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Chapter 3 Border Rivers Valley Water Plan

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Acknowledgement of the Traditional Owners of the Murray–Darling Basin

The Commonwealth Environmental Water Office respectfully acknowledges the Traditional Owners, their Elders past and present, their Nations of the Murray–Darling Basin, and their cultural, social, environmental, spiritual and economic connection to their lands and waters.

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3.1 Region overview

3.1.1 River system

The Border Rivers Valley covers around 49,500 km^2 in southern Queensland and northern NSW, with roughly an equal area in each state (MDBA 2021). Major rivers in the Border Rivers Valley include the Macintyre and Dumaresq rivers, which merge upstream of Boggabilla and continue as the Macintyre River; and the Severn River which rises in Queensland south of Stanthorpe and enters the Macintyre River around 60 kilometres downstream of Pindari Dam (Map BR1) (NSW DPI 2012; MDBA 2021). The Dumaresq, Macintyre and the part of the Barwon River downstream of the junction of the Weir River to Mungindi (the end of the Border Rivers system) forms the border between NSW and Queensland for approximately 470 km (MDBA 2021). The Weir River, wholly in Queensland, is the only significant tributary of the lower Macintyre River (MDBA 2021).

Rainfall in the Border Rivers Valley is summer-dominant and highly variable, resulting in highly variable stream flows between years (CSIRO 2007; NSW OEH 2018; MDBA 2021).

The major public storages are Pindari Dam on the Severn River in NSW (312 gigalitres), Glenlyon Dam on Pike Creek in Queensland (254 gigalitres), and Coolmunda Dam on Macintyre Brook in Queensland (69 gigalitres) (MDBA 2021). The total volume of on-farm storage is comparable to the sum of these public storages, reflecting the importance of unregulated flows to irrigation supplies in the catchment (MDBA 2021). On a long-term average basis, unregulated entitlements (supplementary water licences in NSW and unsupplemented water allocations in Queensland) and use in the Border Rivers Valley exceed regulated water entitlements and use (MDBA 2021).

3.1.2 Traditional Owners

The lands of the Border Rivers catchment have been important to Aboriginal people for thousands of generations (MDBA 2021; NMA 2021). Aboriginal nations of the region include the Bigambul, Euahlayi, Githabul, Kambuwal, Gomeroi/Kamilaroi, Kwiambul, and Ngarabal (MDBA 2021). Traditional owners have longstanding and continuing ties to country and hold the rivers and the many billabongs along the rivers in this catchment in high regard. Of particular importance is the Morella Watercourse/Boobera Lagoon/Pungbougal Lagoon complex located on the Macintyre River floodplain south of Goondiwindi (MDBA 2021). The Commonwealth Environmental Water Office (CEWO) respectfully acknowledges these Nations, their Elders past and present, as the Traditional Custodians of the lands on which this chapter is focused.

3.1.3 Important sites and values

Key environmental assets in the Border Rivers catchment include:

- Border Rivers main channels (Severn, Dumaresq, Macintyre and Lower Macintyre rivers to Mungindi and the Weir River
- anabranches downstream of Yetman/Texas
- Queensland Macintyre River billabongs

- wetlands, billabongs and lagoons in the Lower Dumaresq/NSW Severn and Lower Macintyre rivers
- Toomelah station near the junction of the Macintyre and Dumaresq rivers.

The Border Rivers Valley supports several species and endangered ecological communities listed under the *Environment Protection and Biodiversity Conservation Act 1999*, the NSW *Biodiversity Conservation Act 2016*, or the NSW *Fisheries Management Act 1994*.

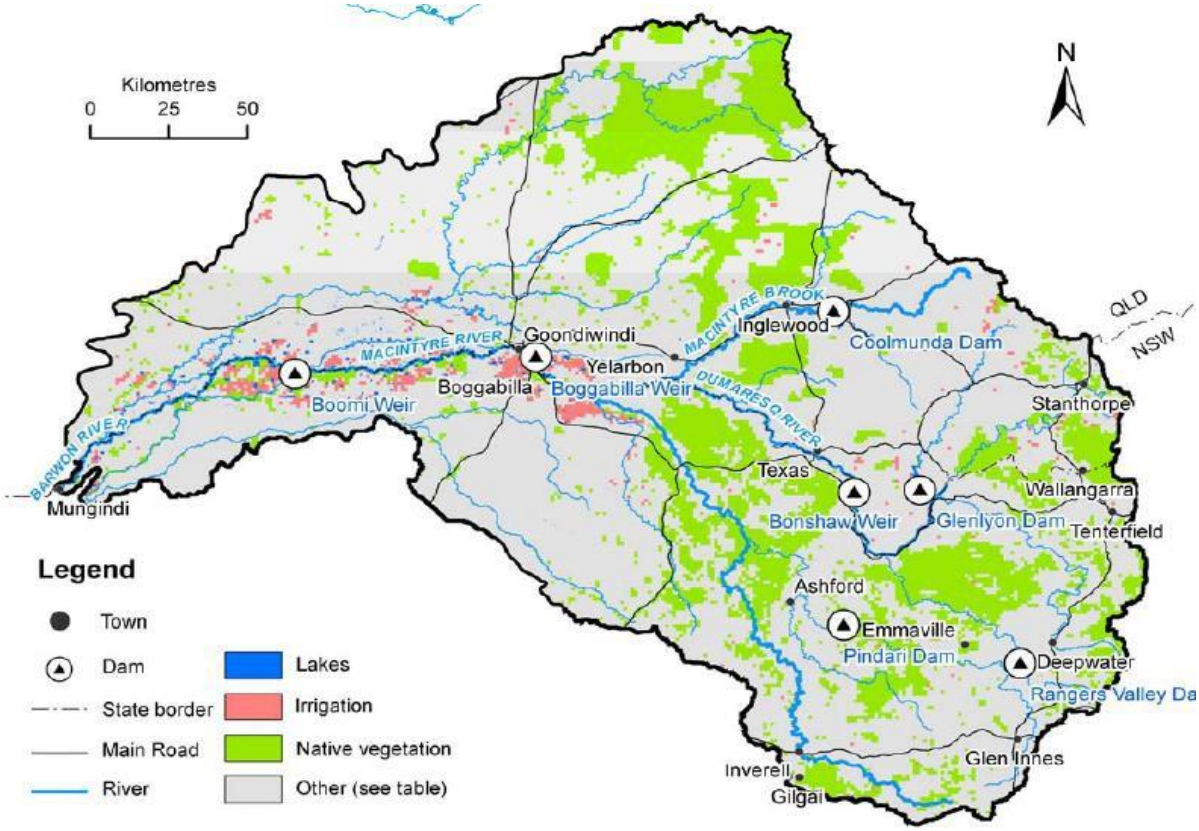
These include native fish species such as Murray cod, silver perch, purple-spotted gudgeon, olive perchlet and eel-tailed catfish. Various wetlands and waterholes also support internationally, nationally and state significant waterbirds, e.g. brolgas, Australian painted snipe, black-necked stork and magpie geese.

