South Australia's River Murray Environmental Watering Report

2016-2017

Australian Government

MURRAY–DARLING BASIN AUTHORITY

Government of South Australia
Department of Environment, Water and Natural Resources

Acknowledgement of the Traditional Owners

The Department of Environment, Water and Natural Resources acknowledges and pays respect to the Traditional owners and their Nations, of the Murray-Darling Basin, who have a deep cultural, social, environmental, spiritual and economic connection to their lands and waters.

Other Acknowledgements

This is the eighth River Murray environmental watering report to be produced by the South Australian Government. It was prepared by staff in the Department of Environment, Water and Natural Resources (DEWNR). The following agencies and organisations are acknowledged for their important role in environmental water management:

Commonwealth Environmental Water Office (CEWO);

Murray-Darling Basin Authority (MDBA) including The Living Murray (TLM) program;

Natural Resources South Australian Murray-Darling Basin (NR SA MDB);

Local Action Planning Associations (LAP);

Ngarrindjeri Regional Authority;

First Peoples of the Murray and Mallee;

Nature Foundation South Australia (NFSA).

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1. Introduction and purpose

The planning, management, delivery, reporting and evaluation of environmental water within the Murray-Darling Basin in South Australia is coordinated by the Department of Environment, Water and Natural Resources (DEWNR) and undertaken in partnership with other government agencies including the Murray-Darling Basin Authority (MDBA) and Commonwealth Environmental Water Office (CEWO), research organisations, non-government organisations and community groups.

Environmental water delivered within South Australia is primarily from two major environmental water holders: the Commonwealth Environmental Water Holder (CEWH) and The Living Murray (TLM) Program of the MDBA. Additional water for use in South Australia is available from the South Australian Minister for Water and the River Murray, non-government organisations, and donations from private irrigators. Water may also be provided by the Victorian Environmental Water Holder (VEWH) and New South Wales in the form of return flows from upstream environmental watering actions.

This report is prepared as a summary of environmental watering for the River Murray in South Australia during the 2016-17 year. Its primary purpose is to provide an enduring and publicly available record of the volumes and locations of all environmental watering, regardless of water holder or manager, undertaken in the region throughout the year. It supplements the detailed and comprehensive reporting required under the Murray-Darling Basin Plan (Basin Plan), which is completed by South Australia on all aspects of Basin Plan implementation including environmental watering.

This report also meets the South Australian Government's commitment to the Council of Australian Governments (COAG) to publish an annual report on River Murray environmental water use in South Australia for public information sharing (National Water Initiative Policy Guidelines for Water Planning and Management 2010).

Within this document, the following have been provided:

- a brief description of the environmental watering actions that were proposed for 2016-17;
- an overview of river conditions in 2016-17;
- a summary of the watering actions that were undertaken including sites, volumes and approximate timing;
- a summary of key environmental outcomes
- an evaluation of environmental water delivery in regard to the environmental watering requirements identified in the SA River Murray Long Term Watering Plan; and
- links to reports that provide more information about monitoring and ecological outcomes.

Latham's Snipe - a migratory wader common in the Coorong that benefits from environmental water
Photo by Martin Stokes

2. Environmental watering actions proposed for 2016-17

Each year DEWNR develops annual environmental watering priorities (annual priorities). All environmental water and site managers in the region are encouraged to participate in this planning process. The annual priorities are published on the DEWNR website and indicate the proposed watering actions for the upcoming water year. This information is provided to the MDBA and to the major environmental water holders (CEWH, TLM) to assist in the development of the Basin-wide annual environmental watering priorities and environmental water delivery planning.

When undertaking planning, environmental managers use a scenario-based approach that takes into account the variety of possible future water resource conditions (e.g. climate, storage levels and water availability). The scenarios that were used in the planning for 2016-17 are shown in Figure 1.

The environmental watering sites and actions that were proposed under each scenario for 2016-17 are summarised in Table 1.

More detailed information is in the 2016-17 Annual Environmental Watering Plan for the South Australian River Murray available at **www.environment.sa.gov.au** .

