EF1	Provide and protect a diversity of refugia across the landscape	Water depth and quality in pools (in-channel), core wetlands and lakes Condition of vegetation in core wetlands and riparian zones	Key wetlands and billabongs and effluent streams (both instream and anabranch) habitats are protected during dry times Very low flows (VFs) and baseflows (BF1) are provided at target magnitudes and durations as specified in planning unit EWRs Cease-to-flow periods do not exceed maximum durations in line with the natural modelled data Adequate water depth is maintained in key instream and anabranch 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, including willows	Rates of fall does not exceed the 5th percentile of modelled natural rates during regulated water deliveries Period for which instream freshes are held at constant level (± 5%) does not exceed modelled natural durations (when not in conflict with the spawning flow requirement) 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">Ecological objectives</th><th rowspan="2">Description and key contributing processes</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td>EF3a</td><td rowspan="2">Provide movement and dispersal opportunities within catchments for water-dependent biota to complete lifecycles:</td><td>a. within catchment</td><td rowspan="2">Dispersal of eggs, larvae, propagules and seeds downstream and into off-channel habitats
Migration to fulfil life-history requirements
Foraging of aquatic species
Recolonisation following disturbance</td><td colspan="3" rowspan="2">Annual detection of relevant species and life stages representative of the whole fish community through key areas and specified planning units
Support fish passage through key fish passages (for example Mollee, Gunidgera, Walgett on the Namoi and Jewry Street causeway, Paradise Bridge water supply pipeline and Calala water gauge on the Peel River).
Increased dispersal opportunities between sub-catchments
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)
Provide longitudinal connectivity and integrity of flows to end-of-system, including flow pulses (regulated, natural or augmented natural). Increase dispersal opportunities between the Namoi and the Barwon-Darling catchments</td></tr>
<tr><td>EF3b</td><td>b. between catchments</td></tr>
<tr><td rowspan="2">EF4</td><td colspan="2" rowspan="2">Support instream and floodplain productivity</td><td rowspan="2">Aquatic primary productivity (algae, macrophytes, biofilms, phytoplankton)
Terrestrial primary productivity (vegetation)
Aquatic secondary productivity (zooplankton, macroinvertebrates, fish larvae, adult fish)
Decomposition of organic matter</td><td colspan="3">Maintain 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>

<table>
<tr><th colspan="2" rowspan="2">Ecological objectives</th><th rowspan="2">Description and key contributing processes</th><th colspan="3">Targets</th></tr>
<tr><th>5 years (2024)</th><th>10 years (2029)</th><th>20 years (2039)</th></tr>
<tr><td>EF5</td><td>Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands</td><td>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</td><td colspan="3">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</td></tr>
<tr><td>EF6</td><td>Support groundwater conditions to sustain groundwater dependent biota</td><td>Groundwater recharge and discharge
Dilution of saline/acidic groundwater
Salt export from the Murray–Darling Basin</td><td colspan="3">Maintain the 2016 mapped extent of groundwater dependent vegetation communities
Maintain groundwater levels within the natural range of variability over the long-term</td></tr>
<tr><td>EF7</td><td>Maintain and improve the contribution of flows into the Barwon–Darling from tributaries</td><td>Provision of end of system flows to support ecological objectives in downstream catchments</td><td colspan="3">Maintain at least 60% of natural level baseflows from the Namoi into the Barwon–Darling
Provide (protect, increase and maintain) low flows (including baseflows) from the Namoi River to the Barwon–Darling catchment 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 Namoi catchment that can reach the Barwon-Darling catchment
A 10% overall increase in flows in the Barwon-Darling: from increased tributary contributions from the Namoi and other northern basin catchments (Condamine-Balonne, Border Rivers, Gwydir and Macquarie-Castlereagh)[8].</td></tr>
</table>

[8] This longitudinal connectivity target is adopted from the Basin-wide Environmental Water Strategy. Note this is not a direct 10% increase from the Namoi catchment alone but a 10% increase of flows into the Barwon-Darling.

4. Environmental water requirements

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

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

Each flow category can provide for a range of ecological functions. For example, a small fresh might inundate river benches that provide access to food for native fish and support in-channel vegetation. Similarly, an overbank flow may support carbon exchange between the river and its floodplain and improve river red gum condition. Flow categories describe the height or level of a flow within a river channel or its extent across a floodplain (Figure 13 and Table 6). Flow rates for flow categories at sites across the Namoi catchment are shown in Table 8.

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

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

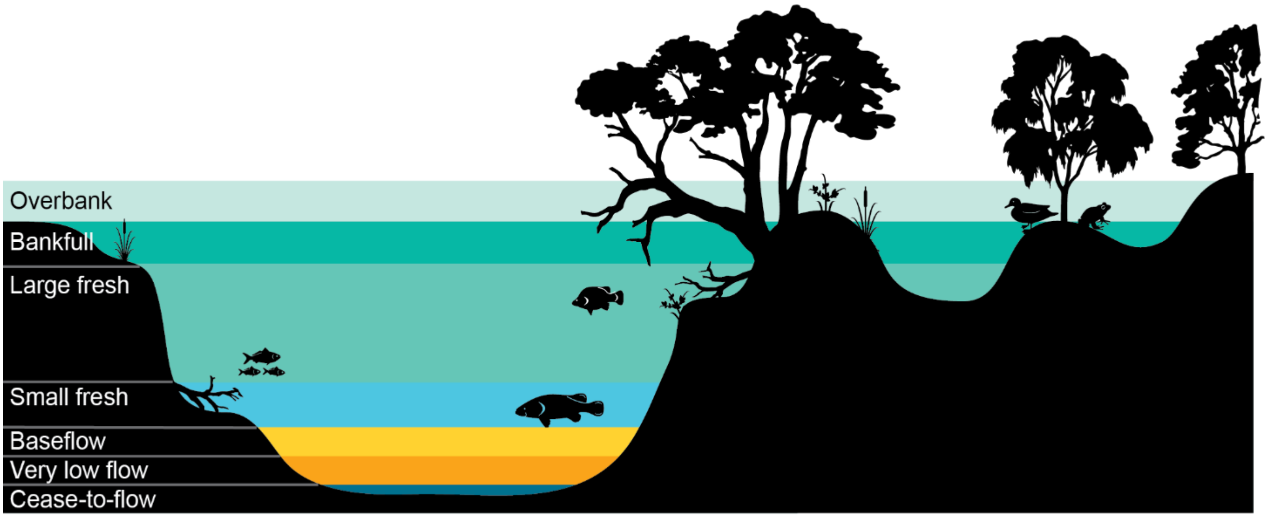

Figure 13 A simplified conceptual model of the role of each flow category

Table 6 Description of the hydrological role of each flow category

Flow category	Description
Overbank (OB)	Overbank flows provide broad scale lateral connectivity with floodplain and wetlands. They support nutrient, carbon and sediment cycling between the floodplain and channel, and promote large-scale productivity.
Bankfull flow (BK)	Inundates all in-channel habitats and connects many low-lying wetlands. They provide partial or full longitudinal connectivity and drown out of most small in-channel barriers (e.g. small weirs).
Anabranch connection flow[9] (AC)	Begins to wet off-channel habitat and provides connectivity along anabranches. It can also commence to fill low lying wetlands at flows below bankfull.
Large fresh (pulse) (LF)	Inundates benches, LWH and inundation-tolerant vegetation higher in the channel. They support productivity and transfer of nutrients, carbon and sediment. They also provide fast-flowing habitat and may connect wetlands and anabranches with low commence-to-flow thresholds.
Small fresh (pulse) (SF)	Improves longitudinal connectivity. They inundate lower banks, bars, LWH and in-channel vegetation, and can flush pools and stimulate productivity/food webs. They can provide a trigger for aquatic animal movement and breeding.
Baseflow (BF)	Provides connectivity between pools and riffles and along channels. They provide sufficient depth for fish movement along reaches.
Very low flow (VF)	Minimum flow in a channel that prevents a cease-to-flow. They provide connectivity between some pools.
Cease-to-flow (CF)	Partial or total drying of the channel. The stream contracts to a series of disconnected pools and there is no surface flow.

[9] Not shown in Figure 13.

4.1 Developing environmental watering requirements to support ecological objectives

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

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

Each EWR is expressed as a flow category that has been assigned a flow rate or volume, an ideal timing, duration and frequency, and a maximum inter-event period based on the suite of plants, animals and functions it supports (see Table 7 for full description of EWR terms). Complete EWRs for each planning unit the Namoi, including flow rates and total volumes, can be found in Part B.

A summary of flow rates for flow categories at sites along the Namoi are shown in Table 8. The timing, duration and frequency components of EWRs, grouped by flow category, for all biota and functions in the Namoi catchment and the objectives they support, are presented in Table 9. Important flow regime characteristics to meet life-history needs and each of the LTWP objectives are described in Table 10.

Table 7 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 2–5 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	The flow rate (typically ML/d) 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.

Term	Definition and guide to interpreting information
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 assets.
Frequency	The frequency at which the flow event should occur to achieve the ecological objective(s) associated with the EWR. Frequency is expressed as the number of years that the event should occur within a 10-year period. In most instances, more frequent events will deliver better outcomes and maximum frequencies may also be specified, where relevant. Clustering of events over successive years can occur in response to climate patterns. Clustering can be ecologically desirable for the recovery and recruitment of native fish, vegetation and waterbirds populations, however extended dry periods between clustered events can be detrimental. Achieving ecological objectives will require a pattern of events over time that achieves both the frequency and maximum inter-flow period, and the two must be considered together when evaluating outcomes or managing systems. Where a range of frequencies is indicated (e.g. 3–5 years in 10), the range reflects factors including the natural variability in population requirements, uncertainty in the knowledge base, and variability in response during different climate sequences (e.g. maintenance of populations during dry climate sequences at the lower end of the range, and population improvement and recovery during wet climate sequences at the upper end of the range). The lower end of the frequency range (when applied over the long term) may not be sufficient to maintain populations and is unlikely to achieve any recovery or improvement targets. As such, when evaluating EWR achievement over the long-term through statistical analysis of modelled or observed flow records, 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.

Term	Definition and guide to interpreting information
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 Floodplain near Bugilbone in the Namoi catchment
Photo: N Foster

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 8 presents the range of flow rates for each flow category at representative gauge sites in the Namoi catchment (Figure 15). The environmental outcomes associated with each flow category are expected to begin occurring at the bottom end of the flow ranges. Greater and sometimes substantially increased outcomes are likely to occur as flows increase in size. While the flow rates for each flow category are expressed as ranges in Table 8, 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.

Table 8 Flow threshold estimates (ML/d) for flow categories in the Namoi catchment[10]

Planning Unit	Gauging site and number	Low flows		Freshes			Bankfull and overbank	
		Very low flow	Baseflow	Small	Large	Anabranch Connection	Bankfull	Small overbank
Regulated Namoi Management Area								
Keepit to Boggabri	Namoi River d/s of Keepit Dam (419007)	5–200	200–500	500–1400	1400–3500	-	3500–6150	6150 +
	Namoi River at Gunnedah (419001)	1–200	200–600	600–5400	5400–32,700	4600–32,700	32,700–40,000	40,000 +
Boggabri to Wee Waa	Namoi River at Boggabri (419012)	1–150	150–350	350–3600	3600–17,750	4600–17,750	17,750–22,000	22,000 +
	Namoi River at Mollee (419039)	1–200	200–500	500–6000	6000–18,750	-	18,750–21,750	21,750 +
Wee Waa to Barwon River	Namoi River at Bugilbone (419021)	1–150	150–350	350–3200	3200–9900	4500–9900	9900–13,400	13,400 +
	Namoi River at Goangra (419026)	1–25	25–65	65–1000	1000–5800	-	5800–8200	8200 +
	Namoi River upstream of Walgett (419091)	1–30	30–200	200–2250	2250–8500	-	8500–10,600	10,600 +
Pian Creek Water Source	Pian Creek at Waminda (419049)	1–50	50–100	100–250	250–900	-	900–2150	2150 +
Peel Management Area								
Peel Regulated River	Peel River d/s of Chaffey Dam (419045)	1–100	100–250	250–900	900–2900	-	2900–6400	6400 +
	Peel River at Piallamore (419015)	1–100	100–250	250–1350	1350–5150	-	5150–13,400	13,400 +
	Peel River at Carrol Gap (419006)	1–100	100–300	300–3900	3900–13,500	-	13,500–40,000	40,000 +

[10] These figures describe the absolute minimum threshold within a flow category – to improve populations (and potentially meet objectives) may require more than achieving the minimum (e.g. recruitment, spawning).