Parts of the Border Rivers are also included in the Lowland Darling River aquatic ecological community, which is listed as endangered under the NSW *Fisheries Management Act 1994*. This includes the Macintyre River below Graman Weir, Severn River below Pindari Dam and the Dumaresq River below the junction with the Mole River, along with their associated lagoons, billabongs, anabranches and floodplains.

3.1.4 Stakeholder engagement

In the Border Rivers Valley, the planning, management, and delivery of Commonwealth water for the environment is undertaken in conjunction with a range of partners and stakeholder groups. Key stakeholders in the NSW part of the catchment include the NSW Department of Planning, Industry and Environment (DPIE), the Department of Primary Industries (DPI) – Fisheries, Local Land Services and WaterNSW. In Queensland, key stakeholders include the Department of Regional Development, Manufacturing and Water (DRDMW), Department of Agriculture and Fisheries (DAF), Department of Environment and Science (DES) and Southern Queensland Landscapes. Advice on the use of Commonwealth water for the environment in the Border Rivers is also provided by landholders, traditional owners, the Boomi Trust, local and regional councils, and Border Rivers Food and Fibre.

Map BR1 Border Rivers Valley



Source: CSIRO (2007)

3.2 Environmental objectives

Based on long-term environmental objectives in the Basin Plan, state long-term watering plans, site management plans, and best available knowledge, the following objectives are relevant for environmental watering in the Border Rivers Valley.

The objectives that are targeted in a particular year may vary, depending on available water, catchment conditions, operational feasibility, and demand for environmental water. These objectives will continue to be revised as part of the CEWO's commitment to adaptive management. The objectives are:

- Vegetation – Maintain the condition, growth and survival of riparian, in-channel, floodplain and wetland vegetation.
- Waterbirds – Increase waterbird abundance and maintain species diversity by supporting naturally triggered breeding events, and maintaining suitable refuge, feeding and breeding habitat at targeted floodplain sites.
- Native fish – Prevent loss of native fish species and improve population structure and distribution, by supporting opportunities for movement, dispersal, reproduction, and recruitment.

- Other vertebrates and invertebrates – Support opportunities for the reproduction and recruitment of other native aquatic species, including frogs, platypus, native water rats, turtles, and freshwater mussels.
- Connectivity – Support longitudinal connectivity, including with the Barwon River, and lateral connectivity between the river, wetlands and floodplains.
- Processes/water quality/resilience – Support key ecosystem functions and promote productivity, maintain water quality in channels and pools, and maintain drought refuge habitat.

3.3 First Nations environmental watering objectives

First Nations representatives from across the northern Basin identified environmental objectives for their country for 2020–21. These objectives were developed through the First Nations Environmental Guidance project undertaken by the Northern Basin Aboriginal Nations organisation. This project was an important first step in incorporating First Nations objectives into environmental water planning.

Following on from this important work, the CEWO, in collaboration with State Environmental Water Managers as appropriate, will continue to work with First Nations groups to learn from them and to better understand and include First Nations objectives and values when planning and managing environmental flows. As the next steps, CEWO will develop and implement a work program to work with First Nations groups in the northern Basin. The work program will refine and build on the work already undertaken, be developed in collaboration with First Nations groups and will be integral in continuing to build relationships and our capacity with First Nations groups. This work will also ensure First Nations groups actively participate in the planning and management of environmental flows.

Sharing the outcomes from environmental flows with First Nations Groups will be a key step in this process and will include a two-way exchange of knowledge. This information exchange and collaboration will improve the outcomes achieved from providing water for the environment, whilst also ensuring First Nations values are part of the environmental water decision-making and management processes.

3.4 Recent conditions and seasonal outlook

3.4.1 Recent conditions and environmental water use

In the first half of 2020–21, the Border Rivers experienced a mix of dry to moderate rainfall conditions which rapidly turned wet in March 2021.

Drier and warmer than average conditions presented in summer 2020–21, with some areas experiencing heatwave conditions (BOM 2021a). Cease-to-flow conditions occurred in some sections of the Macintyre and Dumaresq Rivers (as well as the Barwon–Darling) in December 2020.

The Dumaresq River was particularly dry in the first half of 2020–21, with largely cease-to-flow conditions at Bonshaw, Roseneath and Glenarbon gauges from July 2020 to March 2021 (WaterNSW 2021). Storage levels in the Border Rivers remained low throughout the first half of the water year, with both Pindari and Glenlyon Dams at less than 20% and Coolmunda dam mostly below 30% during spring and summer.

The NSW portion of the catchment was managed at Stage 3 of the NSW Extreme Events Policy at the start of the 2020–21 water year, with water delivery prioritised for essential supplies and low or no allocations for some entitlement holders. This was eased to Stage 2 in September 2020, but with ongoing limited allocations for some entitlement holders. Around 4.5 gigalitres of NSW planned environmental water (stimulus flow) was released from Pindari Dam during October 2020 (NSW DPIE 2020).

The Commonwealth had limited access to held environmental water holdings in the Border Rivers in the first half of 2020–21. However in late 2020, 0.9 gigalitres of Commonwealth environmental water along with 2 GL of NSW planned environmental water (translucency payback) was released from Pindari Dam to improve water quality of waterholes for native fish along the Macintyre and Barwon rivers as part of the Northern Waterhole Top-Up (DAWE 2021). Releases from Glenlyon Dam occurred in February 2021 to supply the upper reaches of the Dumaresq River, Boggabilla and Goondiwindi for consumptive use.