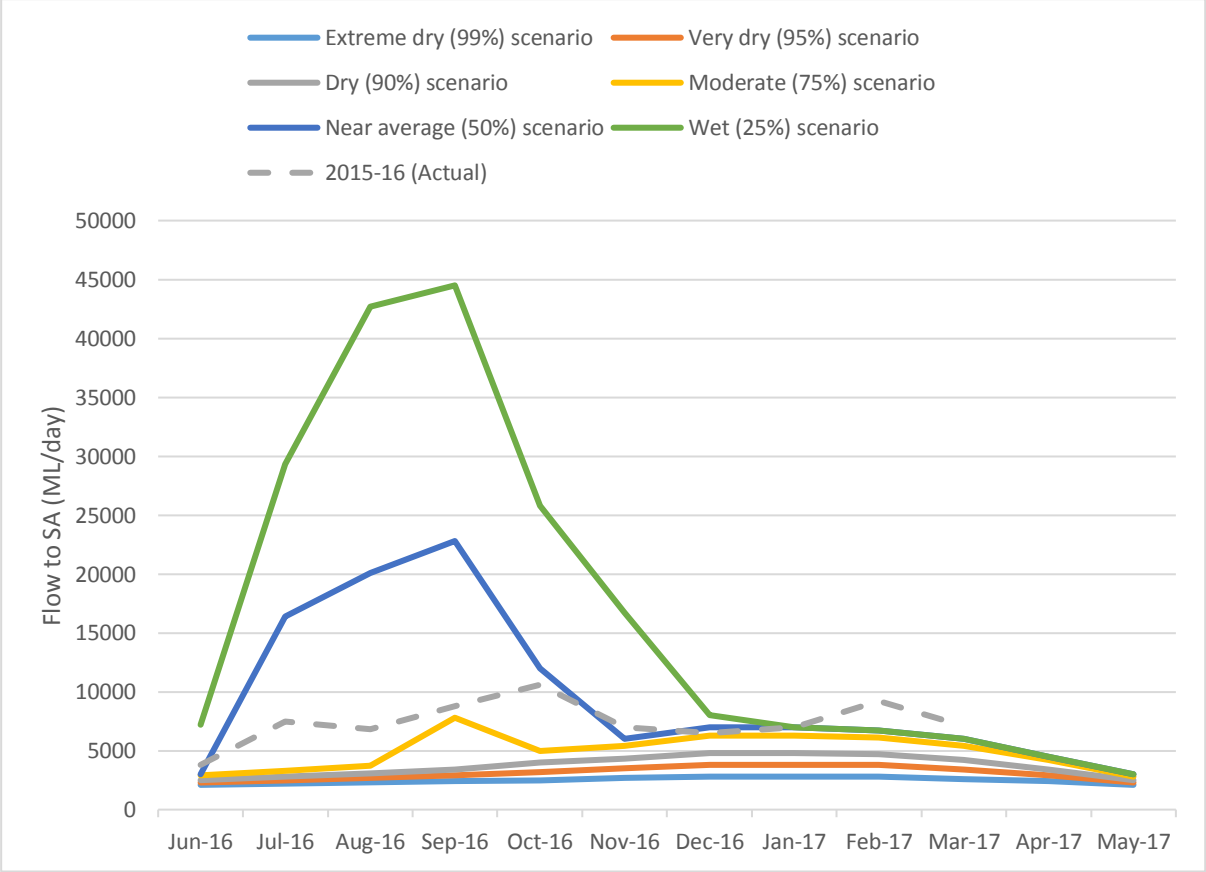

Figure 1. Scenarios used in annual planning for the SA River Murray region in 2016-17. (Source MDBA)

Table 1. 2016-17 Environmental watering priorities for the SA River Murray region

Action	Very dry scenario 95 percent	Dry scenario 90 percent	Moderate scenario 75 percent	Near average scenario 50 percent	Wet scenario 25 percent
1	Spring pulse for CLLMM 12 months of barrage releases	Improved spring pulse for CLLMM	Further improved spring pulse for CLLMM	Enhance barrage releases due to unregulated flows Further improved spring pulse for CLLMM	Enhance barrage releases due to unregulated flows Further improved spring pulse for CLLMM Enhance unregulated flows to 35,000 ML/day for 60 days
2	Provision of water to threatened fish refuges	12 months of barrage releases	12 months of barrage releases	12 months of barrage releases	12 months of barrage releases
3	Pump Chowilla wetlands Pump Valley wetlands Pump Gorge wetlands Pump Lower Lakes wetlands	Provision of water to threatened fish refuges	Provision of water to threatened fish refuges	Provision of water to threatened fish refuges	Chowilla maximum floodplain inundation
4	Chowilla anabranch flow pulse	Raise Weir 2 by 75cm Raise Weir 5 by 50cm Pump Chowilla wetlands Pump Valley wetlands Pump Gorge wetlands Pump Lower Lakes wetlands	Winter pulse through barrages	Winter pulse through barrages Create 15,000 ML/d flow pulse for 90 days Chowilla mid-floodplain inundation Raise Weir 2 by 75cm Raise Weir 5 by 50cm	Winter pulse through barrages
5		Create 10,000 ML/d flow pulse for 60 days Chowilla anabranch flow pulse	Raise Weir 2 by 75cm Raise Weir 5 by 50cm Pump Chowilla wetlands Pump Valley wetlands Pump Gorge wetlands Pump Lower Lakes wetlands	Pump Valley wetlands Pump Gorge wetlands Pump Lower Lakes wetlands	Pump Valley wetlands Pump Gorge wetlands Pump Lower Lakes wetlands
6			Create 10,000 ML/d flow pulse for 60 days Chowilla anabranch flow pulse		

3. Overview of flow conditions in 2016-2017

South Australia began the year receiving less than Entitlement Flow. The forecast conditions matched the 90-95% scenario that had been used in environmental water planning (Figure 1), and represented dry to very-dry conditions. The watering actions proposed under this scenario are shown in

This situation rapidly changed and from mid July 2016 to the end of December 2016, South Australia received substantial unregulated flows that peaked at 94,500 megalitres per day (ML/day) on the 30th of November 2016. As the unregulated flow moved down the river, it inundated large areas of floodplain and wetlands, before making its way to Lakes Alexandrina and Albert, and through the barrages to the Coorong and Murray Mouth. Low dissolved oxygen levels were also observed during the high flow event. This was a result of large volumes of organic material being mobilised and consumed upstream. More frequent watering of floodplains will reduce organic matter accumulation and decrease the likelihood of low dissolved oxygen levels. The improved flow conditions meant that a wider range of actions could potentially be undertaken during the year. The scenario had changed to very wet. The unregulated flow declined rapidly in December 2016, and Entitlement Flow and environmental water were delivered for the rest of the water year. Refer to Section 6 for an assessment of the effect of a flow of 94,500 ML/day on achieving the Environmental Watering Requirements of the ecological assets.

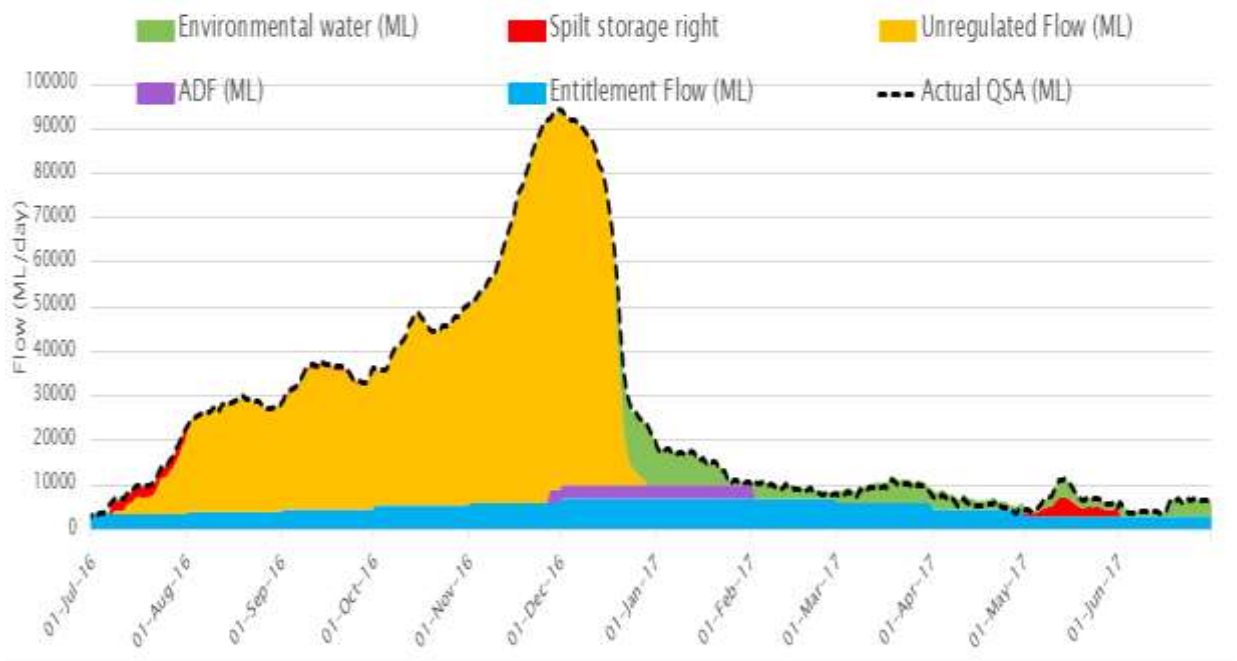

Figure 2. River Murray flows at the South Australian border throughout 2016-17[1]

