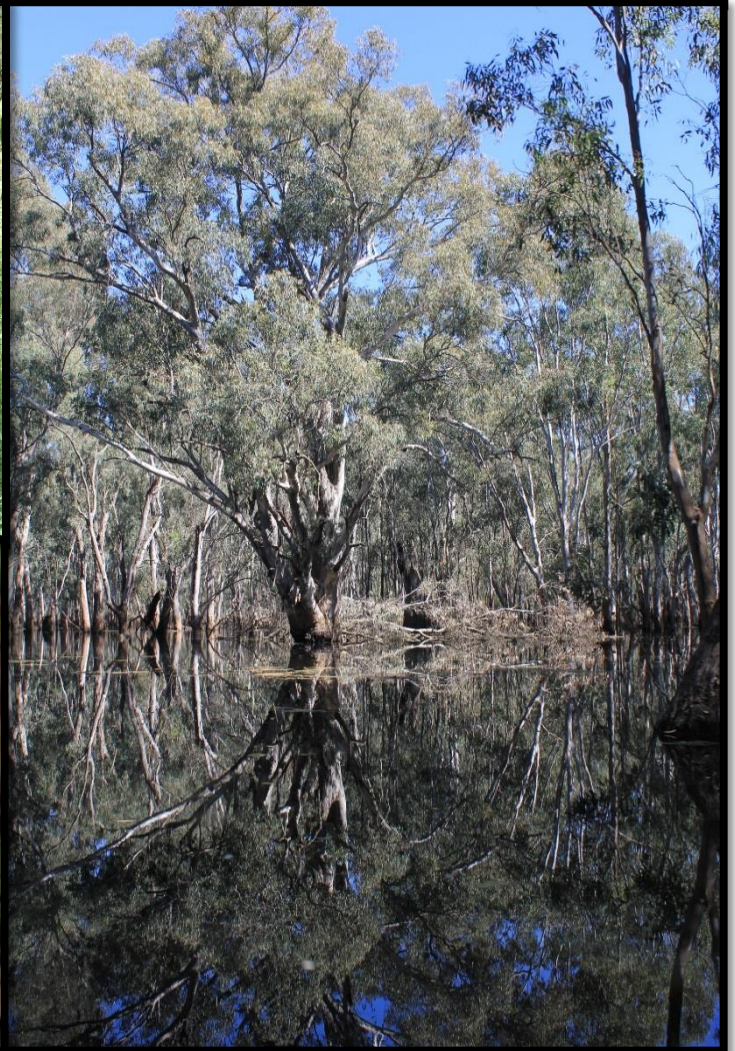




Intervention Monitoring

Millewa Forest

2016-17



Office of
Environment & Heritage
NSW National Parks & Wildlife Service



Report Title: Intervention Monitoring in Millewa Forest, 2016-17

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Report prepared for: The Living Murray Initiative

Front cover photo: Top: Moira Lake (W.O'Brien); From Left to Right: Moira grass *Pseudoraphis spinescens* at Moira Lake (A. Liefing); River Buttercup *Ranunculus inundatus* (A.Borrell); inundation on Porter's Plain (A. Liefing).

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ACRONYMS

CEWH: Commonwealth Environmental Water Holders

CSIRO: Commonwealth Scientific and Industrial Research Organisation

DO: Dissolved Oxygen

DOC: Dissolved Organic Carbon

EWA: Environmental Water Allocation

GL: Gigalitres

IS: Icon Site

MDBA: Murray Darling Basin Authority

ML/d: Megalitres per day

NSW AEW: New South Wales Adaptive Environmental Water

OEH: Office of Environment and Heritage

PEW: Planned Environmental Water

RMIF: River Murray Increased Flows

TLM: The Living Murray

VEWH: Victorian Environmental Water Holder

Summary

In the 2016-17 watering year, a total of 282GL of environmental water was delivered as part of a multi-site watering event along the Murray River. A portion of this water was delivered to Millewa Forest, with natural flows providing flood conditions early in the year, and environmental flows largely delivered post flood event. 44,900ML of the water was contributed by 'The Living Murray' program (TLM), 107,481GL by the Commonwealth Environmental Water Holder (CEWH) (multi-site flow), 84,031 as part of NSW Barmah-Millewa EWA and 4,488 delivered to Reed Beds (NSW AEW), and 50,000 River Murray Increased Flows (RMIF). The primary aim of the environmental water delivery to Millewa was to maintain water heights in the major wetlands that were supporting waterbird breeding, post natural flooding and to promote connectivity between the floodplain and the river to support fish populations. High water levels throughout winter and early spring promoted several small-medium colonial waterbird-breeding events within the forest, in which ten species were recorded breeding: (see report: OEH 2017). The flows also created fish passage and connectivity, and provided river red gum, box and understorey vegetation outcomes across the icon site.