Conditions improved significantly in March 2021, with widespread heavy rainfall across the catchment, resulting in major flooding for the Macintyre River, some parts of the Barwon–Darling River and minor flooding for some tributaries. At Goondiwindi, 84% of the annual total of 437 mm fell between 1 December 2020 to 31 March 2021 (DRDMW 2021).

These flows provided lateral and longitudinal connectivity all the way from the Dumaresq River at Texas to the Barwon River at Mungindi (DRDMW 2021). In-channel flows replenished waterholes, provided flows in anabranch channels and watered instream and riparian vegetation. Approximately 456 gigalitres were accounted as “losses to the floodplain” – this water would have filled floodplain wetlands and improved the condition of floodplain soils and vegetation. This extensive flow connectivity provided opportunities for fish movement, and spawning events in channel and floodplain habitats.

Widespread rainfall also led to a significant improvement in soil moisture across the catchment and rapid increase in storage levels. Coolmunda Dam reached full capacity and both Pindari and Glenlyon dams exceeded 50% of full capacity (as of May 2021). The NSW portion of the Border Rivers moved to Stage 1 under the NSW Extreme Events Policy in April 2021, representing a return to normal river operations. The rainfall of autumn 2021 followed an extended dry period since January 2017, during which rainfall across the catchment was generally below average to very much below average.

‘Unsupplemented’ (unregulated) access was announced in the Queensland Border Rivers in Macintyre, Barwon and Dumaresq zones during March, April and June 2021, with almost 12 gigalitres of Commonwealth water for the environment contributing to natural flows. Supplementary access was also announced in the NSW Border Rivers in March and April 2021. In May 2021, 5 gigalitres of NSW planned environmental water (the remainder of the translucency payback water) was released from Pindari Dam as an extended base flow (Matthew Miles 2021 [NSW Department of Planning, Industry and Environment], pers. comm., 13 May).

Resource availability has now improved with a return to normal operational arrangements in the Border Rivers. The CEWO is likely to be able to call on its entitlements in the Border Rivers in 2021–22.

Learn more about previous Commonwealth environmental water use in the Border Rivers Valley.

3.4.2 Seasonal outlook

According to the Bureau of Meteorology outlook released on 3 June 2021, above average rainfall is predicted in the Border Rivers Valley over winter and early spring (BOM 2021b). The Bureau of Meteorology also predicts slightly below long-term average maximum temperatures but above average minimum temperatures for the catchment (BOM 2021c, d).

The Murray–Darling Basin Authority (MDBA) identifies that the Border Rivers Valley is likely to experience wetter than average conditions for at least July through to September 2021 (MDBA forthcoming). However, persistent, widespread, and above average rainfall is needed to:

- further lift areas out of rainfall deficiencies at the multi-year timescales
- provide relief from the longer-term impacts of the long period of low rainfall, such as by further recharging water storages.

3.4.3 Water availability

The volume of Commonwealth environmental water carried over in the Border Rivers for use in 2021–22 is 6,543 megalitres (5,243 megalitres in Queensland and 1,300 megalitres in NSW).

The Commonwealth works with Queensland and NSW partner agencies to plan, implement and evaluate the delivery of Commonwealth environmental water in conjunction with planned environmental water managed by NSW (e.g. the Pindari stimulus flow). Other flows such as tributary flows, consumptive water and other water orders may also support environmental demands in the Border Rivers Valley.

The Commonwealth also has 1,437 megalitres in NSW supplementary entitlement, and up to 19, 986 megalitres in Queensland 'unsupplemented' (unregulated) entitlements. However, these entitlements rely on large inflows more than regulated river requirements. Unregulated entitlements provide opportunistic access to river flows when water levels exceed trigger values at certain locations, as specified in the entitlement conditions. Each triggered Commonwealth environmental water entitlement leaves water in the river which could otherwise be extracted. This contributes to restoring natural flows, reflecting its flow access windows, take rates and location. The location and size of the event will influence which environmental demands Commonwealth environmental water contributes to. In general, the Commonwealth accounts for the full allowable volume of unregulated entitlements when they are triggered, apart from a small unregulated entitlement in the Dumaresq which we do not account use against in winter.

Based on the expected available volume of water held by the Commonwealth and other water holders, as well as recent and forecast catchment conditions, it is expected that the overall resource availability will be moderate to high in 2021–22 (MDBA forthcoming).

3.4.4 Environmental demands

The environmental water demands for assets in the Border Rivers Valley in 2021–22 are shown in Table BR1. The capacity to contribute to most of these environmental demands is contingent on continued wet conditions in the catchment.

Table BR1 Environmental demands and watering priorities, 2021–22, and outlook for coming year, Border Rivers Valley