Planning Unit	Gauging site and number	Low flows		Freshes			Bankfull and overbank	
		Very low flow	Baseflow	Small	Large	Anabranch Connection	Bankfull	Small overbank
Cockburn	Cockburn River at Mulla Crossing (419016)	1–163	163–455	455–2330	2330–6169	-	6169–18,700	18,700 +
Upper Namoi Management Area								
Mid Macdonald River	Macdonald River at Retreat (419028)	1–50	50–180	180–1500	1500–5570	-	5570–12,700	12,700 +
Keepit Water Source	Manilla River at Brabri (419020)	1–20	20–100	100–500	500–1300	-	1300–2500	2500 +
Upper Namoi	Namoi River at Manilla Railway Bridge (419022)	1–70	70–400	400–6800	6800–19,250	-	19,250–53,000	53,000 +
Lower Namoi Unregulated Management Area								
Mooki River	Mooki River at Breeza (419027)	3–200	200–400	400–1150	1150–3050	-	3050–7600	7600 +
Cox’s Creek	Cox’s Creek at Boggabri (419032)	2–75	75–200	200–700	700–1750	-	1750–3400	3400 +

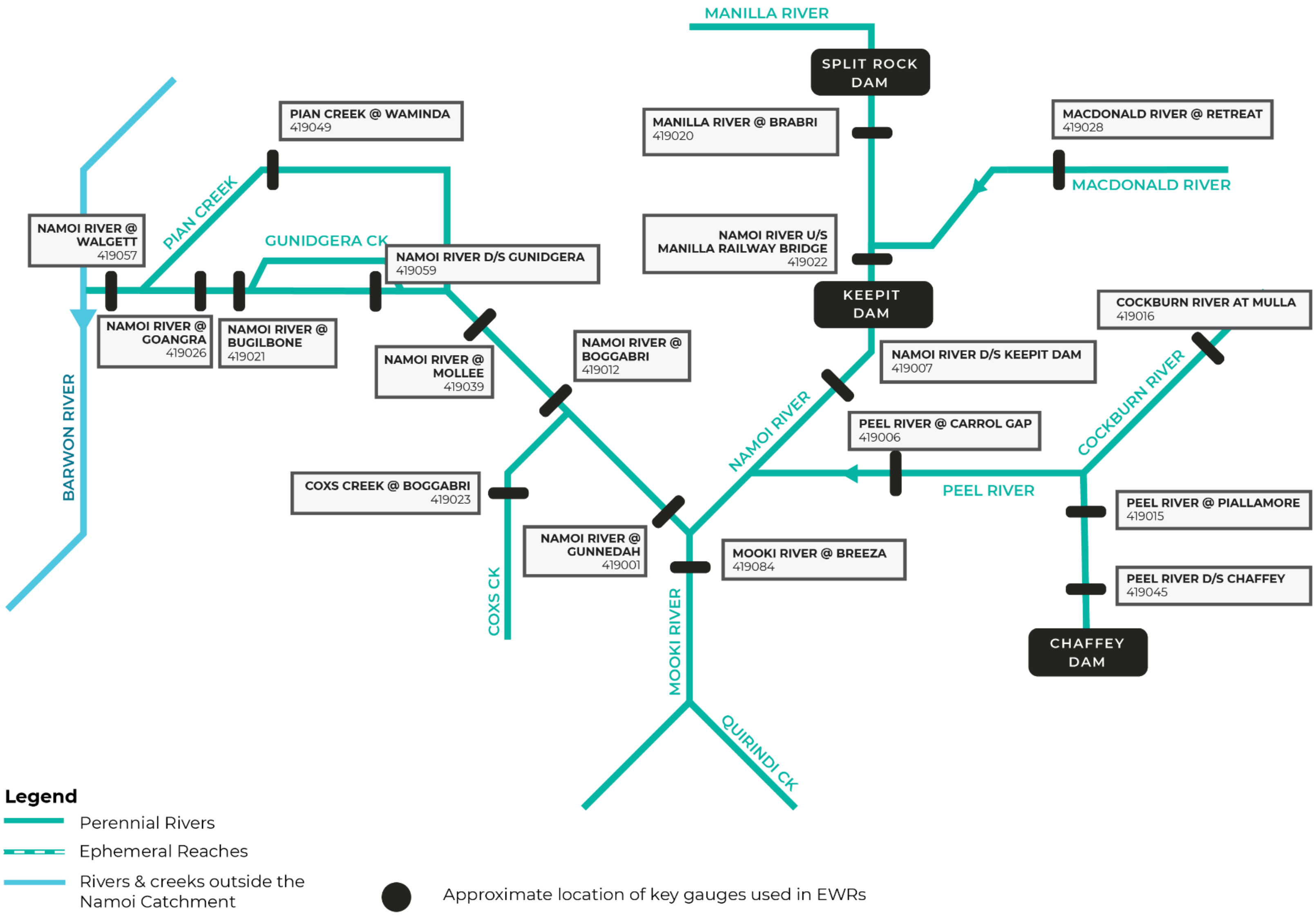

Figure 15 **Schematic diagram of the main watercourses and priority streamflow gauges in the Namoi catchment**

4.3 Catchment scale environmental water requirements

Table 9 Catchment-scale environmental water requirements and the ecological objectives they support[11]

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
Cease-to-flow	CF1	Native fish: NF1 – maintenance/ survival (all fish species) Ecosystem functions: EF1, 2 – refuge habitat Native Vegetation: NV1	In line with historical low flow season (April – June)	In line with natural, unless key refuges endangered	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.
Very–low flow	VF1	Native fish: NF1 – maintenance/ survival (all fish species) Ecosystem functions: EF1, 2	Any time	In line with natural	Annual	No greater than natural	
Baseflow	BF1	Native Fish: NF1, 2, 3, 4, 5, 6, 7, 8, 9 – condition and movement Waterbirds: WB1 Ecosystem functions: EF1, 2, 3a	Any time	In line with natural	Annual	No greater than natural	Minimum depth of 0.3 m to allow fish passage. Flow magnitude should be varied during events to avoid bank notching (within daily limits for rates of rise and/or fall)

[11] Some of the EWRs describe the minimum requirements - to improve populations (and potentially meet objectives) may require more than achieving the minimum (e.g. recruitment, spawning).

[12] See Table 7 for definitions of terms and explanatory text for EWRs.

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
	BF2	Native fish: NF1, 2, 5, 6, 8, 9 – recruitment (riverine specialists, generalists) Native vegetation: NV1 Waterbirds: WB1 Ecosystem functions: EF1	September – March	In line with natural	5–10 years in 10 (75% LTA)	2 years	
Small fresh	SF1	Native fish: NF1, 2, 3, 4, 5, 6, 8, 9 – dispersal / productivity / condition (all native fish groups) Native vegetation: NV1 Waterbirds: WB1 Ecosystem functions: EF1, 2, 3a, 5	October – April (but can occur any time)	Varies by location in line with natural: 2–10 days minimum	Annual (100% LTA)	1 year	>20°C for October to April Australian smelt >11°C Minimum depth of 0.5 m to allow movement of large fish Can follow 2–3 weeks after ‘Large Fresh 2’ for increased likelihood of successful recruitment of fish, productivity and dispersal Flow ideally up to 0.3–0.4 m/s (depending on channel form)
	SF2	Native fish: NF1, 2, 5, 6, 8 – spawning (river specialists, generalists) Native Vegetation: NV1, 2 Waterbirds: WB1 Ecosystem functions: EF1, 2, 3a, 5	September – April	Varies by location in line with natural: 2–14 days minimum (ideally >10 days^)	5–10 years in 10 (75% LTA)	2 years	>20°C; for river blackfish >16°C; for Murray cod September to December >18°C Minimum depth of 0.5 m to allow movement of large fish Flow ideally up to 0.3–0.4 m/s (depending on channel form) ^Ideally 10-day minimum duration to support spawning of riverine specialists and generalist native fish

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
Large fresh	LF1	Native fish: NF1, 2, 3, 4, 5, 6, 7, 8, 9 – Dispersal / productivity / condition (all native fish groups) Native vegetation: NV1, 2, 3, 4a, 4b, 4e, 4f – non-woody vegetation maintenance, forest regeneration Waterbirds: WB1, 2 Ecosystem functions: EF2, 3, 4, 5, 6, 7	July – September (but can occur any time)	5 days minimum	5–10 years in 10 (75% LTA)	2 years	Flow for pre-spawning condition Minimum depth of 2 m to cover instream features and trigger response from fish Flow ideally 0.3–0.4 m/s (depending on channel form)
	LF2	Native fish: NF1, 4, 6, 9 – spawning (flow pulse specialists) Native vegetation: NV4a, 4f – river red gum and coolibah wetland maintenance Waterbirds: WB1, 2, 5 Ecosystem functions: EF2, 3, 4, 5, 6, 7	October – April	5 days minimum	3–5 years in 10 (40% LTA)	4 years	Rapid rise (comparative to natural rates) >17°C Can be followed by 'Small Fresh 1' for increased likelihood of successful recruitment of fish, productivity and dispersal Minimum depth of 2 m to cover instream features and trigger response from fish Flow ideally 0.3–0.4 m/s (depending on channel form)

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
	LF3	Native fish: NF1 Native vegetation: NV1, 2, 3, 4a, 4b, 4e, 4f Waterbirds: WB1, 2, 5 Ecosystem functions: EF1, EF2, EF3b – connectivity between catchments, EF7	July – September (but can occur any time)	5 days minimum (^Ideally >11 days)	9–10 years in 10 (95% LTA) Triggered when LF1 at Barwon @ Collarenebri is detected within 18 months of LF2 at Darling @ Wilcannia	4 years (ideally 1 year in line with natural)	^ In line with natural (pre-development observed data) Connectivity with the Barwon River (Only relevant in Wee Waa to Barwon River PU). Note, this is not the only end-of-system flow EWR
Anabranch connection	AC1	Native fish: NF1, 3 Native vegetation: NV1, 2, 3, 4a, 4b Waterbirds: 1, 2, 5 – maintain waterbird habitat Ecosystem functions: EF1, 2, 3a, 4, 5, 6 – connectivity with low lying flood-runners, wetlands and anabranches in some PUs	August – February (but can occur any time)	Varies by location in line with natural: 2–7 days minimum (ideally to support 1–2 months of asset inundation for regeneration & 5–7 months of asset inundation for maintenance of river red gums)	Varies by location in line with natural: 3–10 years in 10 (65% LTA) to 4–10 years in 10 (70% LTA)	3 years	Possibility to pump into anabranch lagoons and billabongs where there aren’t sufficient flows to reach the ‘commence to fill’ thresholds

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
	AC2	Native fish: NF3 – spawning (floodplain specialists) Native vegetation: NV1, 2, 3, 4a, 4b Waterbirds: 1, 2, 5 – maintain waterbird habitat Ecosystem functions: EF1, 2, 3a, 4, 5, 6 – connectivity with low lying flood-runners, wetlands and anabranches in some Pus; transfer of nutrients and carbon, productivity	October – April	In line with natural. 5–10 day minimum (varies by location)	5 years in 10 (50% LTA)	4 years	Provides connectivity to off-channel habitats (low-lying wetlands and anabranches) to support spawning of floodplain specialist native fish. Complements BK1 and OB1, which connect a larger area of off-channel habitat at a lower frequency.
Bankfull	BK1	Native fish: NF3 spawning (floodplain specialist species) Native vegetation: NV2, 4a, 4b, 4c, 4f – river red gum and coolibah wetland maintenance Waterbirds: WB1, 2, 5 Ecosystem functions: EF1, 2, 3, 4, 5, 6, 7	October – April September – April (some locations)	Varies by location in line with natural: 1–8 days minimum Ideally >10 days^	Varies by location in line with natural: 3 years in 10 (30% LTA) to 5 years in 10 (50% LTA)	Varies by location in line with natural: 4–7 years	>22°C Ideally, recruitment flow 2–4 weeks after spawning flow ^ ideally 10-day minimum for spawning of floodplain specialist native fish

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
	BK2	Native fish: NF1–9 Dispersal Productivity/condition (all native fish groups) Native vegetation: NV2, 4a, 4f – River red gum and Coolibah wetland maintenance Waterbirds: WB1, 2, 5 Ecosystem functions: EF1, 2, 3, 5, 6, 7 – connectivity, productivity	September – February (but can occur any time)	Varies by location in line with natural: 2–5 days minimum	3–5 years in 10 (LTA varies by location in line with natural: 30–40%)	5 years	
Overbank (small)	OB1	Native fish: NF3 spawning (floodplain specialist species) Native vegetation: NV3, 4a, 4b 4c, 4 d, 4e – in-channel and out of channel fringing, wetland; lignum condition Waterbirds: WB1, 2, 5 Ecosystem functions: EF1, 2, 3, 4, 5, 6, 7 – connectivity, productivity	October – April September – April (some locations)	Varies by location in line with natural: 1–10 days minimum Ideally >10 days^	Varies by location in line with natural: 1 years in 10 (10% LTA) to 5 years in 10 (50% LTA)	Varies by location in line with natural: 4–10 years	>22°C Ideally, recruitment flow 2–4 weeks after spawning flow ^ ideally 10-day minimum for spawning of floodplain specialist native fish

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
	OB2	Native fish: NF1, 3, Dispersal Productivity/condition (all native fish groups) Native vegetation: NV4a, 4b, 4c – RRG maintenance Waterbirds: WB1, 2, 5 Ecosystem functions: EF2, 3, 4, 5, 6, 7 – connectivity, productivity	September – February (but can occur any time)	Varies by location in line with natural: 1–5 days minimum	Varies by location in line with natural: 1 year in 10 (10% LTA) to 3–5 years in 10 (40% LTA)	Varies by location in line with natural: 5–10 years	
Overbank (large)	OB3	Native fish: NF1, 2, 3, 4, 5, 6, 8, 9 – dispersal and condition (all species) Native vegetation: NV2, 3, 4a, 4b, 4d – RRG and coolibah Waterbirds: WB1, 2, 5 Ecosystem functions: EF2, 3, 5, 7 – lateral connectivity, productivity	Preferably between August to February	Varies by location in line with natural: 1–2 days minimum (ideally to support 1–4 months of asset inundation)	Varies by location in line with natural: 3–5 years in 10 to 3–10 years in 10 (30–50% LTA)	5 years	

Flow category and EWR code[12]		Ecological objectives[12]	Timing[12]	Minimum Duration[12]	Frequency (LTA frequency)[12]	Maximum inter-event period[12]	Additional water requirements and comments[12]
	OB4	Native fish: NF3 Native vegetation: NV2, 3, 4a, 4b, 4c, 4d, 4e – coolibah, black box and lignum Waterbirds: WB1, 2, 5 Ecosystem functions: EF2, 3, 4, 5, 6, 7 – lateral connectivity, productivity, between catchment connectivity	Preferably between August to February	Varies by location in line with natural: 1–2 days minimum (to ideally support up to 1 month of asset inundation)	Varies by location in line with natural: 1 year in 10 (10% LTA) to 3–5 years in 10 (40% LTA)	Varies by location in line with natural: 5–10 years	
	OB5	Native vegetation: NV4c, 4e – lignum and black box Ecosystem functions: EF2, 3, 4, 5, 6, 7	Any time	2 days minimum	1–4 years in 10 (25% LTA)	Varies by location in line with natural: 6–7 years (ideally 5 years)	

Table 10 Important flow regime characteristics to deliver Long Term Water Plan objectives

Ecological objective	Important flow regime characteristics[13]
NATIVE FISH OBJECTIVES[14]	
NF1: No loss of native fish species (All recorded fish species)	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. Very low flows (VF) and baseflows (BF1): are required for the survival and maintenance of native fish condition as these flows maintain adequate water quality (dissolved oxygen, salinity and temperature) in refuge pools and sufficient flow depth 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). Baseflows (BF2) preferably between September and March with an annual or biannual frequency are required to enhance fish recruitment outcomes for river specialist generalists (minimum depth of 0.3m to allow fish passage). Small freshes (SF1): (at least 0.5 m above cease-to-flow) support movement and dispersal opportunities for large bodied fish (Fairfull and Witheridge 2003; Gippel 2013; O'Conner et al. 2015). Large freshes (LF1): of at least five days duration and occurring ideally between July and September (but can occur at any time) are required to promote dispersal and pre-spawning condition for all native fish species five to 10 years in 10. Large freshes should trigger primary production that will provide food resources and improve fish condition prior to the spring/summer spawning season. Flow velocities of >0.3 m/s are ideal to trigger fish movement. Small overbank (OB2): and floodplain wetland inundating flows, ideally from August 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) are also required to support condition and movement/dispersal outcomes of all native fish groups. Larger flows that inundate off-stream habitat also promote growth and recruitment through increased floodplain productivity and habitat availability. Larger flows that connect low-lying wetlands provide important habitat to support strong survivorship and growth of juveniles.