Introduction

The Barmah–Millewa Forest is in the central Murray Valley between the towns of Tocumwal, Deniliquin and Echuca. The forest is one of the icon sites (IS) under the Murray Darling Basin Authority's 'The Living Murray' program. The IS totals 66,600 ha in size. The Millewa portion of the icon site is reserved as the Murray Valley National and Regional Parks comprising of the Millewa, Moira and Gulpa Island precincts (hereafter called Millewa Forest). Millewa Forest covers an area of 41,957 ha and consists of Inland Riverine Forests, Inland Floodplain Woodlands, Floodplain Transition Woodlands, Riverine Sandhill Woodlands and Inland Floodplain Swamps (Keith, 2004).

Throughout the 2016-17 watering period, intervention monitoring in Millewa included:

- monitoring the depth of water at strategic points across Millewa Forest;
- mapping the area inundated by flows;
- recording water quality which included measuring dissolved oxygen and temperature at selected sites discharging water into the main river channels off the floodplain; and
- monitoring photo points to gauge vegetation responses to inundation within the wetlands. Sites where Moira grass (*Pseudoraphis spinescens*) is found were monitored throughout the event.

In 2016-17, high rainfall lead to a natural flood event, with a peak (from Yarrowonga) of 178,000ML/d. This was the biggest flood peak experienced since 1993 (River Murray Weekly Report 7th Dec). The infrequent event of widespread floodplain inundation resulted in a black water event in the Murray, the Murrumbidgee and parts of the Lachlan (Howitt & Watts, 2016). It also made possible large waterbird breeding events across the basin and promoted good vegetation outcomes in wetlands and across the floodplain.

A total of 282GL of environmental water was delivered as part of a multi-site watering event along the Murray River (Table 1). A portion of this water was delivered to Millewa Forest, with natural flows providing flood conditions early in the year, and environmental flows largely delivered post flood event.

Water quality was monitored for parameters such as temperature and dissolved oxygen throughout the flow event. Poor water quality can have adverse impacts on aquatic biota in Millewa Forest and in the Murray River downstream of Millewa. The development of widespread hypoxic black water downstream caused the death of native fish and crustaceans. Monitoring of water quality in Millewa commenced in September and recorded dissolved oxygen levels, temperature and pH. DO was recorded to have remained above critical levels for the duration of the event.

Moira grass growth was also monitored, however deep water levels in growth areas and access issues meant that monitoring was opportunistic. An increase in percentage cover and height of the Moira grass was observed in the Moira Lake precinct, due to the long duration and depth of inundation received.

Site	Volume	Who By	Objectives
Reed Beds	4,488	NSW AEW	Maintain water levels to support colonial waterbird breeding including Eastern great egrets, royal spoonbills and Australasian bittern.
Pinchgut Regulator	2,033	TLM	To promote native fish movement, recruitment and condition.
Mary Ada	2,439	TLM	To promote native fish movement, recruitment and condition.
Multi-Site Watering	84,032 50,000 107,481 40,700	PEW RMIF CEWO TLM	Flows from Hume throughout the system. This included trialling flows into Toupna Creek for large bodied native fish habitat.

Table 1: Water Delivery relevant to Millewa Forest for 2016-17

Aims & Objectives

The major objectives of environmental watering in 2016-17 were:

- Sustain colonial waterbird nesting sites with adequate water levels to enable fledging of young.
- Promote floodplain connectivity to support large bodied native fish movement such as Murray Cod (*Maccullochella peelii peelii*) and Trout Cod (*Maccullochella macquariensis*)
- Provide suitable habitat and resources for water birds.
- Monitor water quality discharging from the forest floodplain into the Edward and Murray River.

Background & Justification

See OEH (2016), Intervention Monitoring in Millewa Forest, 2015-16.