[1] South Australia's entitlement flow includes approximately 238 GL of held environmental water (HEW) that consists of 151.5 GL of Commonwealth environmental water, 45 GL of TLM water and 42 GL of environmental water held by the SA Minister for Water and the River Murray. ADF is Additional Dilution Flow for dilution of salinity. Spilt storage right is water SA has stored for drought purposes but may spill when Lake Victoria is full. Unregulated flow is flow that cannot be captured for storage as the storages are full. Entitlement Flow is the minimum flow that SA must receive each year.

4. Environmental water delivery

Environmental water was delivered throughout the water year but the largest volume was delivered to coincide with the natural flow recession to slow its very rapid decline. For the first time, environmental water (60 GL) was released from Lake Victoria to manage the flow recession and to improve dissolved oxygen levels for Murray Cod in the Rufus River. This action had been approved by Basin Officials Committee as part of the environmental watering trial for 2016-17.

A total of 1,055,186 ML of environmental water was delivered to priority sites in 2016-17 (Tables 2 and 3); of which 594,500 ML was Commonwealth Environmental Water (CEW) and 231,900 ML was provided by TLM. South Australia also received 43,500 ML from the VEWH, 42,200 ML from the Darling Anabranch and 100,000 ML of River Murray Increased Flow (RMIF).

A total of 42,048 ML of water held on the SA Minister's licences was delivered for environmental outcomes, of which 33,412 ML was (Class 9) wetland water that is specifically for the management of pool-connected wetlands.

The planning for environmental water in South Australia is coordinated by DEWNR staff and is undertaken in consultation with community groups including the Community Advisory Panel for the Coorong and Lower Lakes, the Scientific Advisory Group for the Coorong and Lower Lakes, the Ngarrindjeri Regional Association and the First People of the Murray and Mallee.

The planning and delivery of environmental water in the Southern Connected Basin is coordinated by the Murray Darling Basin Authority staff and the Southern Connected Basin Environmental Watering Committee (SCBEWC) with representatives from NSW, Victoria, South Australia, the Victorian Environmental Water Holder (VEWH) and the Commonwealth Environmental Water Holder (CEWH).

In addition to providing environmental water to the SA Government, the CEWH provides water to Natural Resources SA MDB Board, Nature Foundation SA (NFSA), Renmark Irrigation Trust and Banrock Station to undertake small community prioritised environmental watering projects. Due to the high natural flow in 2016-17, there was a reduced demand for water for this purpose. Refer to Appendix 1 for sites watered via NFSA.

Table 2. Volume of environmental water delivered from different providers in 2016-17

Provider	**Volume in ML[2]**
Commonwealth Environmental Water Holder (CEWH)	594,500
The Living Murray (TLM)	231,900
SA Minister for Water and the River Murray (including Class 9 wetland water, Tolderol)	42,048
Banrock Station	1,038
Victorian Environmental Water Holder (VEWH) return flows	43,500
Darling Anabranch	42,200
RMIF	100,000
Total	**1,055,186**

Table 3. Volume of environmental water used to undertake different types of actions in 2016-17

Watering site	Volume (ML)	Water provider(s)
Coorong, Lower Lakes, Murray Mouth - Lake level management, and fishway and barrage releases	968,613	CEWH, TLM, VEWH, SA Minister for Water and the River Murray, RMIF
Pool-connected (Class 9) wetland management	36,162	SA Minister for Water and the River Murray, Banrock Station
Other (non-Class 9) wetland management	1,692	CEWH, SA Minister for Water and the River Murray
Weir pool raising at Locks 2 and 5	2,719	CEWH
Chowilla Regulator operation	46,000	TLM
Total	**1,055,186**	

5. Outcomes of water delivery

5.1 Site summaries

Lakes Alexandrina and Albert

- From July to early October, water levels in Lake Alexandrina increased from 0.68 to 1.01 metres Australian Height Datum (m AHD). Water levels then fluctuated between ~ 0.7 to 0.875 m AHD until the end of January 2017 and then decreased to a minimum of ~ 0.58 m AHD in April 2017. Water levels recovered to > 0.7 m AHD by the end of June 2017.
- Salinity levels in Lake Albert were 1,890 EC at the start of July 2016 before steadily declining to 1,402 EC in early October 2016. By mid-April 2017, salinity levels increased to 1,795 EC before reducing to 1,686 EC at the end of June 2017.
- Frog monitoring in 2016-17 detected a calling male of the vulnerable-listed southern bell frog (*Litoria raniformis*). A further six species of frogs were recorded across four monitoring locations.
- Monitoring for fish in the Lower Lakes recorded a total of 18,537 fish, represented by 19 native and four alien species.
- The threatened Murray hardyhead *(Craterocephalus fluviatilis)* and southern pygmy perch *(Nannoperca australis)* were recorded at four sites and eleven sites respectively.
- There was a decrease in abundance of small bodied fishes probably due to a reduction in submerged vegetation in the main channel.
- In January 2017 a total of 61,000 waterbirds (44 species) were recorded in the Lower Lakes compared to 85,000 the previous year. The most abundant species were the Australian Shelduck *(Tadorna tadornoides)*, Grey Teal *(Anas gracilis),* Pied Cormorant *(Phalacrocorax varius)* and Pacific Black Duck *(Anas superciliosa)*.