[13] See Table 7 for definitions of terms and explanatory text for Environmental Water Requirements

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

Ecological objective	Important flow regime characteristics[13]
NF2: Increase the distribution and abundance of **short to moderate-lived generalist** native fish species (Australian smelt, carp gudgeon, bony herring, Murray–Darling rainbowfish, unspecked hardyhead, mountain galaxias, dwarf flat-headed gudgeon, obscure galaxias)	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for generalists are listed below. Regular (at least annual) spawning and recruitment events for the persistence of short-lived species. Although spawning often occurs independently of flow events, spawning is enhanced by small freshes (SF2) during the warmer months of October 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. Small freshes (SF2) occurring two to three weeks after spawning enhance recruitment of larvae and juveniles by aiding dispersal and access to habitat and suitable prey. Larger flows that inundate off-stream habitat 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 (Olive perchlet*, southern purple-spotted gudgeon*, flat-headed galaxias)	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for floodplain specialists include: <u>Bankfull, overbank and anabranch connection flows (BK1, OB1, OB3, OB4, AC1, AC2)</u> 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 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 main stem waterways. Flows should be of a long enough duration to support isolated populations. Water temperatures should be above 22°C. Recruitment is enhanced by subsequent flows events (large fresh, bankfull or overbank and wetland inundating flows) 2–4 weeks after spawning flows. Most floodplain specialist species require spawning and recruitment every one to two years for population survival.
NF4: Improve native fish population structure for **moderate to long-lived flow pulse specialist** native fish species (Golden perch, silver perch, spangled perch)	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for flow pulse specialists include: Spawning of flow pulse specialists is triggered by a rapid rise (and potentially 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. <u>A large fresh (LF2):</u> between October to April for a minimum of five days and a rapid rate of rise should meet these spawning requirements. This is needed at least three to five years in 10 with a maximum inter-event period of four years.

Ecological objective	Important flow regime characteristics[13]
	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. LF2 can be followed by LF1 for increased likelihood of successful recruitment of fish, productivity and dispersal.
NF5: Improve native fish population structure for **moderate to long-lived riverine specialist** native fish species (Murray cod, river blackfish, freshwater catfish, southern purple-spotted gudgeon*, Darling River hardyhead)	In addition to the flows listed above for all native fish species, other important aspects of the flow regime for riverine specialists include: Spawning of riverine specialists usually occurs annually, independent of flow events. However, spawning may be enhanced by a small freshes (SF2) between October and April to promote ecosystem productivity and inundate additional spawning habitat. 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. Stable small fresh flows (SF2) are required for nesting species (e.g. Murray cod and Freshwater catfish). Preventing rapid drops in water levels (that exceed natural rates of fall) during, and for a minimum of 14 days after spawning will help to prevent fish nests from drying or abandonment. Recruitment is enhanced by a secondary flow pulse (SF1, large fresh, bankfull or overbank) for dispersal and access to nursery habitat in low-lying wetland habitats. Overall, riverine specialists prefer hydraulically complex flowing streams containing submerged structure (LWH and benches) that provides cover and spawning habitat. Flow variability through the delivery of small and large freshes, bankfull and overbank flows enhance the availability of diverse habitat, enhances growth and condition of larvae and juveniles and provides connectivity for dispersal between habitats.
NF6: A 25% increase in abundance of mature (harvestable sized) Golden perch and Murray cod (Golden perch, Murray cod)	The flow requirement of golden perch (flow pulse specialist) and Murray cod (riverine specialist) are outlined above under NF4 and NF5, respectively. In addition to the flow requirements listed above, LF3 and longer periods of connection generally will be important in facilitating dispersal of Golden perch between the Barwon and Namoi Rivers. Longer periods of connection generally, and connections timed to coincide with movement events in the Barwon River, are important for this objective.
NF8: Increase the prevalence and/or expand the population of key **moderate to long-lived riverine specialist** native fish species into new areas (within historical range)	Flow requirements of riverine specialists are outlined for NF5. Expanding populations into new areas will be particularly dependent on dispersal flows, particularly large freshes (LF1), BKF2, OB2 and anabranch connection flows (OB2, AC1). Complementary actions such as conservation stocking and/or translocation may be required to support these outcomes.

Ecological objective	Important flow regime characteristics[13]
(Freshwater catfish, river blackfish)	
NF9: Increase the prevalence and/or expand the population of key **moderate to long-lived flow pulse specialists** native fish species into new areas (within historical range) (Silver perch)	Flow requirements of riverine specialists are outlined for NF4. Expanding populations into new areas will be particularly dependent on dispersal flows, particularly large freshes (LF1), BNKF2, OB2 and anabranch connection flows (AC1). Complementary actions such as conservation stocking and/or translocation may be required to support these outcomes.
NATIVE VEGETATION OBJECTIVES[15]	
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within and closely fringing channels	Non-woody, inundation tolerant plants occurring on the channel bed, banks, bars and benches require regular wetting and drying to complete life cycles. Variable size and duration of flows including baseflows, variable size freshes and bankfull flows throughout the year will promote diverse communities. Regular inundation will also encourage a dominance of native species over exotic species, as the latter tend to be less tolerant of inundation (Catford et al. 2011). Increased cover of non-woody, inundation tolerant vegetation on banks is likely to stabilise bank material and therefore reduce the risk of excessive bank erosion. Inundation of banks during late winter and early spring by freshes and bankfull flows is required to replenish soil moisture to promote growth during spring. Prolonged submergence of some amphibious species (e.g. especially if there are continuous high flows during the irrigation season) may have detrimental impacts on survival. Small freshes in summer and autumn are important for replenishing soil moisture in river banks to promote survival and maintenance.
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	Anabranch connecting flows, overbank and floodplain wetland inundating flows (OB1–4, AC1): to inundate anabranches, floodplains and wetlands to inundate habitat for two to eight months are required to support non-woody, inundation tolerant vegetation.

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

Ecological objective		Important flow regime characteristics[13]
		Large freshes (LF1) and Anabranch connections (AC1): will support non-woody wetland vegetation instream and in some low-lying wetlands with low commence to flow thresholds. The required duration and frequency vary widely by species. Highly water-dependent, amphibious species such as water couch, spike-rush, and cumbungi require inundation for five to eight months, eight to 10 years in 10. The maximum period between events is two years. Small but frequent overbank and wetland inundating events (e.g. OB1) will be important for maintaining the extent and viability of these species. Larger overbank and wetland inundating flows (OB3, 4) will support amphibious damp species such as floodplain herbs, grasses and sedges that require less frequent (three to ten years in ten) and shorter duration (two to four months) inundation.
NV3: Maintain the extent and maintain or improve the condition of river red gum communities closely fringing river channels		Large freshes (LF1, 2) and bankfull flows (BK1): that recharge alluvial aquifers and soil moisture in the riparian zone are also important for maintaining deep rooted vegetation between inundation events. Bankfulls (BK1) and Overbanks (OB1–4): River red gum and river cooba fringing river channels will be supported by a range of flows including, most importantly, bankfull flows (BK1), which inundate the tops of banks, overbank flows (OB3) and larger wetland inundating flows that inundate the fringing riparian zone (OB1–4). 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. Anabranch connecting flows (AC1) will aid the maintenance and regeneration of lower-lying river red gum communities.
NV4: Maintain the extent and maintain or improve the condition of native woodland and shrubland communities on floodplains	NV4a: River red gum forest	Overbank flows (OB): to inundate vegetation, ideally between one and seven months during August to February. Inundation needs to occur at least 3 years in 10 years, with greater frequency for forested areas (ideal frequency three to 10 years in 10 – 65% LTA, with a maximum period between events of three years). Inundation in the year following a maintenance flow will support the survival of seedlings from the previous year in areas where recruitment is desired. Ideally between August to November.
	NV4b: River red gum woodland	Overbank flows (OB): Maintaining the condition of river red gum woodlands on the floodplain requires overbank flows that inundate vegetation for between one and four months during August to February. For river red gum communities located on lower parts of the floodplain, inundation needs to occur four to 10 years in 10 years with a maximum period between events of five years (OB2). 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 (OB3). 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.

Ecological objective		Important flow regime characteristics[13]
	NV4c: Black box woodland	Large overbank flows (OB4): 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 one to four years in 10 years and a maximum period between events of five years. Greater than five year intervals may result in a reduction in condition. 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). Overbank flows will support regeneration.
	NV4d: Coolibah woodland and NV4e: Lignum shrubland	Overbank flows (OB3, 4): 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 one to four years in 10 and a maximum period between events of five years (OB3–4). Overbank flows (OB3, 4): Regeneration requires more frequent inundation (ideally annual), for one to 12 months between August and March (September to February for vegetative expansion). Large overbank events (OB4) will support maintenance of Lignum and Coolibah wetland located higher on the floodplain, while medium size events (OB3) that occur more frequently will support regeneration and maintenance of Lignum and Coolibah wetland on lower parts of the floodplain.
WATERBIRD OBJECTIVES[16]		
WB1: Maintain the number and type of waterbird species		Sustaining habitats for birds to forage and nest in is integral to maintain the number and type of waterbirds. All of the flow types required to achieve the 'no loss in native fish' objective will provide food for piscivore bird species (Baseflows to Overbanks: see NF1). Maintaining non-woody macrophytic vegetation with flows required to achieve objectives NV1 and NV2 (ranging from baseflows to bankfull, described above) will provide food for herbivore and shorebird species, and habitat for the macroinvertebrates that other species like large waders feed on. Overbank flows (OB1–4, AC1): Maintaining waterbird species richness in the Namoi catchment will require a range of small, medium and large overbank and wetland inundating flows (OB1–4, AC1) to support feeding habitat and maintain habitat condition (WB5). Overbank and wetland inundating flows, preferably 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

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

Ecological objective	Important flow regime characteristics[13]
	there is gradual drawdown of habitats over late summer–autumn this can extend feeding habitat available for migratory and resident shorebird species (small waders).
WB2: Increase total waterbird abundance across all functional groups	As in WB1 provide seasonal (spring–summer) flooding with gradual drawdown over summer into autumn to provide feeding habitat for waterbird species and maintain the condition of waterbird breeding and feeding habitats (WB5). Increasing waterbird abundance in the Namoi area will require increased breeding opportunities for both colonial and non-colonial waterbirds in the wetlands across the Murray–Darling Basin. This can be enhanced through supporting or protecting overbank and wetland inundating flows (OB4) from September to March with inundation duration maintained into May for colonies that commence in March. Small and medium overbank and wetland inundating events (OB1, 2, AC1) will support survival of waterbirds, provide foraging habitat and may support small scale non-colonial waterbird breeding. <u>Overbank flows (OB1, 2):</u> at the same time as neighbouring catchments to provide benefits to waterbird populations by providing habitat across a larger area of the Murray–Darling Basin. Follow-up overbank and wetland inundating flows (OB1, 2, AC1) in years following large breeding events in the other catchments may also promote the survival of juvenile birds and contribute to increased waterbird populations. Increasing total waterbird abundance will also rely on maintaining (and in some cases) improving the condition of key native vegetation types that provide breeding and foraging habitats (see WB5). In the Namoi these include river red gum, river cooba, common reed, lignum and cumbungi. Overbank and wetland inundating flows are critical to maintaining the extent and condition of these breeding habitats (see WB5 for more details).
WB5: Maintain the extent and improve condition of waterbird habitats	Lake Goran, which is an ephemeral lake south of Gunnedah provides important bird habitat for many bird species, especially when full. Water enters the lake through Red Bobs Creek, Coomoo Coomoo Creek and other run off. <u>Overbank flows (OB1–4):</u> Waterbirds depend on a wide variety of breeding and foraging habitats, which are maintained through a range of overbank and wetland inundating flows (OB1–4). <u>Overbank flows (OB1, 2, 4):</u> Important habitat include sites that provide nesting habitat consisting of river red gum, river cooba, belah, lignum and/or cumbungi. Overbank flows of sufficient duration (OB1, 2) are needed to maintain the extent and condition of these vegetation communities across the catchment. This increases the likelihood that sites are in event-ready condition when large overbank events (OB4) initiate large scale colonial waterbird breeding events occur across the wider Murray–Darling Basin. Overbank and wetland inundating flows (OB1–4) will also support a broader range of foraging habitats in the Namoi, 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.