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
Border Rivers main channels: Dumaresq, Severn (NSW), Macintyre, lower Macintyre to Mungindi (including Weir River) Native fish Instream aquatic ecosystems	Native fish resilience, reproduction, conditioning and maintenance. Maintain in-channel habitats during low flows, water quality and longitudinal connectivity. Instream aquatic ecosystem processes e.g. scouring habitat inundation.	**Dumaresq** 100 ML/day baseflow at Glenarbon.	As required in extreme dry conditions or to provide variability. Potential trigger: 10 ML/day for more than 25 days gauged at Glenarbon, impacting on persistence of larger waterholes.	Demand was met annually since 2012 to 2019–20. Demand was also met in 2020–21 but flows at Glenarbon were <10 ML/day from October 2020 to end of January 2021. Baseflows are required annually therefore a high demand in 2021-22, remaining high the following year if the demand is met.	High	A high priority for watering in 2021–22, including under a low resource availability scenario, but likely to be met incidentally by operational dam releases.	High
		Severn/Macintyre Rivers 50 ML/day baseflow at Ducca Marrin.	Potential trigger: <2 ML/day for more than 25 days gauged at Ducca Marrin, impacting on persistence of larger waterholes.	Demand was met annually from 2012 to 2019. The demand was only partially met in 2019–20 and met in 2020–21. These flows are required annually therefore have a high demand in 2021–22, remaining high the following year if the demand is met.	High	A high priority for watering in 2021–22, including under a low resource availability scenario, but likely to be met incidentally by operational dam releases.	High
		Lower Macintyre River 400 ML/day at Mungindi for connectivity Duration and frequency of baseflows dependent on outcomes required (e.g. 7 days in Sept to March in 1 in 1 to 2 years to provide connectivity and sufficient depth for fish movement).	To provide variability (triggers: cease-to-flow (<30ML/day) for more than 30 days at Mungindi).	Demand was met annually from 2012 to 2018 apart from 2014–15. Demand was not met 2018–19. Met in 2019–20 and 2020–21. These flows are required annually therefore have a high demand in 2021–22, remaining high the following year if the demand is met.	High	A high priority for watering in 2020–21, including under a low resource availability scenario.	High
		Dumaresq River Spawning: 515 to 1,040 ML/day at Roseneath for minimum 14 days (small fresh).	Eight in 10 years July to August (Priming pulse before spawning and recruitment).	Demand was not met between 2012 and 2015 nor in 2018–19. Demand was met 2015–16, 2016–17 and 2017–18. Dumaresq recruitment demand not met in 2019–20 but spawning demand was met. Dumaresq spawning or recruitment demands were not met in 2020–21 because the duration requirements were not met. Therefore, this environmental demand is assessed as critical in 2021–22. This would reduce to high the following year if the demand is met.	**Critical**	A high priority for watering in 2021-22, but environmental demand cannot be met through Commonwealth water alone (will also require water from other sources).	High
		Dumaresq River Recruitment: 340 to 600 ML/day at Roseneath for minimum 20 days.	Eight in 10 years Aug to Oct (Peak recruitment season for Murray cod and freshwater catfish).	Demand met or partly met in 6 out of the last 10 years (partly met in 2019–20 and 2020–21 by flow thresholds but duration not met). High environmental demand in 2021–22, remaining high the following year if the demand is met.	High	A high priority for watering in 2021-22, but environmental demand cannot be met through Commonwealth water alone (will also require water from other sources).	High
		NSW Severn / Macintyre rivers Priming pulse: initial peak of 2,000 ML/day at Ducca Marrin followed by recession (duration variable) (large fresh). NSW Severn/Macintyre Spawning and recruitment: Flow height, duration and volume unknown.	Eight in 10 years July to August (Priming pulse before spawning and recruitment).	The priming pulse was met in 2010–11, 2011–12, 2013–14, 2016–17 and 2017–18. However, was not met in 2012–13, 2014–15, 2015–16, 2018–19, 2019–20 or 2020–21. This demand was not met in the last three years, therefore has a critical environmental demand in 2021–22, moving to high the following year if the demand is met.	**Critical**	A high priority for watering in 2021-22, but environmental demand cannot be met through Commonwealth water alone (will also require water from other sources).	High
		Lower Macintyre River Large scale spawning and recruitment aligned with large unregulated pulse in the Weir River post winter (at least two metre rise and water temperature >23°C).	Eight in 10 years July to August (Priming pulse before spawning and recruitment). August to October (Peak recruitment season for Murray cod and freshwater catfish).	Met 2015–2017. Not met in 2017–18, 2018–19 or 2019–20. Met in 2020–21 (large unregulated pulse in the Weir River with >2 metre rise and water temperature around 23°C in March 2021). Demand assessed as high in 2021–22, reducing to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Moderate
		Lower Macintyre River Spawning	Eight in 10 years July to August	Demand met between 2012–13 and 2020–21 apart from 2018–19. Demand assessed as low in 2021–22, remaining low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural	Low

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
		3,100 ML/day at Boggabilla for minimum 14 days (Boggabilla Management Reach).	(Priming pulse before spawning and recruitment).			trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	
		Lower Macintyre River **Spawning** 5,400 ML/day at Mungindi for minimum 14 days (Mungindi Management Reach).	Eight in 10 years July to August (Priming pulse before spawning and recruitment).	Demand was partially met in 2019–20 because the duration was insufficient. The demand was met in 2020–21. Therefore, the demand is low, remaining low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Low
		Fish spawning/recruitment flow targeting long-lived flow dependent specialists (small to medium fresh for at least three days) **Dumaresq River** Flow height with at least a two-metre rise and water temperature >23°C.	Eight in 10 years October to April (Recruitment season for silver and golden perch). At least every second year (prefer annually). September to March Maximum inter-flow period of two years.	Demand was not met between 2012 to 2015 nor in 2018–19. The demand was achieved between 2015 to 2018, 2019–20 and 2020–21. Therefore, a moderate to high demand in 2021–22, reducing to moderate the following year if the demand is met.	Moderate to high	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Moderate
		NSW Severn/Macintyre rivers Flow height with at least a two-metre rise and water temperature >23°C.	Eight in 10 years October to April (Recruitment season for silver and golden perch). At least every second year (prefer annually). September to March Maximum inter-flow period of two years.	Demand has not been achieved since 2012. Therefore, the demand is critical in 2021–22, remaining critical the following year even if the demand is met in 2021–22.	**Critical**	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	**Critical**
		Lower Macintyre River Large flow pulse of at least 10,900 ML/day at Boggabilla for minimum 20 consecutive days (optimum flow). Some outcomes achieved with small pulse of 840 ML/day at Boggabilla Weir.	Eight in 10 years October to April (Recruitment season for silver and golden perch). At least every second year (prefer annually). September to March Maximum inter-flow period of two years.	The demand has only been met 4 of the last 9 years (2012–13, 2016–17, 2019–20 and 2020–21). Therefore, the demand is assessed as high in 2021–22, moving to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other sources of water.	Moderate
Border Rivers main channels (ctd)		Fish condition and maintenance flow targeting long lived in-channel specialists and flow-dependent fish guilds (small/large fresh for minimum 5 days). **Dumaresq River** Up to 2,300 to 6,250 ML/day at Roseneath.	One in one to two years (Maximum dry interval unknown). June–July (Pre-spawning conditioning). March–May (Pre-winter maintenance).	**Dumaresq River** Not met 2018–19. Met in 2019–20 and 2020–21. Low to moderate demand in 2021–22, moving to low the following year if the demand is met.	Low to moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other means.	Low
		NSW Severn / Macintyre rivers Peak up to 2,000 ML/day at Ducca Murrin.	One in one to two years (Maximum dry interval unknown). June–July (Pre-spawning conditioning). March–May	Met 2015–2018. Demand not met 2018–19 or 2019–20. Partly met in 2020–21(pre-winter maintenance). Moderate to high demand in 2021–22, moving to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other means.	Moderate