Work undertaken

Intervention monitoring undertaken as part of the flow surveillance included:

- recording the depth of water at gauges across Millewa;
- water quality monitoring
- monitored waterbird breeding colonies.

Water depth and quality was tested from the 4th of July to the 22nd of February, which encompassed the natural flood event and the following recession and environmental water delivery period. Intervals of data collection varied depending on accessibility. Depths were measured using water depth gauges installed by NSW National Parks and Wildlife Service across Millewa forest (Figure 2). During the peak of the flood event, many gauges were either inaccessible or water depth was above the gauge. Sites tested for water quality were chosen at critical points where water is discharged from the forest into the Edward and Murray Rivers and Gulpa Creek as water levels dropped from the floodplain (Figure 1 **Error! Reference source not found.**).

Inundation extent was also recorded using satellite mapping. This was conducted using satellite imagery attained from the peak of the event and was completed by Water Wetlands and Coast Science branch, Office of Environment and Heritage (OEH). The modelling of flow events allows comparison and evaluation of modelled predictions to be made. The MDBA modelled the inundation in Barmah-Millewa in the 2016-17 event. The satellite mapping undertaken allowed comparisons to be made between the modelled flows for the event and the actual flows received in the Barmah-Millewa Forest, as seen from aerial imagery.

Water quality was recorded using a handheld Hydrolab Quanta water quality sensor which measured dissolved oxygen, temperature, pH and electrical conductivity. These parameters are commonly used to

determine water quality. Temperature is an important factor which can influence the level of dissolved oxygen in the water column. Dissolved oxygen is largely affected by temperature, and increasing temperatures can result in low levels of dissolved oxygen. Results were entered into a spreadsheet and observations were reported to the Barmah-Millewa Operations Advisory Group weekly. Records were also provided to the Murray Darling Basin Authority throughout the hypoxic water event.