Ecological objective	Important flow regime characteristics[13]
PRIORITY ECOSYSTEM FUNCTIONS OBJECTIVES[17]	
EF1: Provide and protect a diversity of refugia across the landscape.	Cease-to-flow periods of durations that are not longer than the persistence of water of sufficient volume and quality in key larger river pool refuges is vital for survival of native plants and animals. Very low flows (VF) and baseflows (BF1, 2) 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. When restarting flows after a cease-to-flow event, consideration should be given to preventing detrimental water quality outcomes (e.g. poor quality water from the bottom of pools can be mixed through the water column).
EF2: Create quality instream and floodplain and wetland habitat	The full range of in-channel and overbank flows are required to maintain quality instream and floodplain habitat. Variable in-channel flows (baseflows – bankfull flows) will provide a diversity of physical and hydraulic habitats. With increasing magnitude of flows, greater areas of the channel are inundated (e.g. benches, bars, LWH and banks at different elevations in the channel). Baseflows (BF) and small freshes (SF) provide areas of slow flowing habitat, while large freshes provide deeper and faster flowing habitats. Small and large freshes are important for flushing fine sediment from pools and maintaining geomorphic features such as benches and bars. Bankfull flows are important for geomorphic maintenance of all channel features. All flows greater than CTF contribute to maintaining water quality in refuge pools under different water availability scenarios, including prevention of stratification and associate risks such as algal blooms and low dissolved oxygen. To protect banks from excessive erosion it is important to replicate natural rates of fall wherever possible in regulated systems. Natural rates typically allow water to drain from the bank slowly, preventing mass failure of the banks. Maintaining natural 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. Bank notching can be avoided by varying flows (avoiding holding flows constant for too many consecutive days) and targeting different peak heights for freshes. Overbank and wetland inundating flows (OB1–4, AC1) are required to provide essential floodplain and wetland habitat for native fish, waterbirds and other aquatic fauna.
EF3: Provide movement and dispersal opportunities within and	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

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

Ecological objective	Important flow regime characteristics[13]
between catchments for water dependent biota to complete lifecycles and disperse into new habitats.	(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 small to medium bodied native fish to move along a channel. Man-made physical barriers throughout the Namoi valley, such as dams, weirs and road-crossings inhibit the longitudinal movement of fish. Larger magnitude flows such as small fresh, large freshes, bankfull flows, and occasionally small overbank flows are important to 'drown-out' these structures to facilitate longitudinal connectivity where fishways are not present. End of System flows from the Namoi are important in connecting the Namoi catchment to the Barwon–Darling River and greater Northern Basin. End of system flows from the Namoi occasionally connect with the Macquarie/ Castlereagh catchment, when it is also experiencing high flows, providing dispersal opportunities for native fish. At Walgett, the Small Fresh or Large Fresh (depending on status of Walgett town weir) provides the minimum depth for all size classes of fish, suitable velocity and water quality to attract immigration into Namoi (and overcome current barriers near the end of system). Smaller end of system flows contribute to overall flows in the Barwon Darling and will therefore benefit fish in that WRPA, but they limit the opportunity for inter-valley dispersal.
EF4: Support instream and floodplain productivity	Overbank and wetland inundating flows (OB1–4): that inundate the floodplain, and enable water to persist 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.). Large freshes (LF1–3) bankfull flows (BK2) and anabranch connection flows (AC1, AC2) may drive small pulses of productivity.
EF5: Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands.	Freshes and bankfull flows are important for mobilising organic matter and sediment from in-channel surfaces (e.g. leaf litter that has accumulated on bars, benches and banks during low flows). This material is transported downstream or deposited in other parts of the channel where it is utilised, in the case of nutrients and carbon, to drive primary productivity, or in the case of sediment, for channel maintenance (e.g. to replenish banks and benches). Overbank and wetland inundating flows (OB1–4) are essential for transferring nutrients and carbon from the floodplain to the channel. This will also be facilitated with Anabranch connecting flows (AC1, AC2).
EF6: Support groundwater conditions to sustain groundwater dependent biota.	Large freshes (LF1–4), bankfull flows (BK1, 2), overbank (OB1–4), and wetland inundating flows (AC1, AC2) 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.

Ecological objective	Important flow regime characteristics[13]
EF7: Increase the contribution of flows into the Murray–Darling from tributaries That is, into the Barwon–Darling from the Namoi catchment.	End of system flows from the Namoi to the Barwon River that provide movement and dispersal opportunities between catchments (see EF3) will also contribute to important EWRs in the Barwon–Darling LTWP/WRPA. Large freshes (LF3) and overbank flows (OB1–4) that reach the end of system will also provide important transfer of nutrients and carbon from floodplains in the Namoi to the Barwon River.

5. Risks, constraints and strategies

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

The Risk Assessment for the Namoi Water Resource Plan Area (DPIE–Water 2019a) was undertaken to inform water resource planning in the Namoi. It identifies risks to areas of conservation value, based on hydrological change within sub-catchments, and presents strategies outlining how those risks are mitigated in the Namoi WRP. This chapter complements that risk assessment and addresses the specific risks and constraints that may affect the implementation of the LTWP.

This chapter focuses on risks to meeting the EWRs of priority environmental assets and functions in the Namoi catchment (Table 11). Beyond achieving, or not achieving the EWRs, it also outlines the risks and constraints that affect our capacity to achieve the ecological objectives of this LTWP (Table 12).

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 25).

Figure 16 Cox's Creek in flood, 1998
Photo: N Albert

5.1 Risks and constraints to meeting environmental water requirements

Table 11 Risks and constraints to meeting environmental water requirements in the Namoi catchment and strategies for managing them

Risk	Description	Potential management strategies	Potential project partners[18]
Insufficient water to meet LTWP objectives	Insufficient water (total volumes, season, flow rate) – amount does not meet environmental demand/ecological requirements – insufficient water to drown out some barriers to fish passage	**Regulated planning units**	
		Recover the remaining amount of environmental water as recommended under the Northern Basin Review (MDBA 2016)	DAWR
		Continue to improve monitoring, research and assessment methods to determine what approaches achieve the best ecological outcomes, and to inform future decision making.	DPIF, DPIE–BC, CEWO
		Continue to enable adaptive water management through review of WRP outcomes against LTWP objectives in 5 years (2024).	DPIF, DPIE–BC
		Improve the seasonal pattern of freshes through seasonally cued HEW and ECA releases	DPIE–BC, CEWO
		There is insufficient environmental water to create larger flow types, of the required frequency and duration, in the Peel and Namoi Rivers – as such, it may be a feasible strategy to allow for environmental water delivery to build on natural events	WaterNSW, DPIE–BC, DPIE–Water, CEWO
		Investigate options for the strategic delivery of consumptive water orders and bulk water transfers (BWT) to mimic natural flow events, with or without the contribution of water for the environment (requires interagency discussion and may have 3rd party impacts that would need to be mitigated)	WaterNSW, DPIE–BC, EWAG, CAG, DPIE–Water, DPIF
		Unregulated planning units	
		Implementation of the WRP rules to protect PEW	DPIE–Water
		Maintain rules restricting trade into water sources with high or medium risks (as defined by the Namoi WRP Risk Assessment)	DPIE–Water

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

Risk	Description	Potential management strategies	Potential project partners[18]
		and/or consider trade out of high-risk areas as a mechanism to ensure that sufficient water is retained for the environment.	
		Review low flow access rules where in-channel flows have been impacted since development	DPIE–Water
		Communicating the whole-of-system management approach to help improve understanding of the importance of protecting environmental flows	DPIE–BC, CEWO. WaterNSW, DPIE–Water
Future water demands impacting on amount and availability of water to meet LTWP objectives	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
Environmental water deliveries are used to substitute for PEW, replenishment flows or end of system flows.	This can impact on achievement of environmental objectives, reduces the effectiveness of environmental water and shifts the costs of providing these flows from the socialised pool to the NSW and Australian public.	Replenishment flow and end of system flow requirements, as defined by the Namoi WSP, be provided from essential supplies reserves and/or unregulated flow sources. River operators and water managers should consult when planning deliveries to make best use of replenishment and end of system flows	WaterNSW, CEWO, DPIE–BC, DPIE–Water
Infrastructure constraints	The valve capacities on Chaffey and Keepit dams limit the magnitude of water that can be released. This constraint increases with decreasing supply level.	Investigate options for increasing the maximum regulated delivery rates from storages during future dam safety upgrades to meet a greater variety of EWRs	WaterNSW, DPIE–Water
		Allow for environmental water deliveries to build on natural events (downstream unregulated)	
Extraction and diversion of environmental water for purposes that are not consistent with LTWP objectives	This includes: Currently legal extraction of environmental water orders below the gauged delivery point, reducing benefits to downstream assets and end of system flows	WSP rules, an effective gauging network and accounting should combat large discrepancies in monitoring environmental water	WaterNSW, DPIE–Water
		Improve communication to inform relevant stakeholders of environmental water deliveries	DPIE–BC, CEWO, WaterNSW
		Refer suspected illegal diversions to the Natural Resources Access Regulator Water Compliance Policy and Strategy	NRAR

Risk	Description	Potential management strategies	Potential project partners[18]
	Unauthorised extraction or diversion of flows	Continue to develop and implement spatial monitoring of flow	NRAR, MDBA
Floodplain structures and barriers preventing flows that would meet overbank and floodplain wetland inundation water requirements	Unmanaged and unapproved construction (e.g. levees, diversion channels, sediment blockage of culverts) has diverted flows and caused barriers to delivering water to floodplain areas.	Implement the Upper and Lower Namoi Valley Floodplain Management Plans	DPIE–Water, WaterNSW
		Investigate opportunities to complete a Peel Valley Floodplain Management Plan	DPIE–Water
		Monitor compliance of infrastructure with the Floodplain Management Plans – and implement compliance and or remediation actions where needed to maximise the benefit of bankfull and overbank flows	NRAR
Bulk delivery release periods limit environmental water deliveries and what assets can be targeted	During dry conditions, consumptive orders may be delivered in bulk to minimise losses. This can restrict periods when environmental water deliveries can be made, or which assets can be targeted.	Proactively plan for delivery of environmental water during years that bulk delivery is not implemented, to maximise environmental outcomes	DPIE–BC, CEWO
Blue green algae resulting in a quarantine or limitation of environmental water use (Related to cold water pollution constraint which is discussed below in Table 12)	Blue green algae limits effective use of multi-level offtakes (MLOs) which affects downstream temperature outcomes. This is due to having to lower MLOs to prevent risk of seeding blue green algae downstream and therefore not being able to release warm surface water.	Implement the clauses in the WSPs that intend to suppress blue-green algae blooms Implement the Namoi River Water Quality and River Flow Objectives Review and update dam operating protocols/multilevel offtake protocols Continue to implement CWP operating protocol: ‘Managing Cold Water Pollution and Cyanobacteria in WaterNSW Rural Storages with Variable Offtake Structures’; monitor performance and revise Through the CWP Inter Agency Working Group, and other agencies partnerships, investigate feasibility and trial alternate technology outcomes not constrained by potentially toxic algae.	WaterNSW, DPIE–Water, DPIF, DPIE–BC
Sub-optimal rate of dam releases	Dam releases occur from Namoi dams as efficiently as possible, meaning river levels rise and fall rapidly in a “blocky” release pattern. This can increase bank	Implement more natural flow patterns to benefit the ecology of the river. This can be achieved by adopting a more natural rate of rise and fall of regulated releases, and by providing variability in flow rates during prolonged deliveries	DPIE–Water, WaterNSW, DPIF, DPIE–BC

Risk	Description	Potential management strategies	Potential project partners[18]
	erosion rates, cause stream banks to collapse and impact on the life cycles of native plants and animals	Investigate whether the likelihood associated with the reduced frequency of certain EWRs can be increased by delivering bulk water in patterns that mimic natural flow conditions. 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 would need to be undertaken between stakeholders and the CAG at pre irrigation season planning meetings, to examine whether delivery patterns can be varied without impacting on water security and efficiency	
Inappropriate timing of dam releases	Consumptive water is released from Namoi and Peel dams as efficiently as possible which can result in dryer rivers during winter months. This has an impact on the life cycles of native plants and animals.	Work with relevant stakeholders to optimise water releases for multiple benefits	DPIE–Water, DPIE–BC, WaterNSW
Lack of protection for environmental flows	Uncontrolled flow access has the capacity to reduce the magnitude and duration of unregulated events that contribute to small fresh and large fresh events in the regulated Manilla River, Lower Namoi and Peel. The current access rules to uncontrolled ECA flows in the regulated Peel River limit its effective use to reinstate natural flow variability and increase likelihood of EWRs, including VLF. Environmental water delivery points are often sub-optimal. Once that delivery point is reached, the environmental water is re-regulated and no longer protected from diversion. This impedes capacity to reach target assets in the mid-	Greater protection of uncontrolled flow events, for example via the introduction of an ecologically appropriate first flush rule (time and or magnitude depending on season), may be beneficial to improving the likelihood of some EWRs.	DPIE–Water, DPIF, DPIE–BC, WaterNSW
		Review of the extent of protection of the Peel ECA, including uncontrolled flow commence and cease-to-pump thresholds, or introduction of seasonal limitations on access to ECA flows will enhance spawning, condition, productivity and connectivity/recruitment outcomes within the regulated Peel and between the Peel and Namoi Rivers.	DPIF, CEWO, DPIE–BC
		Communicate to the Namoi community the whole-of-system management approach to help improve understanding of the importance of protecting environmental flows	DPIE–BC, WaterNSW, DPIE–Water
		Installation of additional gauging and implementation of metering policy to more accurately quantify and protect flows	DPIE–Water
		Investigate WSP mechanism to protect environmental water deliveries (HEW and PEW) from extraction, for example using a Section 324 temporary water restriction	DPIE–BC, CEWO DPIE–Water

Risk	Description	Potential management strategies	Potential project partners[18]
	lower Namoi and achieve inter-valley connectivity	Maintain relationships with water-entitlement holders and formalise agreements that protect environmental water delivery to its intended locations	DPIE–Water, DPIE–BC, CEWO
Ineffective pool drawdown rules impacting on EWRs and drought refuge	'Visible flow' can be an ambiguous trigger for access rules and compliance is difficult to enforce. Pumping from pools during dry periods impacts on valuable drought refuge.	Review of drawdown rules	DPIE–Water, DPIE–BC
		Trade from high risk to lower risk areas in unregulated areas	DPIE–Water, DWAR
		Better monitoring and gauging required	DPIE–Water
		Consider reviewing WSPs for the Namoi Unregulated and Alluvial Water Sources 2012 and the Peel Valley Regulated, Unregulated, Alluvium and Fractured Rock Water Sources 2010 rules in high-risk areas as a mechanism to ensure that sufficient water is protected for the environment during dry times	DPIE–Water
Support compliance with access rules in unregulated catchment	There is a need for more gauging and metering in unregulated catchments to strengthen compliance	Investigate improved metering of pumps. Investigate better gauging to help licence holders and compliance officers understand take	DPIE–Water, NRAR, DWAR, WaterNSW, Riparian Landholders, Water entitlement holders
Potential third party impacts can prevent or restrict the use of e-water	May include disruption to access and infrastructure for environmental flows. Restricts use of HEW in the Peel River	Identify what the constraints are and their nature	LLS DPIE–BC
		Improve stakeholder engagement and education and resources to increase understanding of floodplain inundation patterns – including establishment of an Environmental Water Advisory Group	DPIE–BC
		Communicate intended flow deliveries and provide regular updated information for landholders to understand and determine their own flooding risk of farming on the floodplain	DPIE-BC, CEWO