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
			(Pre-winter maintenance).				
		Lower Macintyre River Natural inflows in the lower Macintyre River reach, including Weir river. Optimal flow height, duration and volume unknown.	One in one to two years (Maximum dry interval unknown). June–July (Pre-spawning conditioning). March–May (Pre-winter maintenance).	The demand was not met from 2017–2019. Met in 2019–20 and 2020–21. Therefore, the demand is low in 2021–22, and will remain low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other means.	Low
	Fish movement/spawning/ reproduction/ recruitment flows targeting short-lived stable low flow spawning fish species.	Stable low flow for 7 to 60 days (spawning/reproduction/recruitment). A minimum stable low flow 7 to 21 days needed for spawning. **Dumaresq River** Up to 100 ML/day at Roseneath.	One in one to two years (low uncertainty). Up to three years (high uncertainty). September to December (Peak spawning season for olive perchlet, includes purple-spotted gudgeon).	Demand met in 2015–16, 2016–17 and 2018–19 and 2020–21). Therefore, the demand is moderate in 2021–22, reducing to low the following year if the demand is met.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Low
		NSW Severn and Macintyre rivers 50 ML/day at Ducca Marrin.	One in one to two years (low uncertainty). Up to three years (high uncertainty). September to December (Peak spawning season for olive perchlet, includes purple-spotted gudgeon).	Stable flows were not met 2015–20. The flows were met in 2020–21. The demand is high in 2021–22, which would reduce to moderate the following year if the demand is met.	High	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Moderate
	Scouring, inundate inter-connected riparian areas and improved longitudinal connectivity for fish movement, (including maintenance and conditioning) of all native species	Large in-channel fresh (Aug to Dec) **Dumaresq River** Peak between 6,250–19,000 ML/day at Roseneath	All reaches Up to three years for scouring (Maximum dry interval unknown). Anytime (only if naturally occurring).	Large in-channel fresh flows were last achieved 2016–17, not achieved 2017–18 or 2018–19. The flow rates were achieved at Roseneath in February 2020 and March 2021 but not within the required August to December timeframe. Therefore, there is a moderate demand in 2021–22, which would reduce to low the following year if the demand is met.	Moderate	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Low
		NSW Severn and Macintyre rivers Flows >2,000 ML/day at Ducca Marrin to change periphyton species	All reaches Up to three years for scouring (Max. dry interval unknown). Anytime (only if naturally occurring).	Large fresh flows were achieved between 2016–17 and 2018–19 and again 2020–21. Therefore, there is a low demand in 2021–22, remaining low the following year if the demand is met.	Low	Secondary priority for Commonwealth environmental watering. Will occur only if natural trigger is met, or under moderate–high resource availability. Demand may be met by other water sources.	Low
	Inundate key habitat (large woody debris), support key ecosystem functions (nutrient, sediment and carbon cycling) and support recruitment opportunities for a range of native aquatic species (fish, frogs, turtles and invertebrates)	Small in-channel fresh **Lower Macintyre and Barwon Rivers** 4,000 ML/day at Mungindi (end of system) for a minimum five to 11 days.	**Inundate habitat and meet needs of threatened fish species** (October to December timing). One in three to four years (maximum dry interval of seven to 14 years for habitat inundation, maximum dry interval for threatened fish species unknown).	**Inundate habitat and meet needs of threatened fish species (October to December)** This demand has only been met three times in the last 10 years and was last met in 2016–17. Therefore, the environmental demand is critical in 2021–22, remaining critical the following year if the demand is not met.	**Critical**	Unable to receive Commonwealth environmental water due to constraints.	**Critical**
		Small in-channel fresh **Lower Macintyre and Barwon Rivers** 4,000 ML/day at Mungindi (end of system) for a minimum five to 11 days.	**Key ecosystem functions** (October to March timing). One in two to three years (maximum dry interval of six to eight years).	**Key ecosystem functions (October to March)** Met in 2012–13 (not met between 2013–14 and 2018–19) and met in 2019–20 and 2020–21. Environmental demand moderate in 2021–22, moving to moderate to high the following year if the demand is not met.	Moderate	Unable to receive Commonwealth environmental water due to constraints.	Moderate to high