Goolwa barrage. Photo by Kirsty Wedge

Sand dunes – adjacent to the Coorong. Photo by Kirsty Wedge

Coorong

- A total of 6,423 gigalitres (GL) of water was released from the barrages during 2016-17.
- There was a large spring-summer barrage outflow that contributed to Ruppia growth, higher baseline barrage outflows and a winter pulse for Lamprey;
- Significant migration of diadromous fish from the estuary through the barrage fishways into the River Murray occurred;
- South Lagoon water levels peaked at 1.038 m AHD in October 2016, and dropped to a minimum of around -0.33 m AHD in March 2017. Water levels from May 2016 until the end of January 2017 were above 0.2 m AHD, which were the highest water levels recorded in the South Lagoon since 2011-12.
- As a result of high barrage flows, and higher water levels, salinities in the Coorong remained well within the preferred ranges.
- The Murray Mouth remained open for the entire year with the assistance of dredging.
- Fishways were open for the entire year, with barrage releases via open bays maintained throughout 2016-17, except where weather conditions, such as storm events, required temporary closures.
- The 2016-17 high flow event saw some patchy results for macroinvertebrates in the mudflats of the North and South Coorong. The average species richness was above the long term reference established from previous monitoring. However, most diversity measures showed a decrease compared to the 2015-16 survey for the North Lagoon.
- In January 2017 a total of 76,207 waterbirds (46 species) were recorded in the Coorong compared with 185,000 (57 species) the previous year. The most abundant species recorded were Australian Shelduck (*Tandorna tadornoides*), Grey Teal *(Anas gracilis)*, Silver Gull *(Chroicocephalus novaehollandiae)*, Australian Pelican *(Pelecanus conspicillatus),* Crested Tern *(Thalasseus bergii)* and Red-necked Stint (*Calidris ruficollis)*.
- The fish assemblage was diverse (28 species) and was dominated by sandy sprat *(Hyperlophus vittatus,* 74.5%), Australian smelt (*Retropinna semoni,* 8.4%), bony herring (*Nematalosa erebi, 6.4%)* and congolli (*Pseudaphritis urvillii, 7.1%)*.
- The aquatic plant *Ruppia tuberosa* showed mixed results in the southern Coorong during spring-summer 2016-17. There was widespread germination of Ruppia, which increased cover and abundance as water levels were maintained through spring allowing plants to produce flowers. The level of flowering was consistent with the optimal water levels, but the plants were covered in thick mats of filamentous green algae *(Ulva sp)* and this resulted in most flower heads being torn off before seeds were produced. The species failed to successfully complete its lifecycle resulting in no net increase in the seed bank.

Chowilla

- The Chowilla environmental regulator was operated between August and November 2016 and was raised to 19.75 mAHD (3.45 m above normal pool level) and Lock 6 was raised to 19.839 mAHD (59 cm above normal pool level). Chowilla operations were managed within identified thresholds for risk management.
- The River Murray high flows and natural flooding in late 2016 coincided with the start of the managed draw-down of the Chowilla regulator. With the floodplain already inundated and major lakes and swamps full, the additional rise in water levels caused by the natural high flows extended

the extent and duration of floodplain inundation – further consolidating the benefits from the regulator event.

- Approximately 7,650 hectares of the Chowilla floodplain were inundated during the regulator operation, filling all of the major wetlands including Coombool Swamp, Lake Littra, Werta Wert and Gum Flat and large areas of river red gum and black box woodland and shrubland vegetation. It provided benefits to floodplain fauna including many species of frogs, birds, and invertebrates. The widespread floodplain inundation mobilised a large amount of organic matter with carbon and nutrients from the floodplain transported to the river channel.

- Fish surveys in key wetlands revealed seven species of native fish and four introduced species. While a large breeding response from the pest species Carp meant it was the dominant fish species recorded, there were also large numbers of small bodied native fish and several adult golden perch detected in the floodplain wetlands. There was an abundance of invertebrates collected during sampling.

- The dissolved oxygen (DO) levels in the Chowilla anabranch remained higher than in the main river channel and above 6 mg/L throughout the managed operation. The levels dropped within the Chowilla anabranch (to 1.49 mg/L) well after completion of the managed inundation as low DO water from upstream moved downstream through the lower Murray system.

- Floodplain inundation extended into areas of Black Box that had previously been water in 2010-11. A range of bird species was observed including Regent Parrots, Major Mitchell cockatoos, little Friar birds, Spiny-cheeked Honeyeaters, freckled Ducks and Apostle birds.

Chowilla. Photo by Jan Whittle

Weir pool raising

- In 2016, weir pool raising at Locks 2 and 5 commenced on 4th July, about one month earlier than had been originally planned, to take advantage of unregulated flow. Weir pool 2 reached a peak

of 75 cm above Normal Pool Level (NPL) by 9th October, while weir pool 5 was raised to a peak of 48 cm above NPL by 30th August (Figs. 3 & 4). Both weir pools experienced rapid draw-down in October when flows exceeded 40 GL/day and logs were removed from weirs to avoid any threat to their structural integrity.

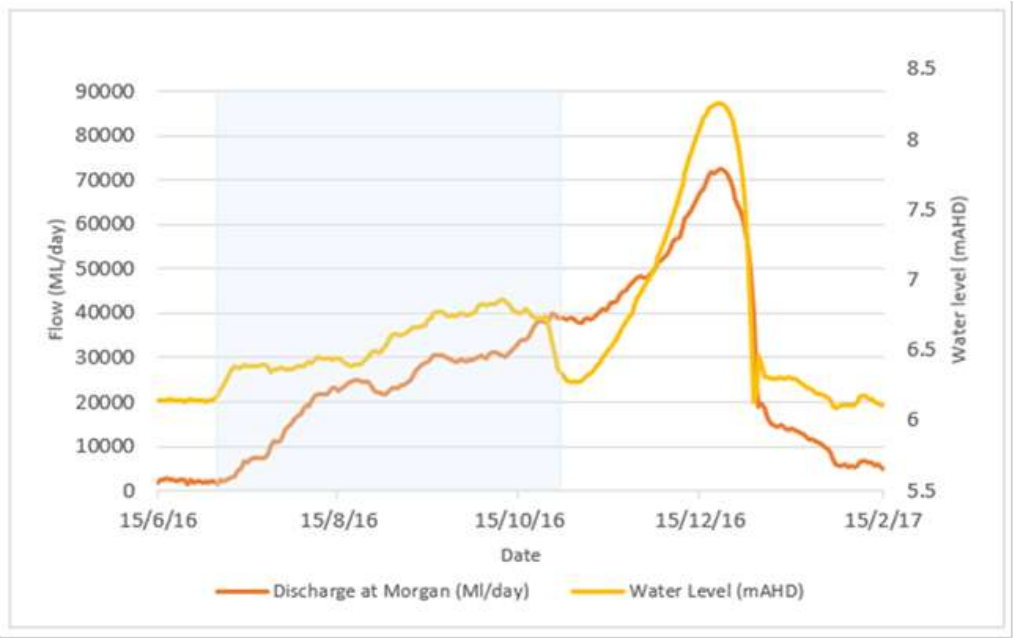

Figure 3. Water level at Lock 2 and flow at Morgan (shaded area shows period of weir pool raising)