Risk	Description	Potential management strategies	Potential project partners[18]
		Investigate improving crossings and provide access, and programs to reduce use of flood prone land for cropping	Councils, LLS, DPIE–BC, CEWO
A reduction of volumes and availability of environmental water (HEW and PEW) in future revisions of the WSPs and other water review processes	Translucency, carryover, and other environmental water provisions are subject to changes resulting from 5-yearly reviews of WSPs	Ensure stakeholders are consulted in any review process for the Namoi and Peel WSPs	DPIE–W
		Implementation/continuation of the NSW Monitoring Evaluation and Reporting plan and Basin Plan Environmental Outcomes Monitoring – Fish to provide evidence of the benefits and outcomes of environmental watering	DPIE–BC, DPIE–Water, DPIF, CEWO
Lack of variability in river height impacts on aquatic plants and animals by impairing ecosystem functions and reducing habitat variability for native fish. Excessive variability also an issue – aim for natural variability	Weirs capture certain flow categories, reducing variability in river flows and create long reaches of lentic habitat with little hydrodynamic complexity River management has changed, altering the natural variability.	Review and update of WaterNSW Operating protocols Translucent flows past weirs Investigate options for optimising management of weir pools and translucent flows considering environmental benefits and informed by science	DPIE–BC, DPIF, DPIE–Water, WaterNSW
Groundwater extraction reducing surface flows	Where there is high connectivity between surface water and groundwater, over-extraction of groundwater can impact on smaller flows, especially during dry times.	Ensure groundwater extraction complies with SDL. Improve monitoring of lower surface water flows and groundwater use in areas known to be highly connected. Improve understanding of surface water and groundwater relationship in highly connected areas	DPIE–Water, DPIE–BC, CEWO

5.2 Non-flow related risks and constraints to meeting Long Term Water Plan objectives

The risks and constraints to meeting the ecological objectives include non-flow related external factors that could potentially impact on achieving the targets outlined in this Plan (Table 12). These may be water related, such as cold-water pollution downstream of Chaffey, Split Rock and Keepit dams, 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 some of these risks and constraints is outside the scope of this Plan, 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.

Figure 17 Namoi River
Photo: E Wilson/DPIE

Table 12 Risks and constraints to meeting ecological objectives in the Namoi catchment

Risk	Description	Potential management strategies	Potential project partners
Current and future instream barriers and structures impacting connectivity related LTWP objectives (Including Mollee Weir)	Instream structures impede natural flow and connectivity which can significantly impact on fish populations by impeding movement, altering habitat and affecting spawning and recruitment Mollee Weir Fish lock is offline due to infrastructure failure which prevents fish dispersal movement	Refer to and implement strategies from NSW Department of Primary Industries, Fisheries and implement the *Fisheries Management Act 1994* Implement NSW Department of Primary Industries, Fisheries (2017): *Fish for the Future: Action in the Northern Basin - NSW proposal for Northern Basin Toolkit measures to promote native fish health* measures to overcome priority fish barriers	DPIF
		Implement existing commitments to fish passage in the Namoi e.g. Gunidgera Weir	WaterNSW
		Ensure fishways are maintained and operated according to protocols	WaterNSW, DPIF
		Pursue remediation of illegal barriers	DPIE–Water, DPIF
		Investigate a Namoi catchment connectivity plan focussed on improving habitat connectivity and seek funding opportunities to treat problematic structures	DPIE–BC, DPIF, DPIE–Water
		Repair, operate and maintain Mollee Weir fish lock according to operational protocol	WaterNSW
Limited knowledge about refuge pools and fish spawning hotspots	There's limited knowledge about the location and persistence refuge pools and fish spawning hotspots. This knowledge would help define better watering priorities and management strategies.	Larval monitoring and otolith micro-chemistry analysis to assess the natal origin of fish will inform success of improved water management for the environment and drive adaptive management. Improved knowledge of high spawning success reaches will allow water managers to develop strategies to target watering of those areas Mapping key habitat features including refuge pools, throughout the catchment would add value to the future revision of EWRs needed to inundate and maintain key features	DPIF, DPIE–BC, CEWO

Risk	Description	Potential management strategies	Potential project partners
Future development of water infrastructure in the Peel Valley (and potentially elsewhere in the future)	There is a current proposal to build: • a pipeline between Chaffey Dam and Dungowan • a new dam at Dungowan and • a second pipeline between Dungowan dam and Tamworth City as a drought measure. This proposed infrastructure has unknown impacts to the local environment and hydrology between Chaffey Dam and Tamworth, with potential effects felt further downstream.	Ensure EWRs are considered when assessing feasibility and impact of new infrastructure projects. Any model runs should test against EWRs in the LTWP Ensure there is no reduction in PEW when considering any new infrastructure projects DPIE–EES to provide input into the environmental impact assessment process	DPIE–W, WaterNSW, DPIE–BC and DPI–F
Cold water pollution (CWP)	Cold water releases from Keepit Dam was considered high risk in the DPI Risk Assessment. Research has shown that both Chaffey and Split Rock Dams also cause cold-water pollution downstream, in spite of them being fitted with multi-level outtakes. This temperature suppression can change the distribution of species, reduce the opportunity and success for effective reproduction and recruitment, reduce body growth, condition, metabolism, swim speed, and decrease riverine productivity	Continue to implement the NSW Cold Water Pollution Strategy Continue to implement CWP operating protocol: 'Managing Cold Water Pollution and Cyanobacteria in WaterNSW Rural Storages with Variable Offtake Structures'; monitor performance and revise accordingly Acknowledging the limitations of surface level offtake infrastructure where blue green algae is problematic. Through the CWP Inter Agency Working Group, and other agencies partnerships, investigate feasibility and trial alternate technology not constrained by potentially toxic blue green algae to improve temperature outcomes Future Keepit DSU planning should consider the performance of the *Managing Cold Water Pollution and Cyanobacteria in WaterNSW Rural Storages with Variable Offtake Structures'* protocol in achieving desired temperature outcomes in the scoping of appropriate CWP mitigating options	DPIE–Water and WaterNSW

Risk	Description	Potential management strategies	Potential project partners
		If it is determined that the revised operating protocols to mitigate CWP across relevant Namoi dams are ineffective, alternate mitigation measures should be pursued	
Pumps and other water offtakes impacting on LTWP fish objectives	Irrigation development and associated pumping from rivers in the MDB has been identified as a significant impact on native fish. Fish mortality and entrainment is most significant in instances where high flow pumps are used (> 200mm)	Implement Fish and Flows report recommendation for fish protection measures / fish screening to be installed on pipes over 200mm diameter Implement NSW Department of Primary Industries, Fisheries (2017): *Fish for the Future: Action in the Northern Basin - NSW proposal for Northern Basin Toolkit measures to promote native fish health* measures for fish-friendly water extraction	DPIF
Poor water quality, including hypoxic and thermal pollution impacts affecting LTWP fish and functions objectives	Water quality affects the ecology and survival of aquatic organisms. Hypoxic events can occur with the release of water after dry or low-flow periods. 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 Thermal pollution can occur at Chaffey and Split Rock Dams when the multi-level offtakes are not operated optimally for temperature outcomes in instances when algal blooms are present. CWP can occur any time at Keepit dam	Implement recommendations and strategies for use of WQA detailed in the *Water Quality Management Plan*	DPIE–Water
		Implement water management and river operations practices that promote healthy waterways, for example the use of very low flows to destratify refuge pools and maintain water quality	WaterNSW
		Manage salinity in accordance with the *Basin Salinity Management Strategy*	DPIE–W
		DPIE–BC operating protocols for restarting rivers with flow rates that reduce the risk of hypoxic blackwater, informed by water quality monitoring (refer to the Gwydir protocol)	WaterNSW
		Provide flow regimes that avoid extended dry or very low-flow periods	Water NSW, DPIE–BC and DPIE–W
		Map high-risk areas and high-priority refuge areas, and determine their persistence and water quality	DPIE–BC, DPIE–W and DPIF
		Monitor dissolved oxygen for active management of water actions	DPIE–W

Risk	Description	Potential management strategies	Potential project partners
		Support and implement land management strategies that aim to reduce impacts on water quality (for example revegetation, prevent run-off)	LLS with Landholders, Landcare, DPIE–BC, DPIF, CEWO
Native vegetation clearing impacting on LTWP vegetation and waterbird habitat objectives	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 using legislation and native vegetation planning processes	DPIE–BC, LLS, BCT and DPI
		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 LLS and landholders	DPIE–BC, DPIF, BCT, LLS
Impacts of unmanaged total grazing pressure and stock access to waterways impacting on LTWP vegetation targets	If not managed carefully, grazing pressure from stock and access of stock to riverbanks can: reduce native vegetation cover which allows weeds to establish reduce streambank stability damage important instream habitat reduce water quality Grazing on the floodplains can also prevent necessary regeneration and recruitment of woodland vegetation, resulting in the loss of important riparian vegetation over the longer term.	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, landholders, LLS
		Implement grazing strategies that protect and restore wetland vegetation	LLS, Landholders
		Investigate incentives to improve management of wetlands on private land	LLS, DPI Agriculture
		Communicate and promote best practice management	LLS
		Inform community about funding opportunities for rehabilitation of riparian habitats	DPIE–BC, DPIF, LLS
		Communicate sensitive grazing practices to graziers to allow for natural generation within stream and on the floodplain	DPIE–BC, DPIF, LLS
		Work with landholders to protect areas of natural regeneration	DPIE–BC, DPIF, LLS
Spread and success of pest plant species	The environmental flow regimes required for native fish, vegetation and	Map and identify riparian and aquatic habitat condition to inform development of formal agreements in a unified strategy	DPIE–BC, DPIF, LLS

Risk	Description	Potential management strategies	Potential project partners
impacting on achieving LTWP vegetation objectives	waterbirds can sometimes also promote the growth and spread aquatic and terrestrial weed species including lippia, Noogoora burr, tobacco weed, Alligator week, Willows and other invasive species. The community are also very concerned about Willows along the riparian corridor, how much water they use and how they perpetuate erosion along the riverbank compared to native species.	Prioritise reaches for weed management in partnership with LLS and landholders	DPIE–BC, 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, Local Council
		Negotiate and implement easement agreements that recognise greater need for weed management to supplement existing weed management on private land	DPIE–BC, LLS
		Initiate a weed control program that focuses on the removal of Willows and Weeds of National Significance (WONS) along infested reaches – incorporate interested members of the community where possible	DPIE–BC, LLS, Landholders
		Inundate wetlands for enough time to favour native wetland species growth and reduce the extent of invasive species	DPIE–BC, CEWO
Spread of pest animal species impacting on achieving LTWP vegetation, fish and waterbird objectives	The current flow regime, including environmental water may support range expansion and population growth of pest species. These pest species reduce the benefit of environmental water for native species	Investigate a carp management plan for the Namoi catchment and support the development and implementation of the carp herpes virus	DPIF, WaterNSW and DPIE–BC
		Support education and awareness of aquatic biosecurity risk, including preventative Tilapia education and awareness	DPIF, DPIE–BC, CEWO, LLS, MDBA. Local Government, recreational fishers, aquarium industry, cultural groups and riparian landholders
		Implement proposals in *Fish for the Future: Action in the Northern Basin—NSW proposal for Northern Basin Toolkit measures to promote native fish health*. (NSW Fisheries, 2017)	DPIE–BC, DPIF

Risk	Description	Potential management strategies	Potential project partners
		Support recommendations in pest species management plans, with implementation of control programs such as those for: • carp (see NSW I&I 2010), including the cyprinid herpesvirus-3 if recommended by the National Carp Control Program (FRDC in prep) • other invasive fish such as Redfin and Gambusia and Tilapia (competition with native fish and predation) • pigs (vegetation, predation impacts) • goats (vegetation impacts) • foxes and cats (predation impacts).	DPIF, LLS, Landholders, DPIE–BC and NPWS
		Investigate the use of regulatory structures to complement water actions. For example, close regulating structures after watering to allow wetland drying and kill invasive fauna	DPIE–BC, DPIF, WaterNSW
Reduced in-channel productivity due to sedimentation	Removal of scouring flows has allowed sedimentation to accrue which impacts on in-channel productivity	Consider reinstating flows of appropriate velocity to create scour	DPIE–BC, CEWO, WaterNSW
Erosion and sedimentation may impact upon various LTWP objectives	Erosion (both natural and accelerated) and sedimentation may result in a variety of changes that affect the LTWP targets, including: vegetation (inundation extent change, changes in streams) waterbird habitats water quality longitudinal and lateral connections Refuge pool persistence	Protect variable flows and ecologically desirable flow recession rates in river operations to reduce bank slumping	DPIE–BC, 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, WaterNSW
		Manage environmental waters to mimic natural flow patterns and variability (where possible)	DPIE–BC, DoI–W, WaterNSW, CEWO
		Investigate methods for improving the seasonal pattern and variability of water delivery	DPIE–BC, WaterNSW, CEWO

5.3 Dealing with risks of climate change

Climate change is a key long-term risk to river, wetland and floodplain health. It does, and will continue to, 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.

In NSW, average temperatures have been steadily rising since the 1960s. The decade from 2009 to 2018 was the hottest on record, while 2018 was the hottest year in NSW (BOM 2019). Projections for the state's annual average rainfall range from a becoming 10% dryer to 11% wetter by 2030 (OEH 2014).

The Namoi region has warmed by around 0.8°C since 1950 (CSIRO 2007). Maximum temperatures are projected to increase by 0.7°C in the near future (2030) and by 2.2°C in the far future (2070) (OEH 2014). Spring will experience the greatest changes in maximum temperatures increasing by 2.5°C by 2070 (OEH 2014).