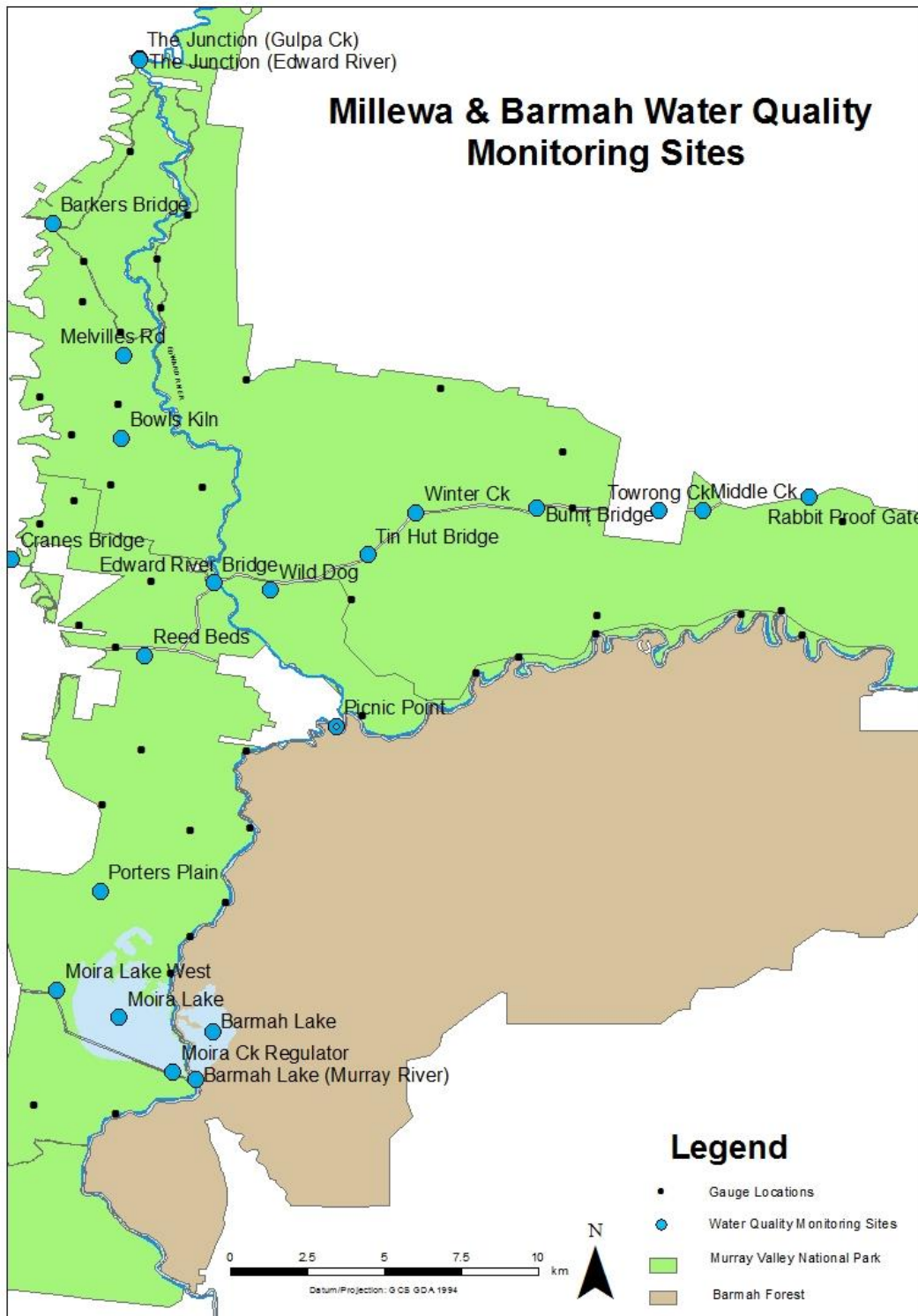


Figure 1: Water Quality monitoring sites in Millewa Forest, 2016-17

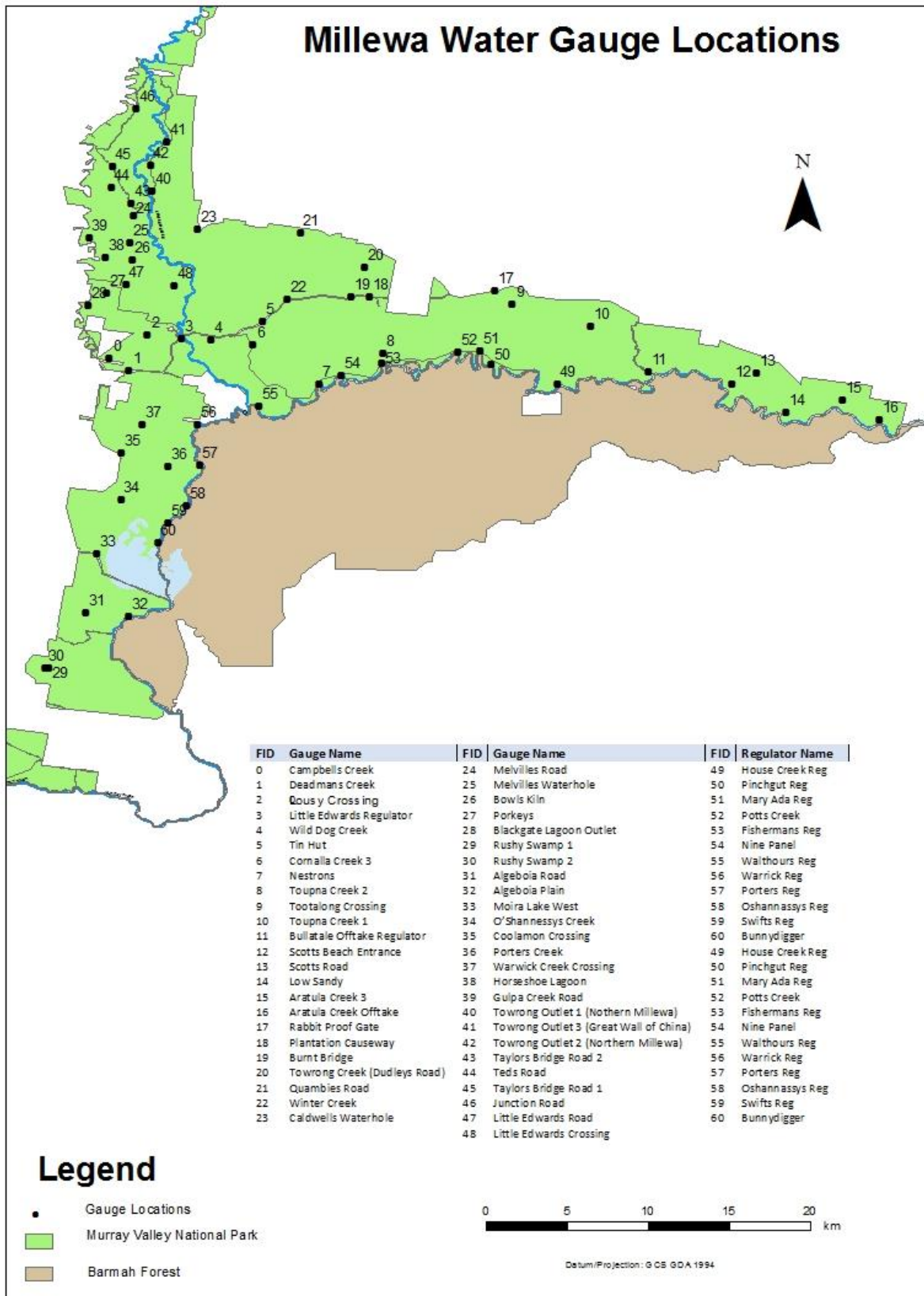


Figure 2: Gauge locations in Millewa Forest.

Results

Water Depth and Quality

2016 experienced higher than average months of rainfall in the region from May to September (Figure 3). September 2016 was the Murray-Darling Basin’s wettest September on record (MDBA, 2017), with the area-averaged rain totalling 249% over the long term monthly mean (Figure 4). The wet