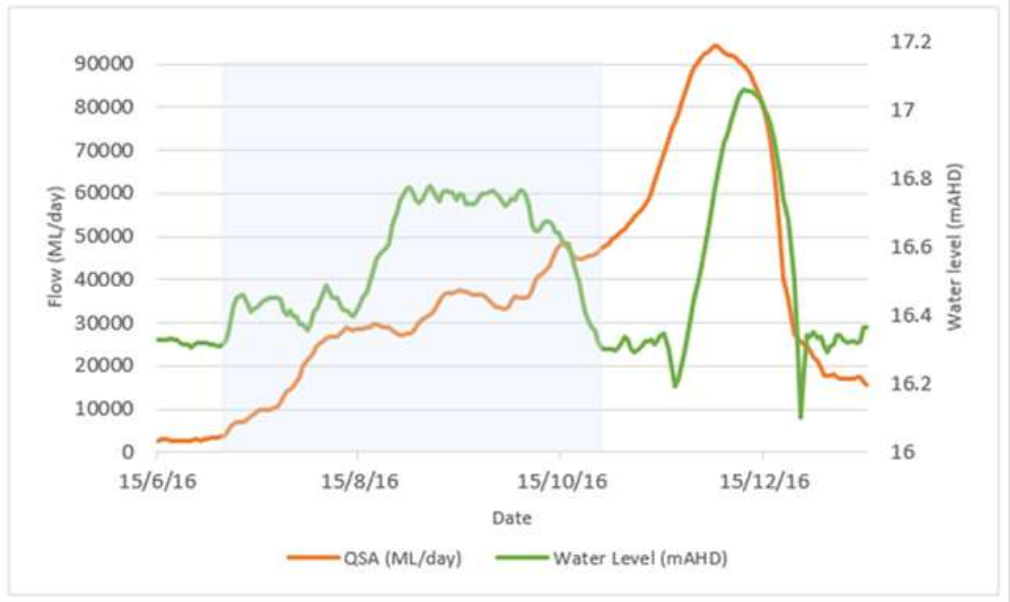

Figure 4. Water level at Lock 5 and flow at SA border (shaded area shows period of weir pool raising)

- From mid-August until the point at which the weir pools were drawn down, Lock 2 experienced increasing flows of 22 - 40 GL/day, while Lock 5 experienced flows of 28 - 48 GL/day.

- The combination of moderately high flows and raised pool levels enabled the achievement of a greater area of inundation than was achieved by weir pool raising at the same locks in 2015 i.e. an increase of 68 hectares at Lock 2 and an increase of 852 hectares at Lock 5).
- The 2016 raising achieved an inundation area at the lower and mid sections of the weir pool equivalent to, or greater than, that achieved by a 60 GL/day flow in the absence of weir pool manipulation. See Figures 5a, 5b and 5c below.
- Salinity response was monitored, with no detectable response under the high flow conditions experienced.

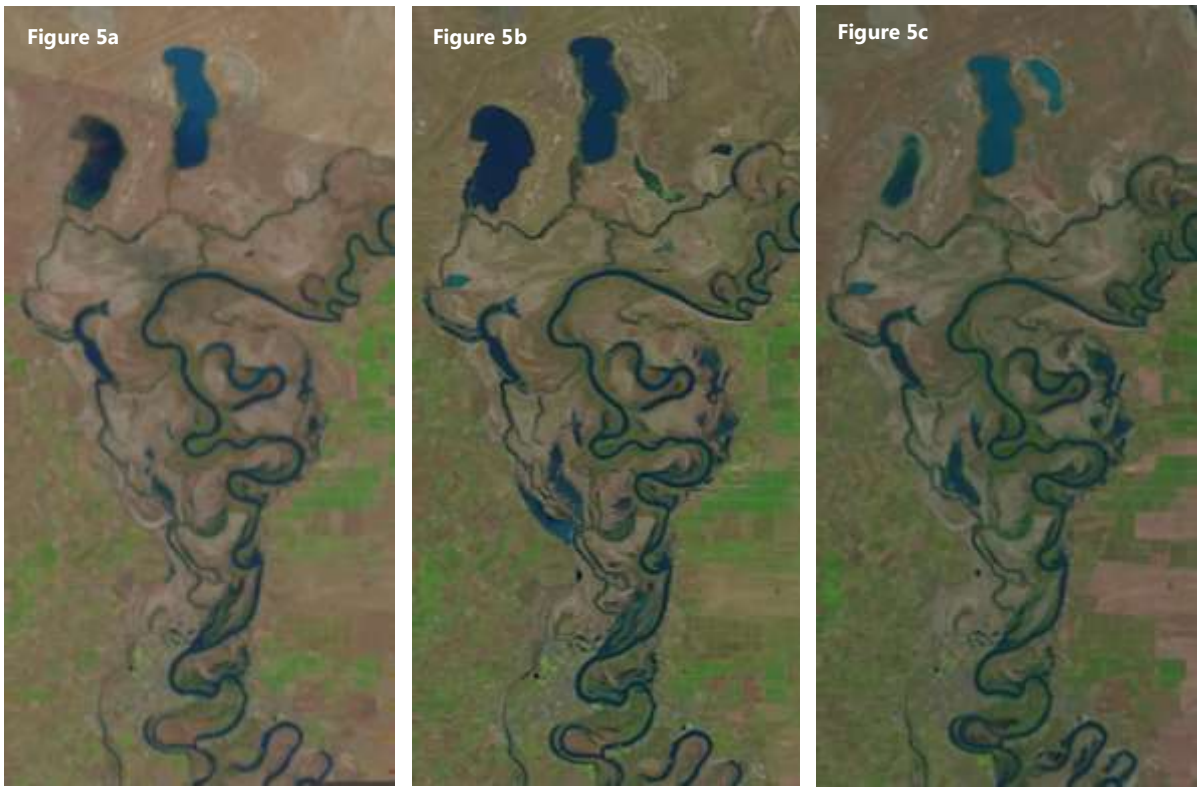

Figure 5. Landsat images of the River Murray floodplain upstream of Lock 5 under different flow rates and Lock 5 weir pool raising (a) October 2015 - 10 GL/day + 46 cm WPR; (b) September 2016 - 35 GL/day + 48 cm WPR; (c) April 2012 - 60 GL/day + no WPR

River Murray Channel and wetlands

- The high flow inundated approximately 50,000 hectares of floodplain
- The delivery of environmental water slowed the decline of the peak recession and slightly increased the period of floodplain and wetland inundation.
- Environmental water contributed to the mitigation of oxygen depletion that occurred as a result of organic matter washed from the floodplain during the high unregulated flow.
- The pool connected wetlands were naturally inundated by the high unregulated flow. All the regulators were opened. In addition, many temporary wetlands were also inundated and flushed.