The number of droughts per decade are predicted to double by 2030 (CSIRO 2007). Rainfall projections span both drier and wetter scenarios in the near future: of up to an additional 13% rainfall, to a reduction in rainfall of 9% (OEH 2014). Beyond the 2070 timeframe, the predictions are more severe, for example a potential four-fold increase in the number of droughts per decade (CSIRO 2006).

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 Namoi region (CSIRO 2008). Surface water and runoff across the entire basin are expected to decline due to climate change, with up to:

- a 10% reduction in average annual runoff to rivers in the Namoi catchment
- a 13% reduction in end-of-system flows (not withstanding WSP rules).

According to the NSW and ACT Regional Climate Model "NARCLiM" model[19] (scenario 2), the changes in Table 13 are predicted by 2030 and 2070 across different areas of the catchment.

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

[19] 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 13 Potential climate-related risks in the Namoi catchment

Potential climate change risk	Description of risk		**NARCLiM projection** (scenario 2)					
			2020–39			**2060–79**		
			Upper Namoi[20]	South west Namoi [21]	Lower Namoi[22]	Upper Namoi	South west Namoi	Lower Namoi
Change in rainfall	Rainfall is projected to vary across the region, with the greatest increases predicted to occur during summer and autumn and a decrease during spring.	Summer	-3.3%	-1.1%	+3.1%	+9.8%	+13.2%	+12.6
		Autumn	+14.9%	+14.7%	+14.1%	+16.8%	+13.5%	+13.7
		Winter	-7.6%	-4.2%	-7.2%	-0.7%	+5.4%	+4.1%
		Spring	+2.6%	-7.6%	-10.3%	-0.7%	-5.8%	-5.4%
Change in average temperature	Mean temperatures are projected to increase in both the near and far future, by up to 2.49 ºC. All models show there are no declines in mean temperatures across the Namoi regions.	Summer	+0.89ºC	+0.95°C	+0.90ºC	+2.4 ºC	+2.44°C	+2.49ºC
		Autumn	+0.75ºC	+0.65°C	0.59ºC	+2.16ºC	+2.04°C	+2.05ºC
		Winter	+0.48ºC	+0.40°C	0.41ºC	+1.92ºC	+1.65°C	+1.64ºC
		Spring	+0.8ºC	+0.80°C	0.80ºC	+2.33ºC	+2.30°C	+2.31ºC
Change in number of hot days (maximum temperature >35°C)	Hots days are projected to increase across the region by an average of 9.2 days per year by 2030. The greatest increases are seen further west in the region, past Wee Waa. By 2079, this area could have an additional 35 days above 35 ºC.	Annual	+7.1	+9.1	+11.5	+23.4	+27.0	+35.1

[20] Upper Namoi refers to the New England and North West region in the NARCLiM.

[21] South west Namoi refers to the Central west and Orana region in the NARCLiM.

[22] Lower Namoi refers to the Western NSW region in the NARCLiM.

Potential climate change risk	Description of risk	NARCLiM projection (scenario 2)						
			2020–39			2060–79		
			Upper Namoi[20]	South west Namoi [21]	Lower Namoi[22]	Upper Namoi	South west Namoi	Lower Namoi
Change in number of cold nights (minimum temperature <2°C)	Cold nights are projected to decrease across the region by an average of 6.5 fewer nights per year by 2030. Changes in cold nights can have considerable impacts on native ecosystems.	Annual	-8.8	-7.7	-3.2	-26.1	-22.5	-9.5
Bushfires Changes in number of days a year FFDI>50[23]	All fire weather is likely to increase across the Namoi catchment, especially in the west. Severe fire weather is projected to increase across the region by 2030 during summer and spring. There is no increase in the Forest Fire Danger Index in Autumn and Winter.	Annual	+0.2	+0.5	+1.3	+0.9	+1.3	+3.2
Hillslope erosion[24]	Changes in erosion can have significant implications for natural assets and water quality. Removal of groundcover will increase the risk of erosion significantly, especially by 2079.	Mean per cent change	4.3%	4.6%	4.32%	17.4%	20.0%	17.41%
Biodiversity	Rising temperature, increased fire frequency and changing fire regimes, storm damage and potentially drought will all affect species composition							

[23] 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.

[24] Xihua *et al.* 2015

Strategies for mitigating climate-related risks

Environmental water managers have become experienced in dealing with variable water availability, using management practices and responses that have been 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 and forecasts, such as rainfall and evaporation rates, to inform their understanding of the impacts of climate at the catchment scale.

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.

Nevertheless, for the long-term survival of the environmental assets of the Namoi catchment, a proactive approach will be required to adapt to climate change. This involves:

- supporting a resilient aquatic ecosystem to buffer some effects of changing climate
- proactively managing for worst-case scenarios and setting aside water to manage assets during dry times
- undertaking important research to answer important questions about how climate change will affect river operations. For example:
  - How will the volume of water stored in Chaffey, Split Rock and Keepit Dams be affected by climate change?
  - How will water availability, reliability and quality be affected by climate change?
  - 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 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 Namoi?
- partaking in the Critical Water Advisory Panel and implementing the Extreme Events Policy
- reviewing the Available Water Determination (AWD) process to ensure it is adaptive and includes severe droughts that have occurred in recent times in the Namoi
- proactively managing breeding of threatened fish species in hatcheries, so that local extinctions do not occur, and to also to aid dispersal objectives and targets
- working with all stakeholders to manage the catchment as a complete system, including groundwater, surface water, regulated and unregulated components.

Beyond this, there are other projects in the Namoi catchment that aim to create a more resilient region in a future affected by climate change. The Western Enabling Regional Adaptation (WERA) project builds on local knowledge to understand climate vulnerabilities in the New England North West region and identifies opportunities to respond to them. Eight regional systems were identified as particularly vulnerable and in need of change to ensure effective ongoing government service planning and delivery. Water was identified as a key system to transition and the project acknowledges the importance of water availability across all eight systems.

There may be opportunities in the future to align the WERA transition projects with the management strategies of this LTWP to achieve environmental outcomes in the catchment. Embedding the actions in the transition pathways into project and program development will aid cross-sectoral adaptation and support regional efforts to transform to a desirable future.

6. Water management under different water availability scenarios

6.1 Prioritisation of ecological objectives and watering in regulated areas

Environmental water managers 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 chapters contains three parts:

1. the broad priorities to guide management under the particular scenario
2. the potential management strategies for achieving these priorities
3. tables identifying the priority LTWP objectives for each scenario and target flow categories (marked with an X) (Tables 14–21).

Some of the wording of the LTWP objectives has been adjusted to highlight the most relevant aspect of the objective under the scenario. For example, a LTWP objective that over 20 years seeks 'improvement' may only seek to 'maintain' under a dry scenario. Some of the objectives have been 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.

Figure 18 Namoi River, The Rocks, near Wee Waa
Photo: T Cooke

Water resource availability scenario: Very dry – Protect

Table 14 Management priorities and strategies for a very dry RAS

	Broad management priorities	Management strategies for achieving priorities
Very Dry	Avoid critical loss of species, communities and ecosystems Maintain refuges Avoid irretrievable damage or catastrophic events Avoid unnaturally prolonged dry periods between flow events Support targeted longitudinal connectivity within catchment for functional processes and a range of flora and fauna Prevent two consecutive years of extreme dry to core wetland areas	Focus on limiting exceedance of maximum inter-flow periods through the following strategies: Allow dry down consistent with historical wetting-drying cycles Sustain water level and water quality in key in-channel pools, instream habitat and core wetland areas[25] 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 water shortage or similar critical incident restricts the use of water for the environment, then DPIE–BC as part of the Critical Water Advisory Panel, will work to minimise exceedances of maximum inter-flow periods for important areas.

[25] Alternative watering actions may be required to support floodplain habitats to prevent threatened fish species from drying out.

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

Priority objectives	Flow categories: Cease-to-flow	Very Low Flow	Baseflow	Small Fresh[26]	Large Fresh	Bankfull	Anabranch connection	Small Overbank	Large Overbank
NF1: No loss of native fish species	X	X	X						
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	X	X	X					
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in core wetlands			X						
WB5: Maintain the extent and improve condition of waterbird habitats			X						
EF1: Protect a diversity of refugia across the landscape	X	X	X	X					
EF2: Maintain quality instream and wetland habitat	X	X	X						
EF3: Provide movement and dispersal opportunities within catchments			x						
EF7: Connection to Barwon Darling[27]		x							

Water resource availability scenario: Dry – Maintain

Table 16 Management priorities and strategies for a dry RAS

	Broad management priorities	Management strategies for achieving priorities
Dry	Support the survival and viability of threatened species and communities Maintain refuges Maintain environmental assets and ecosystem functions Avoid unnaturally prolonged dry periods between flow events Support longitudinal connectivity for functional processes and a range of flora and fauna	Allow dry down consistent with historical wetting-drying cycles Sustain key in channel pools, instream habitat and core instream wetland areas Provide freshes to channels and 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

[26] Small freshes may be important and achievable in a very dry scenario to protect core wetland habitats and avoid critical habitat loss.

[27] This will connect catchments, but not provide sufficient water for dispersal or migration opportunities for fish.

Table 17 Priority objectives and flow categories in a dry RAS

Priority objective	Flow categories								
	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Bankfull	Anabranch connection	Small Overbank[28]	Large Overbank
NF1: No loss of native fish species	X	X	X	X					
NF2: Maintain the distribution and abundance of short to moderate-lived generalist native fish			X	X					
NF3: Maintain the distribution and abundance of short to moderate-lived floodplain specialist native fish			X	X					
NF4: Maintain native fish population structure for moderate to long-lived flow pulse specialist native fish			X	X					
NF5: Maintain native fish population structure for moderate to long-lived riverine specialist native fish			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					
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in core wetlands			X	X					
WB1: Maintain the number and type of waterbird species			X	X					
WB2: Maintain total waterbird abundance across all functional groups			X	X					
WB5: Maintain the extent and improve condition of waterbird habitats			X	X					
EF1: Protect a diversity of refugia across the landscape		X	X	X					
EF2: Maintain quality instream, floodplain and wetland habitat	X	X	X	X					
EF3: Provide movement and dispersal opportunities within catchments			X	X					
EF5: Support nutrient, carbon and sediment transport along channels				X					
EF7: Connecting to Barwon-Darling		X	X						

Water resource availability scenario: Moderate – Recover

Table 18 Management priorities and strategies for a moderate RAS

	Broad management priorities	Management strategies for achieving priorities
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 and bankfull flows to channels where possible at ecologically relevant times[29] Improve condition of key off channel waterholes[1] 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 Consider carrying over water to support water use in drier years

Table 19 Priority objectives and flow categories in a moderate RAS

Priority objectives	Flow categories								
	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Anabranch	Bankfull	Small Overbank	Large Overbank
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			X	X	X				
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish			X	X	X	X		X	
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish			X	X	X				
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish			X	X	X				
NF6: A 25% increase in abundance of mature (harvestable sized) Golden perch and Murray Cod			X	X	X				

[29] Includes extending duration of flows to support waterbird colonies if they establish and need intervention.

Priority objectives	Flow categories								
	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Anabranch	Bankfull	Small Overbank	Large Overbank
NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish into new areas			X	X	X			X	
NF9: Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish 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	X	
NV2: Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains							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	
NV4a: Maintain the extent and maintain or improve the condition of native woodlands and shrublands on floodplains						X	X	X	
NV4b:						X	X	X	
NV4c:						X	X	X	
NV4d:						X	X	X	
NV4e:						X	X	X	
WB1: Maintain the number and type of waterbird species							X	X	
WB2: Increase total waterbird abundance across all functional groups							X	X	
WB5: Maintain the extent and improve condition of waterbird habitats							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			X	X	X	X	X	X	
EF4: Support instream and floodplain wetland productivity					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: Connect to the Barwon					X		X	X	

Water resource availability scenario: Wet – Improve

Table 20 Management priorities and strategies for a wet RAS

	Broad management priorities	Management strategies for achieving priorities
Wet	Enable growth, reproduction and large-scale recruitment for a diverse range of flora and fauna Support longitudinal connectivity within and between catchments for functional processes and a range of flora and fauna Support high flow lateral connectivity and end of system flows Set aside water for use in drier years	Where possible, build on natural events to provide wetland and floodplain inundation at ecologically relevant times4 Protect naturally occurring floodplain wetland inundating events and high flow connectivity with the Namoi Provide flows to systems that are otherwise cut off from natural flows 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 21 Priority objectives and flow categories in a wet RAS

Priority objectives	Flow categories								
	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Anabranch connection	Bankfull	Small Overbank	Large Overbank
NF1: No loss of native fish species	X	X	X	X	X	X		X	X
NF2: Increase the distribution and abundance of short to moderate-lived generalist native fish			X	X	X	X			X
NF3: Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish			X	X	X	X		X	X
NF4: Improve native fish population structure for moderate to long-lived flow pulse specialist native fish			X	X	X	X			X
NF5: Improve native fish population structure for moderate to long-lived riverine specialist native fish			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
NF8: Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish into new areas			X	X	X	X		X	X
NF9: Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish into new areas			X	X	X	X		X	X

Priority objectives	Cease-to-flow	Very Low Flow	Baseflow	Small Fresh	Large Fresh	Anabranch connection	Bankfull	Small Overbank	Large Overbank
	Flow categories								
NV1: Maintain the extent and viability of non-woody vegetation communities occurring within channels	X	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 improve the condition of river red gum communities closely fringing river channels					X	X	X	X	
NV4a: Maintain the extent and maintain or improve the condition of native woodlands and shrublands on floodplains						X		X	X
NV4b:						X		X	X
NV4c:						X		X	X
NV4d						X		X	X
NV4e						X		X	X
WB1: Maintain the number and type of waterbird species						X	X	X	X
WB2: Increase total waterbird abundance across all functional groups						X	X	X	X
WB5: Maintain the extent and improve condition of waterbird habitats					X	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	X
EF3: Provide movement and dispersal opportunities within and between catchments			X	X	X	X	X	X	X
EF4: Support instream and floodplain wetland productivity					X	X	X	X	X
EF5: Support nutrient, carbon and sediment transport across the catchment				X	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 Barwon-Darling from tributaries		X	X	X	X		X	X	X

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

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

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

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

Tables 22 and 23 describe critical water quality incidents and extreme conditions respectively, and recommended management strategies for environmental water managers. In these two instances, the management priorities of water managers are to:

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

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

Figure 19 Cattle crossing on the Namoi River at Walgett
Photo: T Cooke

Table 22 Priorities and strategies for managing water during extreme conditions

Extreme conditions description	Identifying features	Management strategies for achieving priorities
A critical drought and/or water shortage where only restricted town water supply, stock and domestic and other restricted high priority demands can be delivered	Very low to no natural or regulated flows resulting in disconnected pools Limited water held in storages Limited ability to deliver water for critical human needs WSP may be suspended	DPIE–BC will develop priority environmental water needs in consultation with Namoi stakeholders, 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[Error! Bookmark not defined.] to r elieve severe unnatural prolonged dry periods and support suitable water quality in critical refuge pools

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[30]	Weir/refuge pools are stratified Water quality sampling and analysis demonstrates unfavourable conditions: • lack of dissolved oxygen[31] • unnatural change in temperature • unnatural change in pH • unnatural change in salinity • excess suspended particulate matter[32] • elevated levels of nutrients[33] • chemical contamination[34]	DPIE–BC will develop priority environmental water needs in consultation with Namoi stakeholders, 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[35] to support suitable water quality in rivers and critical refuge pools[36] 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 Limit exceedance of maximum inter-event periods for floodplain inundating flows to reduce the risk of hypoxic blackwater events

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

6.3 Protection of ecologically important flow categories in unregulated areas

In areas where water cannot be delivered through a regulating structure, the primary means of protecting environmentally important flows is through pumping access rules in the WSP for the Namoi Unregulated and Alluvial Water Sources 2012 and the WSP for the Peel Valley regulated, unregulated, alluvial and fractured rock water sources 2010. Table 24 sets out potential management strategies that could be implemented in the WSP to ensure important flows are protected.