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	**Required frequency (maximum dry interval)**		**Environmental demands for water (all sources)**	**Potential Commonwealth environmental water contribution?**	**Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22**
In channel assets – Boomi River	Inundate key habitat Boomi (large woody debris and fallen timber on bench platforms and inset floodplain areas), native fish assets (including recorded or expected threatened native fish species).	Baseflows of >five ML/day for seven days (September to March) at Boomi River upstream of Boomi Weir Offtake	One in one to two years (75%) (baseflow) (maximum dry interval unknown).	Baseflows met annually since 2013–14. Required every 1 to 2 years. Therefore, there is a low environmental demand in 2021–22, moving to moderate the following year if the demand is not met.	Low	A low priority for Commonwealth environmental water contribution under low water resource availability scenarios, however Commonwealth unregulated entitlements could contribute unregulated flows, if triggered.	Moderate
		Small fresh 1: >20 ML/day at Boomi River upstream of Boomi Weir Offtake for minimum 10 days (October to April)	Annual (100%) (maximum dry interval one year).	Small fresh 1 demand has been met in each year since 2013–14. Required annually, therefore the demand is high in 2021–22, moving to critical the following year if the demand is not met.	High		**Critical**
		Small fresh 2: 20 to 750 ML/day for minimum 14 days (September to April)	One in one to two years (75%) (maximum dry interval unknown).	Small fresh 2 demand has been met in each year since 2013–14. These are required every 1 to 2 years therefore the demand is low in 2021–22, moving to low to moderate the following year if the demand is not met.	Low		Low to moderate
		Large fresh 1: >750 ML/day for five days (July to September)	One in one to two years ((75%) (maximum dry interval unknown).	Large fresh 1 demand was not met from 2013–14 to 2019–20. These flows were met in 2020–21. These flows are required every 1 to 2 years, therefore the demand is high in 2021–22, moving to critical the following year if the demand is not met.	High		**Critical**
		Large fresh 2: >750 ML/day for five days (October to April)	One in two to three years (42%) (commencing as a rising flow only). (maximum dry interval unknown).	Large fresh 2 flows were not met in 2013–14, 2014–15, 2015–16, 2017–18 or 2018–19, but were met in 2016–17, 2019–20 and 2020–21. These flows are required every 2–3 years, therefore have a low to moderate demand in 2021–22, moving to moderate the following year if the demand is not met.	Low to moderate		Moderate
Anabranches downstream of Yetman/Texas Nutrient and carbon cycling enhanced primary production. Support fish movement and condition.	Infrastructure assisted watering to maintain refuge habitat E.g. Morella watercourse lagoons (if agreed with landholders) 1,500 to 4,000 ML per action (infrastructure assisted) to target specific wetlands with long-term flow deficit.	1,500 to 4,000 ML per action (infrastructure assisted) to target specific wetlands with long-term flow deficit.	Maximum: up to 10 years between filling (Morella watercourse).	Little to no inflows since 2010, however local rainfall provided some water to Morella watercourse and Boobera Lagoon in 2019–20 and 2020–21. Therefore, the demand is low to moderate in 2021–22, moving to moderate if the demand is not met.	Low to moderate	Additional information is needed before supporting a watering action.	Moderate
Wetlands, lagoons and billabongs	Support movement, spawning and recruitment of aquatic species. Riparian vegetation health. Nutrient and carbon cycling Maintain refuge for aquatic biota and fish Lateral and longitudinal connectivity, support movement, spawning and recruitment of aquatic species. Maintain riparian habitat for other species i.e. water birds Fish (all guilds) and other aquatic dependent biota refuge Aquatic ecosystems	Connection to lower Dumaresq wetlands/NSW Severn wetlands **Dumaresq River** Small fresh to connect >30% of wetlands in the Dumaresq reach > 1,040 ML/day at Roseneath	One in three to four years for wetland vegetation. One in two to three years for fish outcomes.	This demand was not met between 2012–2017 but has been met since then (from 2017 to 2020–21). Therefore, the demand is low in 2021–22, moving to moderate the following year if the demand is not met.	Low	A low priority for CEW under low to moderate water resource availability scenarios. Potential for contribution under a high water resource availability scenario, in conjunction with similar flow requirements for fish outcomes	Moderate
		NSW Severn and Macintyre rivers: 1,200 ML/day at Ducca Marrin to connect upper reach wetlands	One in three to four years for wetland vegetation. One in two to three years for fish outcomes.	Demand met annually from 2012 to 2018–19 but not met in 2019–20. Met in 2020–21. Therefore, the demand is low in 2021–22, moving to moderate the following year if the demand is not met.	Low	A low priority for CEW under low water resource availability scenarios, however, Commonwealth unregulated entitlements could contribute unregulated flows, if triggered.	Moderate
		Connection to lower Macintyre River wetlands **Connect wetlands and anabranches - Goondiwindi to Mungindi** >20,000 ML/day (low connectivity) (bankfull-small overbank flow) >60,000 ML/day (high connectivity) (large overbank event) at Goondiwindi for seven days	One in three to four years for wetland vegetation. One in two to three years for native fish outcomes. Every three years for small fish outcomes.	Not met from 2012–13 to 2019–20. Low connectivity (>20,000 ML/day) demand met, and high connectivity demand partially met in 2020–21 (duration not met) (flows gauged at Goondiwindi >60,000 ML/day for three days between 25 March and 27 March 2021). Therefore there is a moderate environmental demand for these flows in 2021–22, moving to moderate to high the following year if the demands are not met).	Moderate	Unable to receive Commonwealth environmental water due to constraints. Unregulated entitlements could contribute to flows at Goondiwindi if there are in-range announced flows.	Moderate to high

Environmental assets	Target values	Indicative demand (for all sources of water in the system)		Watering history (from all sources of water)	2021–22		Implications for future demands
		Flow/volume	Required frequency (maximum dry interval)		Environmental demands for water (all sources)	Potential Commonwealth environmental water contribution?	Likely urgency of demand in 2022–23 if watering occurred as planned in 2021–22
		Low level wetland connection in Lower Macintyre 10,000 to 15,000 ML/day at Goondiwindi (bankfull) 4,000 to 6,000 ML/day at Terrewah (large fresh and bankfull) for four to eight days in October to March	One in three to four years for wetland vegetation. One in two to three years for native fish outcomes. Every three years for small fish outcomes.	Not met from 2012–13 to 2018–19. Met in 2019–20 and in 2021. Therefore, the demand is low in 2021–22, moving to moderate the following year if the demand is not met.	Low		Moderate

Note: Contributions to meet Barwon–Darling environmental requirements may be considered subject to water availability, antecedent conditions and environmental demands (see chapter 9 of the CEWO Water Management Plan 2021-22). All watering history sourced from NSW Department of Planning, Industry and Environment and Queensland partner agencies, WaterNSW Water Balance Reports, and data from the following gauges (WaterNSW 2021 and DRDMW 2021) – 416040 Dumaresq River at Glenarbon, 416067 Severn River at Ducca Marrin, 416001 Barwon River at Mungindi, 416011 Dumaresq River at Roseneath, 416207A: Weir River at Mascot, 416201A, Macintyre River at Goondiwindi, 416047 Macintyre River at Terrewah, 416037 Boomi River at Boomi Weir offtake, 416002 Macintyre River at Boggabilla, , 416047 Macintyre River at Kanowna.

Key

Potential watering in 2021–22

- High priority for Commonwealth environmental watering (likely to receive water even under low water availability)
- Secondary priority for Commonwealth environmental watering (watering to occur only if natural trigger is met, or under moderate – high water resource availability); or water demand likely to be met via other means
- Low priority for Commonwealth environmental watering (under high – very high water resource availability); or unable to provide water because of constraints or insufficient water

Environmental demands (demand is considered at a generalised scale; there may be specific requirements that are more or less urgent within the flow regime)

- High to critical demand for water (needed in that particular year or urgent in that particular year to manage risk of irretrievable loss or damage)
- Moderate demand for water (water needed in that particular year, the next year, or both)
- Low demand for water (water generally not needed in that particular year)

3.5 Water delivery in 2021–22

Based on the demand for water for the environment, water availability (supply), and catchment conditions, the overall purpose for managing Commonwealth water for the environment in the Border Rivers Valley in 2021–22 is to further support recovery and protect the health and resilience of native fish and aquatic ecosystems. Under dry conditions and due to the relatively small volume of regulated river entitlements, the focus would be on in-channel habitats, drought refugia and fish condition and resilience, particularly in the Border Rivers main channels. Should there be further inflows, the CEWO could add water and/or protect these natural inflows to maximise their ecological benefits.