weather conditions, which began in May provided high flows throughout the system across winter and early spring. Millewa experienced 187 days of flows exceeding channel capacity. This provided a much needed flush across at least 80% of Millewa’s floodplain and provided long duration flooding across much of the lower floodplain and wetlands. The peak volume discharged from Yarrawonga was 178 GLs (Figure 5).

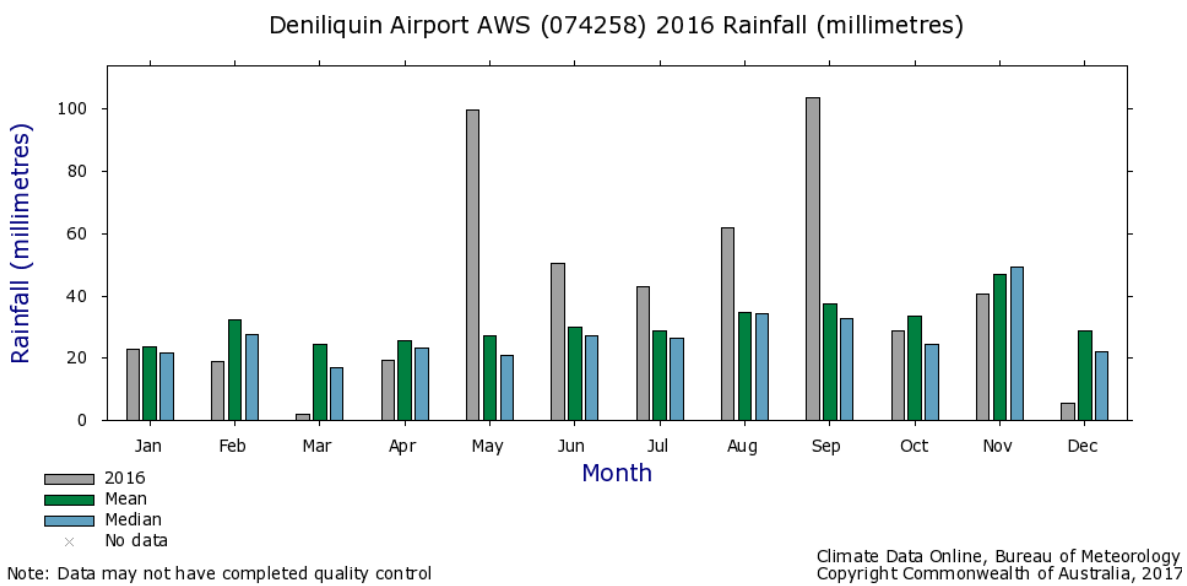


Figure 3: Rainfall recorded at Deniliquin Airport 2016 (BOM, 2017)