5.2 Monitoring reports

Information on the response to environmental watering is gathered through a number of existing monitoring programs, including:

- The CEWO Long Term Intervention Monitoring Project, which collects data along the SA River Murray Channel;
- Condition and intervention monitoring at the Chowilla and LLCMM icon sites through the MDBA's Living Murray Program;
- The Coorong Lower Lakes and Murray Mouth Recovery Project;
- Monitoring associated with weir pool raising, which is coordinated by DEWNR and
- Monitoring of selected South Australian River Murray wetlands and floodplain areas undertaken by the Wetlands and Floodplain team of Natural Resources SA Murray-Darling Basin (SAMDB) in partnership with Local Action Planning and Landcare associations and community groups.

Monitoring reports are produced for each of these projects and Appendix 2 provides a list of the reports that are available for 2016-17. Monitoring synthesis reports are published for the weir pool raising project and for TLM icon sites and these reports are published on WaterConnect (www.waterconnect.sa.gov.au) and the MDBA website (www.mdba.gov.au/publications), respectively. Reports for the CEWO Long Term Intervention Monitoring Project are published at https://www.environment.gov.au/water/cewo/catchment/lower-murray-darling/monitoring.

Murray Mouth. Photo by Callie Nicholai

6. Evaluation against environmental water requirements

Environmental water requirements (EWRs) describe the water regime needed to support aquatic ecosystems at a low level of risk (Department of Environment, Water and Natural Resources, 2014). EWRs were developed as part of the long-term environmental watering plan (LTWP) for the South Australian River Murray (DEWNR 2015) and are presented in Appendix 3. They include five EWRs for the SA River Murray Floodplain (EWR-FP1 to EWR-FP5), seven EWRs for the SA River Murray Channel (EWR-IC1 to EWR-IC7) and four EWRs for the Coorong, Lower Lakes and Murray Mouth (EWR-CLLMM1 to EWR-CLLMM4).

Actual flow data has been assessed to see which of the EWRs were met in the 2016-17 water year[3]. This assessment can be used to inform future environmental watering decisions and indicate potential environmental outcomes. It should be noted that each set of EWRs represents a water regime that needs to occur over multiple years, with the outcomes from any given year strongly influenced by prior conditions and the achievement of ecological targets requiring multiple events (Wallace *et al*. 2014).

For assessment of the floodplain and channel EWRs, data from site A4261001 on WaterConnect (Government of South Australia) was used to represent actual flows to South Australia (QSA) in 2016-17. Four EWR metrics had to be met concurrently – median discharge, discharge range, duration and timing. It was assumed that if a higher magnitude EWR was met then the lower magnitude EWRs for the same asset had also been met e.g. if EWR-IC3 (median discharge of 20,000 ML/day) was met then EWR-IC2 (median discharge 15,000 ML/day) and EWR-IC1 (median discharge 10,000 ML/day) had also been met (Wallace *et al*. 2014).

For assessment of the CLLMM EWRs, calculated daily barrage flow data from the barrage calculator was used to represent actual flow conditions in 2016-17. Average daily water levels for Lakes Alexandrina and Albert and minimum daily water levels in the Coorong South Lagoon data were taken from WaterConnect (Government of South Australia).

[3] As this is a single year analysis, the average return interval and maximum interval metrics have not been assessed. However, these metrics must also be met in order for ecological targets to be met.

Collecting fyke net at the Lower Lakes. Photo by Owen Love

6.1 Channel and floodplain

Flow to SA was over 35,000 ML/day from 30 September to 21 December 2016 (83 days), with a median discharge of 56,016 ML/day over this period. These results meant that the discharge (median and lower range), duration and timing elements of channel EWR IC6 were met (Table 4). These flow conditions also met the discharge and timing metrics of channel EWR IC7 but not duration which is at least 90-days.

Between 13 November and 18 December 2016, flows exceeding 65,000ML/day occurred for 35 days. The median discharge over this timeframe was 88,172 ML/day, allowing the discharge, duration and timing elements of the third highest floodplain EWR (FP3) to be fully met (Table 5). Flows exceeded 75,000 ML/day for 29 days rather than the 30 days specified by the second highest floodplain EWR (FP4).

River Murray in flood. Photo by Callie Nicholai

Table 4. Comparison of actual flow to South Australia in 2016-17 to metrics for SA River Murray Channel EWR-IC6 and EWR-IC7 [4]

Green shading indicates that the actual flow conditions met the EWR metric value. Orange shading indicates that the actual flow conditions were within 10% of the EWR metric value.

	Discharge (ML.day^{-1})		Duration (days)	Preferred Timing
	Median	Lower range		
EWR-IC6 values	35,000	30,000	60	Sep-Mar
EWR-IC7 values	40,000	35,000	90	Sep-Mar
QSA results 2016-17	**56,016**	**35,779**	**83**	**30 Sep - 21 Dec**

Table 5. Comparison of actual flow to South Australia in 2016-17 to metrics for SA River Murray Floodplain EWR-FP4 and EWR-FP5 [4]

	Discharge (ML.day-1)		Timing	
	Median	Lower range	Duration (days)	Preferred Timing
EWR-FP3 values	70,000	65,000	30	Sep-Dec
QSA results 2016-17	**88,172**	**66,231**	**35**	**13 Nov – 17 Dec**
EWR-FP4 values	80,000	75,000	30	Sep-Dec
QSA results 2016-17	**89,776**	**75,669**	**29**	**17 Nov-15 Dec**

[4] Data is only presented for the highest EWRs that were fully or partially met during 2016-17. All lower EWRs are considered to have been achieved through delivery of these higher EWRs

6.2 Coorong, Lower Lakes and Murray Mouth (CLLMM)

A total volume of 6,423 GL was released out of the barrages in 2016-17, with peak flows occurring between October and December. This high volume allowed for the achievement of the barrage flow requirements of the second highest EWR CLLMM3 (Table 6).