Consistent with the demands and purpose identified, the CEWO is considering supplying water for the environment to the following actions in 2021–22:

- Avoid extended cease-to-flow conditions, provide flowing water habitats, and maintain suitable river depth (particularly in the Severn-Macintyre and Dumaresq). This will help to support native fish and other native aquatic animals such as freshwater mussels and shellfish, shrimp, platypus, turtles, frogs, water dragons, water rats (rakali).
- Contribute to suitable flow regimes to help maintain and restore instream and riparian vegetation at important sites in the Dumaresq, Severn and Macintyre river systems.
- Contribute to suitable flow regimes in the Dumaresq, Macintyre and Severn rivers to support priming, reproduction, conditioning and movement opportunities for native fish communities, including Murray cod, silver perch, freshwater catfish, purple-spotted gudgeon and olive perchlet.
- Contribute to suitable flow regimes to support refuges, feeding resources and breeding opportunities for waterbirds including listed migratory and threatened species, and species of economic, social and cultural importance.
- Contribute to connected flow events to meet within-catchment outcomes and the downstream Barwon–Darling river system.

As in previous years, the use of Commonwealth water for the environment in the Border Rivers will be adaptively managed throughout 2021–22, in response to changing water resource availability and environmental conditions and demands.

3.6 Monitoring and lessons learned

3.6.1 Monitoring

In the Border Rivers, monitoring is undertaken by NSW and Queensland agencies including NSW DPI Fisheries (native fish), NSW DPIE Water (water quality) and Queensland DRDMW, DAF and DES. The CEWO has also funded several short-term intervention monitoring projects to evaluate the environmental responses of native fish, and to map aquatic habitat in the Dumaresq and Macintyre Rivers.

Learn more about monitoring activities funded by the CEWO in the Border Rivers Valley.

3.6.2 Lessons learned

Outcomes from monitoring and lessons learned in previous years are a critical component for the effective and efficient use of Commonwealth water for the environment. These learnings are incorporated into the way environmental water is managed.

Key findings from fish (NSW DPI & DAF 2019; Marshall & Lobegeiger 2020), aquatic habitat (NSW DPI 2018, forthcoming) and flow monitoring (DAWE 2020; Eco Logical Australia 2020) in the Border Rivers Catchment is summarised in Table BR2.

Table BR2 Key lessons learned in the Border Rivers Catchment

Theme	Lessons learned
Native fish and aquatic invertebrates	• Water for the environment benefits the relatively healthy and diverse native fish community in the Border Rivers, which includes a few nationally and state listed threatened species (e.g. Murray cod, olive perchlet) (NSW DPI & DAF 2019.) Water for the environment helps maintain habitat, supports condition and recruitment, and provides opportunities for movement and increased productivity. • The unregulated Weir River in the Border Rivers catchment supports a relatively healthy population of golden perch, including evidence of natural spawning and recruitment (Rolls et al. 2013; Stuart and Sharpe 2020). These golden perch juveniles may then end up in other Northern Basin catchments including the Lower Balonne (Greg Ringwood [Murray–Darling Basin Authority] 2021, pers. comm., 20 March); and contribute to downstream golden perch populations as far as Menindee Lakes and the Lower Darling. The mainstem Macintyre and Barwon River may also contribute golden perch juveniles to downstream habitats (Rolls et al 2013; Stuart & Sharpe 2020). • A relatively large proportion (22%) of the river channel in the Queensland Border Rivers (including the Weir River) remained wet during peak drought compared to other catchments (Marshall & Lobegeiger 2020). • Water for the environment in the Border Rivers during late winter/early spring contributes to increased Murray cod and freshwater catfish spawning and recruitment. It also provides benefits to unspecked hardyhead, Murray–Darling rainbowfish and carp gudgeon (abundance, spawning and recruitment). • Rapid assessment of priority refuge pools in parts of the Border Rivers through the NSW native fish drought response process in 2019–20 suggests that the Lower Macintyre fish community may be in relatively poor condition. Extensive die-off of freshwater mussels was also observed at some sites. There are also concerns about the status of the Darling River hardyhead in the Border Rivers. • NSW DPI Fisheries sampled upland and montane unregulated systems of the Border Rivers in 2020-21, with preliminary results showing a diverse fish community including ten native fish species and three introduced species. Threatened native fish species including freshwater catfish, Murray cod, olive perchlet and purple-spotted gudgeon were present, as well as the iconic golden perch. Olive perchlet and purple-spotted gudgeon were detected in reasonable numbers, a great finding after the prolonged drought and recent floods in 2021 (Charlie Carruthers 2021, [NSW Department of Primary Industries Fisheries], pers.comm., 16 June),
Aquatic habitat	• Mapping of aquatic habitat features in parts of the Border Rivers (Dumaresq from Pike Creek to connection with the Macintyre and from the Macintyre-Dumaresq junction to Mungindi) has identified habitat that is important for native fish and other animals. Riparian

Theme	Lessons learned
	vegetation condition was also mapped. Key habitat features noted included large woody habitat, refuge pools, and bars and benches.
Connectivity	• The Northern Connectivity Event in 2017–18, Northern Fish Flow in 2018–19 and Northern Waterhole Top Up in 2020–21 highlighted the importance of coordinated flow delivery and protection of environmental flows from the Border Rivers and Gwydir system into the Barwon–Darling river system. The Northern Waterhole Top-Up in 2020–21 was the first time the CEWO and NSW have delivered a connectivity event during summer in the Northern Murray–Darling Basin. The Northern Waterhole Top-Up demonstrated that summer connectivity events can help refill refuge pools and connect tributaries with the Barwon–Darling. • The Border Rivers is estimated to have contributed around 312 gigalitres of water (from all sources) to flows in the Barwon–Darling during March to May 2021. Commonwealth held environmental water contributions to these flows are small relative to the total proportion of water. However, completion of the cross-border accounting project between NSW and Queensland in combination with active management in the Barwon–Darling by NSW will support better tracking and protection of Commonwealth environmental water from upstream tributaries to the Barwon–Darling. Future monitoring by Queensland and NSW partner agencies could also help better understand the role of protecting unregulated tributary flows for waterhole persistence and connectivity, water quality and native fish response.
Other aquatic animals	• There are platypus colonies in the Border Rivers catchment, including in the Severn River (Sundown National Park, near Ashford and reaches downstream of Pindari Dam), Tenterfield Creek; the Dumaresq River downstream of Glenlyon Dam; and also, possibly Macintyre Brook. There are historical records of platypus in lowland areas of the Border Rivers as far downstream as Goondiwindi, but these populations are now considered unlikely to be present. • Delivery of the Pindari stimulus flow in previous years (NSW planned environmental water) took the flow needs of platypus into account, and research in other parts of Australia has also sought to better understand their environmental flow needs. The rakali or native water rat is also widespread throughout the Border Rivers, but little is known about their flow requirements in the catchment. • Persistence of health populations of freshwater mussels (particularly *Alathyria jacksoni,* which is endemic to the Murray–Darling Basin) is dependent on permanent river reaches and waterholes. The provision and protection of minimum baseflows is vital to their persistence, and for populations to recover from the significant losses experienced during the 2017–20 drought. • Recolonisation of freshwater mussels is dependent on the recovery and movement of native fish populations through the northern Basin. Therefore, the minimum flow requirements of native fish also need to be provided to support recovery of both fish and mussel populations. • Bankfull and overbank flows are required to maintain the condition of waterholes and adequate depth to support freshwater mussels (Sheldon et al. 2020). • Additional information on these water dependent species is required to better inform the future management of water for the environment.