Table 24 Potential management strategies to protect ecologically important flows in unregulated areas

Flow category	Potential management strategies	Most relevant weather scenarios
Cease-to-flow	Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate Consider reviewing cease-to-pump rules to reduce the length of cease-to-flow periods Consider implementing a first flush rule to ensure cease-to-flow periods are broken at ecologically relevant times and with events of sufficient magnitude to avoid adverse water quality incidents	Very dry Dry
Low flows and baseflows	Consider rostering landholder water access during low flow months or when flows begin to approach the cease-to-pump flow rate Consider reviewing cease-to-pump rules to better protect low flows and baseflows especially during dry times or ecologically important months	Very Dry Dry
Freshes	Consider implementing a first flush rule to protect freshes at ecologically relevant times Consider implementing extraction limits during ecologically important months[37]	Very dry Dry Moderate
Entire flow regime, including overbank and wetland inundating flows	Consider targeted water access licence purchases from willing sellers where flows are acutely impacted Ensure compliance with water access licence conditions[38] Consider implementing extraction limits during ecologically important months[8] Consider protection of water for the environment (PEW and HEW) that originates from regulated planning units that enters unregulated sections[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

[37] 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

[38] Potentially requires improved water metering and gauging in certain areas

[39] Requires adequate compliance measures and potentially requires improved water metering and gauging in certain areas

7. Going forward

The BWS notes that 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). This section identifies opportunities for cooperation and priority investments that make the best use of all water and support environmental objectives.

7.1 Cooperative arrangements

River operations to benefit the environment

Making the best use of all water is a key strategy to achieve the objectives in this Plan. In some cases, river operating practices could be revised to provide the operators with a mandate to manage rivers so that environmental outcomes can be achieved. The risks and constraints to achieving the EWRs (Tables 11 and 12) described in this Plan identify some river management practices that are currently limiting or impacting on the ability to achieve ecological objectives.

The Plan identifies the following strategies to maximise the benefit of all water in the system:

- investigate options for the delivery of water orders to more closely mimic natural flow events
- establish better channel sharing or enabling delivery 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 all three Namoi catchment dams to mimic natural rates of fall.

Coordinating deliveries of held environmental water with consumptive deliveries or natural/tributary flow events can help to achieve greater flow volumes from the smarter use of all water. Such arrangements could enable larger in-channel and, where permitted, 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 the volumes described in many EWRs, without any contribution of environmental flows or 'top-up' flows to meet specific breeding requirements or durations. One of the primary recommendations of this LTWP is to investigate the potential to optimise these outcomes, by supporting collaboration between DPIE-BC and WaterNSW to assist in shaping consumptive deliveries to meet EWRs 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.

In NSW, water for the environment is managed cooperatively by three government agencies: DPIE–BC, CEWO and DPIE–Water. Together these agencies manage the NSW environmental contingency allowance, Commonwealth HEW portfolios (DPIE–BC and CEWO), and the WSPs that provide PEW throughout the system (DPIE–W).

Environmental Water Advisory Groups (EWAGs) are a collaborative model that draw on the expertise and experience of community members to help inform how discretionary environmental water may be used. They may include water managers, recreational fishers, landholders, Aboriginal groups, independent scientists, local government representatives and a variety of partner agencies. An EWAG will be established in the Namoi catchment.

This LTWP recommends building on the existing cooperative arrangement to further optimise outcomes from all dedicated environmental water and increasing the scope for strategic and coordinated environmental water management.

Cooperative natural resource management for environmental outcomes

To achieve the LTWP's 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 plan in these areas.

Complementary management of water dependent environmental assets is vital to the success of this plan. 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, private industry groups, individual landholders and community groups that ensure adequate stewardship of environmental assets are essential to the success of this plan. Actions to secure and formalise the continuity of these arrangements with relevant landholders and agencies are supported.

Cooperative investment opportunities

A number of significant investment priorities have been identified in the Namoi catchment (Table 25). Identification of funding opportunities and subsequent implementation of projects to address these priorities would contribute significantly to the environmental outcomes identified in this plan.

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

Table 25 Investment opportunities to improve environmental outcomes from water management in the Namoi catchment

Investment opportunity	Description	Potential project partners
Increase engagement capacity	There is a strong community in the Namoi catchment, who share a keen interest and willingness to be involved in how water is managed across the catchment. As part of the creation of the LTWP, DPIE–BC initiated a number of stakeholder workshops in the catchment. Through these workshops it was clear that the community want: • Increased engagement, including the formal creation of Environmental Water Advisory Group (EWAG) with diverse representation from the community • Increased education and understanding about environmental water and water management in the catchment. The ongoing direct support of the community and landholders is essential to any system-level efforts to arrest the decline and restore important ecological assets and functions in the Namoi catchment. Integrating the community into all of the potential investment projects below will ultimately lead to a better LTWP outcomes in the future.	NBAN, Land council, Traditional Owners, Local council, LLS, landholders, general community
Improving knowledge of EWRs in the Namoi to facilitate improvements in the LTWP	Despite recent research, there are considerable knowledge gaps in the Namoi that require further research and monitoring to fully understand the value, condition and watering requirements of key wetland and channel assets. Such understanding will broaden the number and effectiveness of EWRs identified by this LTWP. Key work areas include: • ·extending remote-sensed inundation mapping • ·identifying high quality habitat drought refugia • ·expanding habitat mapping • ·identifying the location and watering needs of cultural assets • ·hydrological analysis and modelling to determine the underlying reasons for some EWRs that are unlikely to occur in the future • ·predicted impacts of climate change on current and future water availability in the WRPA • ·identifying water-dependent communities that are supported by groundwater As regionally specific information grows, revision of the objectives, targets and/or EWRs will be required.	DPIE–BC, CEWO, DPI-F
Identifying cultural assets and capacity building for First Nations people	Many of the ecological values across the Namoi catchment have cultural value and significance to First Nations people and Traditional Owners. Better engagement, opportunities for co-learning and the sharing of knowledge, including of contemporary water management and cultural values and uses will provide benefits to both local communities and environmental water management. This engagement will help identify the co-benefits that environmental water management can deliver relative to water dependent cultural uses and values. Inclusion of First Nations representation into the future EWAG will provide opportunity for First Nations people to inform decisions about how environmental water is used.	First Nations people, DPIE–BC, CEWO, MDBA and DPI-F.

Investment opportunity	Description	Potential project partners
Aquatic habitat mapping	From the NSW Proposal for the Northern Basin Toolkit (NSW Government 2017): Detailed aquatic habitat mapping has been undertaken along a 150 km section of the Namoi River from Gunnedah to Mollee Weir. The mapping recorded a benchmark of aquatic habitat features, as well as issues affecting habitat condition. Features of instream and riparian habitat, including large woody habitat, deep refuge areas (and how long they persist for during dry times), riffles, aquatic macrophytes, exotic plant species extent and distribution, and effects of land management such as erosion, have been recorded and digitised to identify key habitat elements, as well as identify locations for protection or improvement. Continuing and expanding this project would provide essential information to underpin water management actions and priorities across the whole of the Namoi–Peel catchment. This project could also inform the success and review of EWRs relating to flows required to replenish and de-stratify refuge pools.	NSW Government (LLS, DPIE–BC, DPIF, BCT), CEWO, Landholders, Local Council
Reconnecting the Northern Basin – Fish passage barrier remediation	Native Fish are declining within the Murray–Darling Basin. Both the NSW Proposal for the Northern Basin Toolkit (NSW Government) and the Fish and Flows report (DPI–F 2018 in prep) have identified that barriers to fish dispersal and migration are a key reason for this decline and propose remediation of fish barriers. Continuing to remove, remediate or re-engineer these structures will help achieve long term outcomes for fish and ecosystem function in the catchment and enhance the benefits of water recovery efforts in the Namoi and Northern Basin. Proposed remediation options include rock ramp fishways and vertical slot fishways. Refer to the Fish and Flows report (DPI–F 2019 in prep) for information on specific barriers which are of concern.	DPIF, DPIE–Water, landholders, WaterNSW
Cold water pollution mitigation at Chaffey, Split Rock and Keepit Dams	In the NSW Proposal for the Northern Basin Toolkit (NSW Government 2017), three priority dam structures are proposed for remediation, improving water quality to 294 km of waterway in the Namoi catchment. Cold water pollution mitigation activities would complement previous habitat rehabilitation and fish passage investment within the valley, enhancing river health and native fish outcomes in the Namoi. • Keepit Dam on the Namoi River: 141km impacted by CWP • Split Rock Dam on the Manilla River: 90km impacted by CWP • Chaffey Dam on the Peel River: 63km impacted by CWP This project will be able to protect and restore water-dependent ecosystems such as rivers, wetlands and floodplains, protect and restore ecosystem functions of water dependent ecosystems including water quality and connectivity, ensure that water-dependent ecosystems are resilient to climate change and other risks and threats and optimise social, economic, environmental outcomes arising from the use of Basin water resources.	WaterNSW (project owner), NSW Government (DPIF, DPIE–BC), MDBA, CEWO.

Investment opportunity	Description	Potential project partners
Protect and improve riparian habitat	From the NSW Proposal for the Northern Basin Toolkit (NSW Government 2017): The riparian and aquatic habitat of the Namoi has suffered a serious decline in quality and quantity since European settlement. This pressure has impacted the integrity of the ecological communities themselves and the wildlife that depend on them. It is proposed that a range of rehabilitation activities be undertaken at priority locations to protect and restore water-dependent ecosystems such as rivers, wetlands and floodplains and their ecosystem functions. This project would include grazing management and strategies that protect and restore wetland vegetation, bank stability and water quality. The intent is to provide incentives to landholders to improve management of riparian and or water-dependent vegetation and wetlands on private land and commence wetland restoration activities in key assets, in partnership with private landholders. This would build upon the demonstration reach between Gunnedah and Wee Waa. Extensive community engagement has also been undertaken as part of these activities, and a monitoring and evaluation plan has been developed focussing on trends in fish assemblages across the reach.	NSW Government (LLS, DPIE–BC, DPIF, BCT), CEWO, Landholders, First Nations people
Fish-friendly water extraction	From the NSW Proposal for the Northern Basin Toolkit (NSW Government 2017) It is an objective of this plan and the Basin Plan to ensure no loss of native fish species. However, currently millions of native fish are lost from rivers every year, being extracted by pumps and diverted into channels, significantly compromising our ability to achieve these objectives. Screens can stop fish and debris entering pumps and diversions. This large-scale project will begin transformational change in the Murray-Darling Basin by installing diversion screens at priority sites across the Northern Basin, including the Namoi. In the Namoi catchment, there are 245 small (200–500 mm), 205 medium (500–900 mm) and 6 large (>900 mm) pumps. Screening greatly reduces fish entrainment, the mostly passive movement of fish and other aquatic organisms carried along with diverted flow. This work identified a substantial opportunity to collaborate with industry and tertiary institutions to improve water diversion practices in a way that can protect and boost native fish populations and the river ecosystems they inhabit.	DPIF, CEWO, WaterNSW
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

Investment opportunity	Description	Potential project partners
Restoring flow connections between environmental assets in floodplains	Floodplain wetlands are increasingly disconnected from rivers due to river regulation. Some floodplain structures also prevent water from flowing across the landscape. Understanding and improving the connection between rivers and floodplain wetlands will improve the health of these systems. Under the NSW Healthy Floodplains Project, there is a strategy in place to identify and prioritise the remediation of existing flood works that are causing significant impacts on important environmental assets across the Northern Basin floodplains of NSW.	DPIE-Water, MDBA, DPIE
Improve measurement of floodplain harvesting take	Floodplain harvesting take is not currently measured in NSW. Accurately measuring floodplain harvesting take is important to building the evidence base around the hydrologic and ecological impacts of floodplain harvesting. It would also help water managers better understand 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.	DPIE–Water, MDBA, DPIE-BC
Research - Vegetation mapping west of Wee Waa	The floodplain vegetation west of Wee Waa out to Walgett has been mapped as containing large swathes of coolibah black box EEC. It is currently unclear about what condition this vegetation is in, how frequently it is being inundated, whether regeneration is occurring successfully and what land management practices are currently occurring in those areas. Investing in a vegetation mapping project for this area would provide a lot of useful information that could help direct management actions and help monitor and evaluate the implementation of this Plan.	DPIE–BC, LLS