Average daily lake levels were managed to remain above the lower value of 0.56 mAHD. Results also demonstrated good seasonal lake level variability with the maximum lake level of 1.01 mAHD exceeding the EWR value of 0.83 mAHD, although this peak occurred in September-October instead of December-February.

Water level is important for ecological outcomes in the Southern Lagoon of the Coorong and is included in the CLLMM EWRs. However, some refinement to the EWR values are needed and so actual data has not been presented. High water levels in the Coorong during spring/summer inundated shoreline mudflats at levels that severely reduced or prevented shorebirds from using these areas as foraging habitat (Paton *et al.* 2017a). Water levels appear to have been conducive for *Ruppia* outcomes, with widespread germination and growth in the South Lagoon observed. Although 2016/17 provided ideal water level conditions for *Ruppia* germination and growth, seed-set was severely impacted by the presence of filamentous green algae, leading to no improvement in resilience (Paton *et al.* 2017b).

Table 6. Comparison of actual hydrological conditions in 2016-17 to metrics for EWR-CLLMM3 and EWR-CLLMM4 [5]

Green shading indicates that the actual conditions met the EWR metric value. Red shading indicates that the actual conditions did not meet the EWR metric value.

EWR	Barrage flow		Lakes water level	
	Annual flow (GL.yr-1)	Timing	Range (m AHD)	Timing
EWR-CLLMM3 values	>6,000	Jul-Jun, with peak barrage outflows in Oct–Dec.	0.4 – 0.83	Max levels: Dec–Feb Min levels: Mar–May
EWR-CLLMM4 values	>10,000	Jul-Jun, with peak barrage outflows in Oct–Dec.	0.4 – 0.9	Max levels: Dec–Feb Min levels: Mar–May
Results for 2016-17	**6,567**	**Peak flows Oct-Dec**	**0.56-0.96**	**Max levels: Sep-Oct** **Min levels: Mar–May**

[5] Data is only presented for the highest EWRs that were fully or partially met during 2016-17. All lower EWRs are considered to have been achieved through delivery of these higher EWRs

Hooded plover. Photo by Martin Stokes

7. Challenges

Each water year presents environmental water holders and managers with new challenges. 2016-17 initially presented as a very dry scenario but this changed rapidly to a wet year. The high flow occurred in spring-summer and lead to great outcomes for the floodplains in particular. Some of the challenges faced by managers are listed below.

- High tides, swells and wind caused reverse head conditions and lead to frequent closure of barrages in winter and early spring.
- High water levels in the Coorong led to low wader numbers. This may be because mudflat habitat in the South Lagoon remained underwater for much of the peak migration season, rendering feeding habitat unusable.
- Filamentous green algae in the Coorong disrupted the flowering and seed set of *Ruppia tuberosa*.
- The changing flow outlook meant that managers had to adapt operations – i.e. make judgements about when to start and conclude events to be confident that there would be enough flow to undertake large scale events and avoid false starts.
- If water flows out on to the floodplain, large amounts of organic matter will be returned to the river if there has been a long period of time since the previous flooding. This may have a serious impact on dissolved oxygen levels in the river and can lead to major fish kills.
- Following high flows, the river levels may drop rapidly and this can result in birds abandoning their nests, river bank instability, and rapid disconnection with wetlands.

Coorong. Photo by Kirsty Wedge

8. Summary

When planning began for 2016-17, the outlook was for a dry year. This changed when unregulated flow began and slowly increased from July to the flow peaked in November – the highest flow in 20 years. This lead to important environmental outcomes for the whole Southern Connected Basin. The Chowilla floodplain benefitted significantly from the operation of the regulator close to its maximum level followed by the high flow. All of the South Australian environmental assets and ecosystem functions benefitted from this flow and the additional delivery of over **1,000,000 ML** of environmental water during the year.

The volume of environmental water available is slowly increasing. There is an increasing understanding of the need for and an increasing willingness to undertake cooperative environmental watering that includes all environmental water holders. This is not always an easy path but is assisted by the willingness to trial and codify new operational practices and delivery arrangements. This progress is largely being driven by the MDBA and supported by all of the Basin States. Of particular interest to South Australia is the transfer of return flows to SA from upstream environmental watering actions as part of routine operations, the ability to utilise Lake Victoria to enhance environmental outcomes, and the improving opportunities to align flow throughout the Basin to maximise flow to SA in spring-summer which is the period of greatest demand for native flora and fauna.

River Murray near Cobdogla. Photo by Callie Nicholai

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Rainbow bee-eater at Chowilla. Photo by Jan Whittle

Appendix 1. NFSA watering using CEW

Wetland	ML
Amazon Junction	66.64
Big Bend Black Box	0.37
Kroehns Lagoon	2.96
Renny Lagoon	43.73
Riversleigh Lagoon	180.01
Loxton floodplain terrace	4.63
Lyrup Lagoon	110.54
Merreti floodplain	592.00
Ramco river terrace	2.71
Rillis Lagoon	30.80
Thieles Lagoon	11.19
Warnock dripper on Black Box	0.79
Warnock/McDonald	4.57
Woolpolool Swamp	574.40

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Appendix 3. Environmental Water Requirements

SA River Murray Channel Environmental Water Requirements

EWR #	Median discharge (ML day--1)	Discharge (ML day-1)	Duration (days)	Preferred timing	Average return frequency (years)	Percentage of years flow is required	Maximum return interval (years)
IC1	10,000	7,000 - 12,000	60	Sep-Mar	1.05	95	2
IC2	15,000	15,000 - 20,000	90	Sep-Mar	1.33	75	2
IC3	20,000	15,000 - 25,000	90	Sep-Mar	1.80	55	2
IC4	25,000	20,000 - 30,000	60	Sep-Mar	1.70	59	2
IC5	30,000	25,000 - 35,000	60	Sep-Mar	1.80	55	2
IC6	35,000	30,000 - 40,000	60	Sep-Mar	1.80	55	2
IC7	40,000	35,000 - 45,000	90	Sep-Mar	2.10	48	3