References

BOM 2021a ,Water reporting summary – NSW Border Rivers catchment 3 May 2021, Bureau of Meteorology, Canberra, accessed 26 May 2021.

——2021b, Climate outlooks: rainfall – the chance of above median for July to September 2021, Bureau of Meteorology, Canberra, accessed 3 June 2021.

——2021c, Climate outlooks: temperature – the chance of above median maximum temperatures for July to September 2021, Bureau of Meteorology, Canberra, accessed 3 June 2021.

——2021d, Climate outlooks: temperature – the chance of above median minimum temperatures for July to September 2021, Bureau of Meteorology, Canberra, accessed 3 June 2021.

CSIRO 2007, Water availability in the Border Rivers: a report to the Australian Government from the CSIRO Murray-Darling Basin sustainable yields project, CSIRO, Canberra, accessed 3 June 2021.

DAWE 2020, Final report on the Northern connectivity event (April – July 2018), Department of Agriculture, Water and The Environment, Canberra, accessed 27 May 2021.

——2021, Northern Waterhole Top-up, Department of Agriculture, Water and the Environment, Canberra, accessed 27 May 2021.

DRDMW 2021, Queensland water monitoring information portal streamflow data Border Rivers Basin, Department of Regional Development, Manufacturing and Water, Brisbane, accessed 26 May 2021.

——forthcoming, *Border Rivers and Moonie water plan area – annual watering priorities 2021-22 (draft May 2021),* Department of Regional Development, Manufacturing and Water, Toowoomba.

ELA 2020, Barwon Darling water quality during the Northern fish flow March-August 2019, report prepared for the Commonwealth Environmental Water Office, Eco Logical Australia, Armidale, accessed 27 May 2021.

Marshall, J & Lobegeiger, J 2020, *Fish population resilience following severe drought in the northern Murray–Darling Basin. Progress report 1 incorporating highlights and conceptual models from water drought mapping and flow connectivity analysis (Milestone 2*),. Queensland Department of Environment and Science, Brisbane.

MDBA 2021, Water management: catchments – Border Rivers, Murray-Darling Basin Authority, Canberra, accessed 3 June 2021.

——forthcoming, *Climate context for 2021-22 Basin annual environmental watering priorities (draft as of 19 May 2021*), Murray–Darling Basin Authority, Canberra.

NMA 2021, Defining moments in Australian history: 65,000 years ago archaeological evidence of first peoples on the Australian continent, National Museum of Australia, Canberra, accessed 7 June 2021.

NSW DPI and DAF 2019, Fish and flows intervention monitoring in the Border Rivers: final report prepared for the Department of the Environment and Energy September 2019, Department of the Environment and Energy, Canberra, accessed 27 May 2021.

NSW DPI 2012, Water resources and management overview Border Rivers catchment, NSW Department of Primary Industries Office of Water, Sydney, accessed 15 June 2021.

——2018, Mapping the Dumaresq – aquatic habitat mapping to inform water management, report prepared for the Commonwealth Environmental Water Office, NSW Department of Primary Industries, Dubbo, accessed 27 May 2021.

——forthcoming, *Mapping the Macintyre river – Macintyre-Dumaresq junction to Mungindi – aquatic habitat mapping to inform water management*, report prepared for the Commonwealth Environmental Water Office, Canberra.

NSW DPIE 2020, Drought-recovery flow for native fish in the Severn River 16 October 2020, NSW Department of Planning, Industry and Environment, Sydney, accessed 27 May 2021.

——2021, Waterinsights portal – allocation and usage in Border Rivers regulated river,. NSW Department of Planning, Industry and Environment, Sydney, accessed 26 May 2021.

NSW OEH 2018, NSW Border Rivers long-term water plan parts A and B draft for exhibition. State of NSW and NSW Office of Environment and Heritage, Sydney, accessed 3 June 2021.

Rolls, RJ, Growns, IO, Khan, TA, Wilson, GG, Ellison, TL, Prior, A & Waring, CC 2013. Fish recruitment in rivers with modified discharge depends on the interacting effects of flow and thermal regimes, *Freshwater Biology,* vol.58, p.1804, DOI: 10.1111/fwb.12169, accessed 27 May 2021.

Sheldon, F, McCasker, N, Hobbs, M, Humphries, P, Jones, H, Klunzinger, M & Kennard, M 2020, Habitat and flow requirements of freshwater mussels in the northern Murray–Darling Basin, report to the Commonwealth Environmental Water Office, Canberra, accessed 20 May 2021.

Stuart, IG & Sharpe, CP 2020, Riverine spawning, long distance larval drift, and floodplain recruitment of a pelagophilic fish: a case study of golden perch (*Macquaria ambigua*) in the arid Darling River, Australia, *Aquatic Conservation Marine and Freshwater Ecosystems,* vol.30, p.675, DOI: 10.1002/aqc.3311, accessed 27 May 2021.

WaterNSW 2021, NSW real time water data rivers and streams 416 – Macintyre River Basin. WaterNSW, Sydney, accessed 26 May 2021.