Investment opportunity	Description	Potential project partners
Research - Understanding the current hydrology and hydrodynamics of the Namoi catchment	A strong outcome of the plan is to improve cooperative river management. This may include combining environmental water to consumptive deliveries to achieve the optimal durations of EWRs. Similarly, cease-to-flow events have been increasing in duration and frequency to the west of the catchment which are affecting end-of-system flows and the connection between the Namoi and the wider Murray-Darling Basin. Having greater insight into the current hydrology and its potential ecological impacts could help direct future river operations or prioritisation of EWRs. As a component of this task, understanding the attenuation of flows through the Namoi River to the confluence would aid understanding and management of the northern basin. Analysis and modelling of the local flow hydrodynamics (including the mosaic of still and flowing habitats, hydrological connectivity, transport of carbon, hydraulic complexity, etc.) in the Namoi catchment would provide a deeper understanding of how aquatic biota survive and recruit. Similarly, understanding inundation characteristics of floodplains for vegetation maintenance and regeneration would provide more specific information about the magnitudes of flows required to achieve necessary periods of inundation for managed vegetation.	DPIE–BC, DPIF
Adapting to climate change	There are climate change adaptation projects in the Namoi catchment that aim to create a more resilient region in a future effected by climate change. The Western Enabling Regional Adaptation (WERA) project builds on local knowledge to understand climate vulnerabilities in the New England North West region and identifies opportunities to respond to them. There may be opportunities in the future to align the WERA transition projects with the management strategies of this LTWP to achieve environmental outcomes in the catchment. Secondly, there is a need to improve understanding about how climate change will affect future water availability in the Namoi catchment. Research on this topic and topics raised in section 5.2.1 would help the community proactively adapt to climate change.	DPIE–BC, Local Councils, DPIE-Water
Monitoring, Evaluation and Reporting	The *NSW Namoi Surface Water Monitoring, Evaluation and Reporting Plan 2019* (NSWMERP) coordinates NSW Government agencies' approach to MER to deliver on Basin Plan and NSW requirements. With additional funding opportunities, further expansion of M&E activities consistent with the intent of the NSWMERP will be considered.	DPIE–BC, DPIF, DPIE–Water

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 landscape and how the environment responds informs ongoing improvements to water management. This information will also assist in informing revisions of this LTWP every five years.

The bulk of NSW Government monitoring and evaluation activities in the Namoi catchment have traditionally been associated with river health related responses to Water Sharing Plan implementation. In more recent times, however, given the purchase of Water Access Licenses by the Commonwealth Government, the implementation of a discretionary Environmental Water Allowance in the Peel River and general Basin Plan implementation, an increased level of monitoring and evaluation activities are now required from both NSW and Commonwealth agencies.

The NSW Monitoring, Evaluation and Reporting Plan (NSWMERP) provides a unified approach to delivering Basin Plan and NSW evaluation and reporting requirements. coordinates NSW Government agencies' approach to MER to deliver on Basin Plan and NSW 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).

Pending the provision of funding for expanded MER programs, the proposed monitoring and evaluation activities in the Namoi catchment include:

- monitoring and reporting by DPIE on the meeting of EWRs (hydrological analysis) and the response of fish, flow-dependent vegetation and waterbirds to decisions made in the management of discretionary environmental flows (Peel ECA and Lower Namoi CEWO HEW)
- Basin Plan Environmental Outcomes Monitoring (BPEOM) of fish populations over time at several locations in the WRPA including the Lower Namoi, Peel, Cockburn and Upper Namoi
- water quality monitoring at key points across the catchment by WaterNSW on behalf of DPIE–Water.

There are also current resources for research by DPIE–Water and others to test the effects of varying supplementary flow water sharing plan rules on the fish population of the Lower Namoi River[40].

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 Namoi 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 Namoi catchment that is relevant to environmental watering
- improved understanding of the effects of climate change and its impacts on the Namoi 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 20 Royal spoonbills
Photo: M Todd

[40] Pending discussions in 2019 and 2020

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Appendix A. Ecological objectives relevant to each planning unit

Table 26 Ecological objectives for each priority environmental asset in the Namoi regulated management area

Code	Ecological objective	Keepit Water Source	Pian Creek Water Source	Lower Namoi Water Source	Keepit to Boggabri	Boggabri To Wee Waa	Duncans Creek	Wee Waa To Barwon River
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	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
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	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
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
NF9	Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish species into new areas (within historical range)		X					X
WB1	Maintain the number and type of waterbird present	X	X	X	X	X	X	X
WB2	Increase total waterbird abundance	X	X	X	X	X	X	X

Code	Ecological objective	Keepit Water Source	Pian Creek Water Source	Lower Namoi Water Source	Keepit to Boggabri	Boggabri To Wee Waa	Duncans Creek	Wee Waa To Barwon River
WB5	Maintain the extent and improve condition of waterbird habitats	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
NV2	Maintain the extent and viability of non-woody vegetation communities occurring in wetlands and on floodplains	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
NV4a	Maintain the extent and maintain or improve the condition of river red gum forest		X	X		X	X	X
NV4b	Maintain the extent and maintain or improve the condition of river red gum woodland	X	X	X	X	X	X	X
NV4c	Maintain the extent and maintain or improve the condition of black box woodland		X	X		X	X	X
NV4d	Maintain the extent and maintain or improve the condition of coolibah woodland	X	X	X	X	X	X	X
NV4e	Maintain the extent and maintain or improve the condition of lignum shrubland		X	X	X	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 for water dependent biota to complete lifecycles and disperse into new habitats.	X	X	X	X	X	X	X
EF4	Support instream and floodplain productivity.	X	X	X	X	X	X	X
EF5	Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands	X	X	X	X	X	X	X

Code	Ecological objective	Keepit Water Source	Pian Creek Water Source	Lower Namoi Water Source	Keepit to Boggabri	Boggabri To Wee Waa	Duncans Creek	Wee Waa To Barwon River
EF6	Support groundwater conditions to sustain groundwater dependent biota.	X	X	X	X	X	X	X
EF7	Increase the contribution of flows into the Murray and Barwon-Darling tributaries.	X	X	X	X	X	X	X

Table 27 Ecological objectives that apply to planning units in the Peel management area

Code	Ecological objective	Peel Regulated River	Cockburn River Water Source	Upper Peel River Tributaries Water Source	Goonoo Goonoo Creek Water Source	Lower Peel River Tributaries Water Source	Chaffey Water Source
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	X	X
NF3	Increase the distribution and abundance of short to moderate-lived floodplain specialist native fish species	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
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	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
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
NF9	Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish species into new areas (within historical range)						
WB1	Maintain the number and type of waterbird present.	X	X	X	X	X	X
WB2	Increase total waterbird abundance.	X	X	X	X	X	X
WB5	Maintain the extent and improve condition of waterbird habitats	X	X	X	X	X	X

Code	Ecological objective	Peel Regulated River	Cockburn River Water Source	Upper Peel River Tributaries Water Source	Goonoo Goonoo Creek Water Source	Lower Peel River Tributaries Water Source	Chaffey Water Source
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 maintain or improve the condition of river red gum communities closely fringing river channels	X	X	X	X	X	
NV4a	Maintain the extent and maintain or improve the condition of river red gum forest				X	X	
NV4b	Maintain the extent and maintain or improve the condition of river red gum woodland	X	X	X			
NV4c	Maintain the extent and maintain or improve the condition of black box woodland						
NV4d	Maintain the extent and maintain or improve the condition of coolibah woodland						
NV4e	Maintain the extent and maintain or improve the condition of lignum shrubland						
EF1	Provide and protect a diversity of refugia across the landscape.	X	X	X	X	X	X
EF2	Create quality instream, floodplain and wetland habitat.	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	X
EF5	Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands	X	X	X	X	X	X
EF6	Support groundwater conditions to sustain groundwater dependent biota.	X	X	X	X	X	X
EF7	Increase the contribution of flows into the Murray and Barwon-Darling tributaries.	X	X	X	X	X	X

Table 28 Ecological objectives that apply to planning units in the unregulated Lower Namoi management area

Code	Ecological objective	Coxs Creek Water Source	Maules Creek Water Source	Etoo and Talluba Creeks Water Source	Werris Creek Water Source	Bundock Creek Water Source	Baradine Creek Water Source	Bluevale Water Source	Eulah Creek Water Source	Rangira Creek Water Source	Coghill Creek Water Source	Bohena Creek Water Source	Spring and Bobbiwaa Creeks Water Source	Brigalow Creek Water Source	Lake Goran Water Source	Warrah Creek Water Source	Quirindi Creek Water Source	Mooki River Water Source	Phillips Creek Water Source
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
NF2	Increase the distribution and abundance of short to moderate-lived generalist native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	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	X	X	X	X	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	X	X	X	X
NF5	Improve native fish population structure for moderate to long-lived riverine specialist native fish species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
NF6	A 25% increase in abundance of mature (harvestable sized) Golden Perch and Murray Cod	X	X	X		X	X	X	X	X		X	X		X	X	X	X	X
NF8	Increase the prevalence and/or expand the population of key moderate to long-lived riverine specialist native fish species into new areas (within historical range)	X	X	X	X		X	X	X	X		X			X	X	X	X	X
NF9	Increase the prevalence and/or expand the population of key moderate to long-lived flow																		

Code	Ecological objective	Coxs Creek Water Source	Maules Creek Water Source	Etoo and Talluba Creeks Water Source	Werris Creek Water Source	Bundock Creek Water Source	Baradine Creek Water Source	Bluevale Water Source	Eulah Creek Water Source	Rangira Creek Water Source	Coghill Creek Water Source	Bohena Creek Water Source	Spring and Bobbiwaa Creeks Water	Brigalow Creek Water Source	Lake Goran Water Source	Warrah Creek Water Source	Quirindi Creek Water Source	Mooki River Water Source	Phillips Creek Water Source
	pulse specialists native fish species into new areas																		
WB1	Maintain the number and type of waterbird present.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
WB2	Increase total waterbird abundance.	X	X	X	X	X	X	X	X	X	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	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	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	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
NV4a	Maintain the extent and maintain or improve the condition of river red gum forest	X	X	X		X	X						X	X					
NV4b	Maintain 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

Code	Ecological objective	Coxs Creek Water Source	Maules Creek Water Source	Etoo and Talluba Creeks Water Source	Werris Creek Water Source	Bundock Creek Water Source	Baradine Creek Water Source	Bluevale Water Source	Eulah Creek Water Source	Rangira Creek Water Source	Coghill Creek Water Source	Bohena Creek Water Source	Spring and Bobbiwaa Creeks Water Source	Brigalow Creek Water Source	Lake Goran Water Source	Warrah Creek Water Source	Quirindi Creek Water Source	Mooki River Water Source	Phillips Creek Water Source
NV4c	Maintain the extent and maintain or improve the condition of black box woodland			X		X	X						X						
NV4d	Maintain 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
NV4e	Maintain the extent and maintain or improve the condition of lignum shrubland			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
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
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	X	X	X	X	X	X	X	X	X	X	X	X
EF4	Support instream and floodplain productivity.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
EF5	Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands	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

Code	Ecological objective	Coxs Creek Water Source	Maules Creek Water Source	Etoo and Talluba Creeks Water Source	Werris Creek Water Source	Bundock Creek Water Source	Baradine Creek Water Source	Bluevale Water Source	Eulah Creek Water Source	Rangira Creek Water Source	Coghill Creek Water Source	Bohena Creek Water Source	Spring and Bobbiwaa Creeks Water Source	Brigalow Creek Water Source	Lake Goran Water Source	Warrah Creek Water Source	Quirindi Creek Water Source	Mooki River Water Source	Phillips Creek Water Source
EF7	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

Table 29 Ecological objectives that apply to planning units in the Upper Namoi management area

Code	Ecological objective	Mid Macdonald River Water Source	Upper Namoi Water Source	Upper Manilla Water Source	Split Rock Water Source	Upper Macdonald River Water Source
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	X	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	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	
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	

Code	Ecological objective	Mid Macdonald River Water Source	Upper Namoi Water Source	Upper Manilla Water Source	Split Rock Water Source	Upper Macdonald River Water Source
NF9	Increase the prevalence and/or expand the population of key moderate to long-lived flow pulse specialists native fish species into new areas (within historical range)	X				
WB1	Maintain the number and type of waterbird present.	X	X	X	X	X
WB2	Increase total waterbird abundance.	X	X	X	X	X
WB5	Maintain the extent and improve condition of waterbird habitats	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 wetlands and on floodplains	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			
NV4a	Maintain the extent and maintain or improve the condition of river red gum forest					
NV4b	Maintain the extent and maintain or improve the condition of river red gum woodland		X			
NV4c	Maintain the extent and maintain or improve the condition of black box woodland					
NV4d	Maintain the extent and maintain or improve the condition of coolibah woodland					
NV4e	Maintain the extent and maintain or improve the condition of lignum shrubland					
EF1	Provide and protect a diversity of refugia across the landscape.	X	X		X	X
EF2	Create quality instream, floodplain and wetland habitat.	X	X	X	X	X

Code	Ecological objective	Mid Macdonald River Water Source	Upper Namoi Water Source	Upper Manilla Water Source	Split Rock Water Source	Upper Macdonald River Water Source
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
EF4	Support instream and floodplain productivity.	X	X	X	X	X
EF5	Support nutrient, carbon and sediment transport along channels, and between channels and floodplains/wetlands	X	X	X	X	X
EF6	Support groundwater conditions to sustain groundwater dependent biota.				X	
EF7	Increase the contribution of flows into the Murray and Barwon-Darling tributaries.	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 sourced from the Bureau of Meteorology and state water agencies. As set out in section 8.61 of the Basin Plan, a RAS will be one of: very dry, dry, moderate, wet, or very wet.

To determine the RAS, the following steps are followed:

a. determine the antecedent conditions for a given WRPA by (the 'X' axis of the matrix in Table 30):
   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 30):
   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 WRPA using all of the historical climate condition data that are available (in Table 30, this is the surface water availability percentile)
d. using the following matrix below, determine the applicable water RAS.

Table 30 Default matrix for determining the RAS

Surface water availability	Antecedent conditions				
	Very dry (0–15%)	Dry (16–45%)	Medium (46–60%)	Wet[42] (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.

[42] Wet and Very wet RAS are combined in this LTWP because the management strategies are the same.