SA River Murray Floodplain (up to 80,000 ML/day) Environmental Water Requirements

EWR #	Median discharge (ML.day-1)	Discharge range (ML.day-1)	Duration (days)	Timing	ARI (years)	Maximum interval (years)	Max rate of water level rise (m.day-1)	Max rate of water level fall (m.day-1)
FP1	50,000	45,000 - 55,000	30	Sep-Dec	1.6	5	0.05	0.025
FP2	60,000	55,000 - 65,000	30	Sep-Dec	2.0	5	0.05	0.025
FP3	70,000	65,000 - 75,000	30	Sep-Dec	2.6	5	0.05	0.025
FP4	80,000	75,000 - 85,000	30	Sep-Dec	3.6	5	0.05	0.025
FP5	80,000	75,000 - 85,000	60	Sep-Dec	7.6	8	0.05	0.025

CLLMM environmental water requirements

EWR #	Average return interval	Maximum interval	Annual barrage flow (GL/yr)	Barrage flow timing	Lakes water level range (mAHD)	Lakes water level timing	Coorong south lagoon water level (mAHD)	Coorong south lagoon water level timing	Coorong south lagoon duration
LLCMM1	1 in 1	N/A	>650*	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.75	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.00 to 0.20	Sept - Nov	≥90 days
							-0.20 to -0.40	Feb - Mar	-
LLCMM2	1 in 2	N/A	>3150**	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.83	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.35 to 0.45	Sept - Dec	≥120 days
							0.00 to -0.50	Mar - April	-
LLCMM3	1 in 3	5	>6,000	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.83	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.35 to 0.45	Sept - Jan	≥150 days
							0.00 to -0.5	Feb - April	-
LLCMM4	1 in 7	17	>10,000	Jul-Jun, with peak barrage outflows in Oct-Dec	0.4-0.9	Maximum lake levels Dec-Feb and minimum lake levels in Mar-May	0.35 to 0.45	Sept - end Feb	≥180days
							n/a	n/a	-

* A total average barrage outflow of 2,000 GL/yr over a three year rolling period (i.e. not less than 6,000 GL over three years) and not less than 650 GL/yr in any one of the three years (Henneker 2010; Lester et al. 2011)
** A total average barrage outflow of 4,000 GL/yr over a three year rolling period (i.e. not less than 12,000 GL over three years) and not less than 3150 GL/yr in any one of the three years (Henneker 2010; Lester et al.

Appendix 4. Glossary

Term	Meaning
ADF – Additional Dilution Flow	Flow provided in addition to Entitlement Flow to help manage salinity in the River Murray
AHD - Australian Height Datum	Height above sea level
Annual exceedance probabilities (AEP)	A 90% AEP reflects that 90% of the historical records for annual river flow indicate that this flow rate was achieved; therefore there is a 90% chance of receiving at least this flow in any year
BWEWS	Basin Wide Environmental Watering Strategy
CEW	Commonwealth Environmental Water
CEWH	Commonwealth Environmental Water Holder
CEWO	Commonwealth Environmental Water Office
CLLMM	Coorong Lower Lakes and Murray Mouth
DEWNR	SA Department of Environment, Water and Natural Resources
EC	A measure of water salinity
ECD	Ecological Character Description
EF – Entitlement Flow	The flow South Australia is entitled to receive under the Murray-Darling Basin Agreement
EPBC Act	Environmental Protection and Biodiversity Conservation Act (Commonwealth) 1999
EWR	Environmental water requirement - the water regime needed to sustain the ecological values of aquatic ecosystems and biological diversity at a low level of risk.
FPRMM	First Peoples of the River Murray and Mallee Region - native title holders in the Riverland, South Australia, including areas of the River Murray around Renmark, Berri, Barmera, Waikerie and Morgan.
GL	Gigalitres – a measure of volume, where a gigalitre equals 1,000 megalitres or 1,000,000,000 litres.
HEW	Held environmental water – defined within Section 4 of the *Water Act 2007*.
KNYA	Kungun Ngarrindjeri Yunnan Agreement.
Longitudinal connectivity	Water is allowed to travel the full length of the river and is not captured in storages – this allows distribution of seeds, fish and nutrients down the length of the river
LTIM	Long Term Intervention Monitoring
Lower Lakes	Lakes Alexandrina and Albert
LTWP	Long Term Environmental Watering Plan (Basin Plan Chapter 8 requirement)
MDBA	Murray Darling Basin Authority
ML/d	Megalitres per day
NRA	Ngarrindjeri Regional Authority - the peak regional organisation of the Ngarrindjeri people, descendants of the original indigenous inhabitants of the lands and waters of the Murray River, Lower Lakes and Coorong and adjacent areas.
PEW	Planned Environmental Water

Term	Meaning
Pool connected wetland	A wetland that can be connected to the main River channel when South Australia is receiving its Entitlement and normal operating pool levels are being maintained.
PPM	Pre-requisite policy measure - constraints that coincide with the unimplemented policy measures identified in s7.15 of the Basin Plan.
QSA	Flow at the South Australian border. Unless otherwise stated, flow rates (or discharges) are expressed with respect to flow at the South Australian border.
Ramsar Convention	An international convention that recognises important wetlands that meet defined criteria
SCBEWC	Southern Connected Basin Environmental Watering Committee - a multi-jurisdictional committee that provides advice on the coordinated delivery of environmental water.
SDL	Sustainable diversion limit – defined in the Basin Plan as the long-term average sustainable diversion limit.
Spilt Storage Right	SA must store water for future drought conditions. If the place of storage fills then this stored water will spill and be delivered to SA for environmental use.
Tailwater	Water located immediately downstream from a hydraulic structure, such as a dam (excluding minimum release such as for fish water), bridge or culvert.
Temporary wetland	A wetland basin that is not connected to the main River channel when South Australia is receiving its Entitlement flows and normal operating pool levels are being maintained.
TLM	The Living Murray Program – a long-running collaborative programme between the Murray-Darling Basin Authority and partner governments aimed at restoring the health of the River Murray system by recovering 500 gigalitres of water and constructing major water management structures at six environmental icon sites.
Unregulated flow	Water received in South Australia above legislative requirement and not traded
VEWH	Victorian Environmental Water Holder.
WRP Area	Water Resource Plan Area – water planning units identified for the purpose of implementing the Basin Plan. The water resource plan areas are listed in Chapter 3 of the Basin Plan.