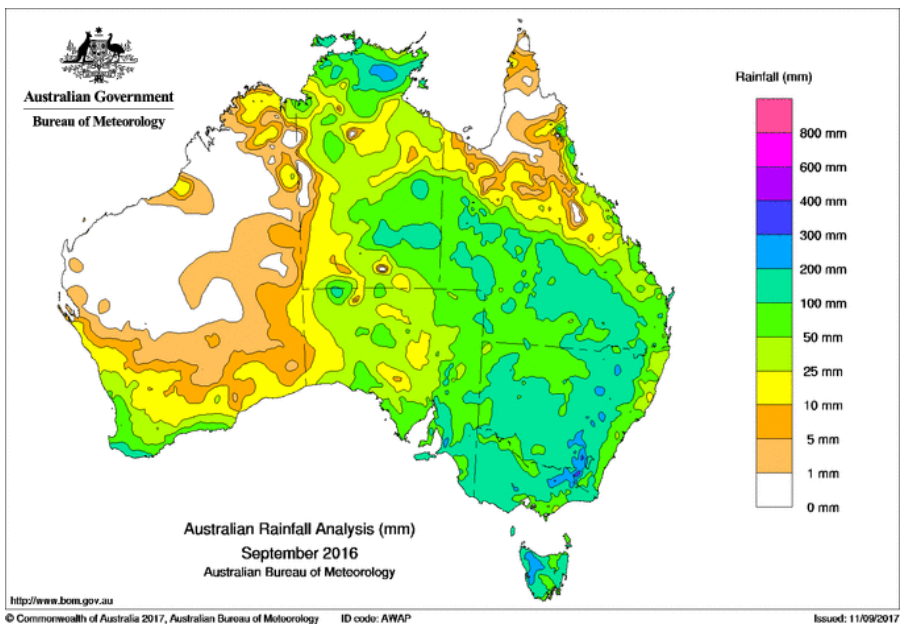


Figure 4: Rainfall analysis across Australia in the wettest September for the Murray Darling Basin on record, BOM 2016.

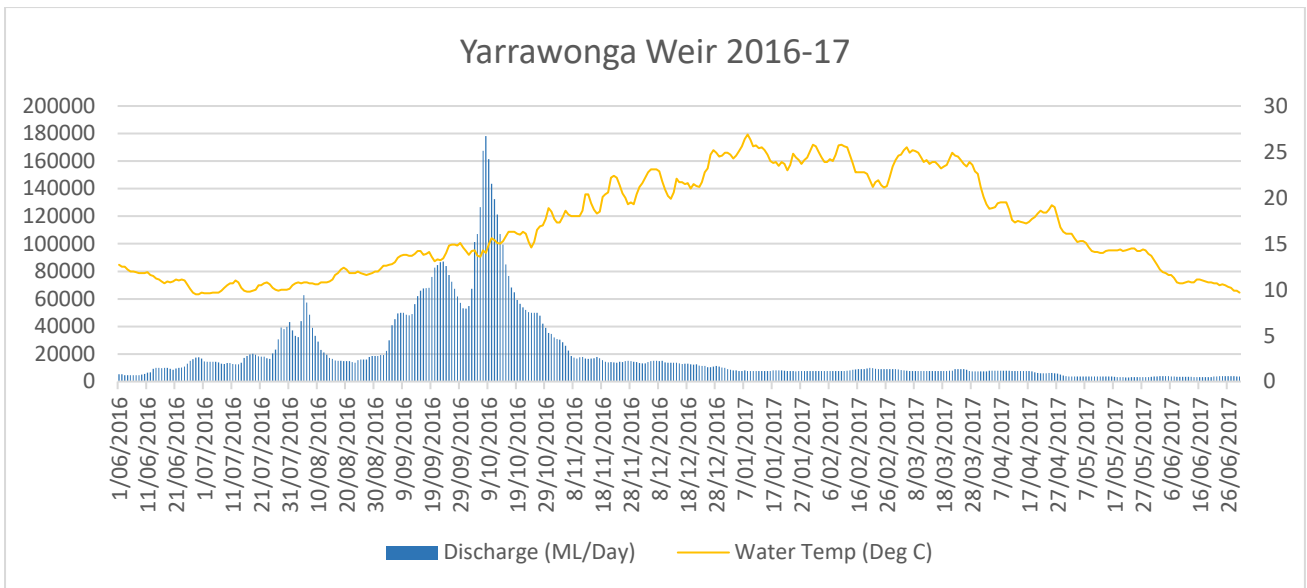


Figure 5: Flows and temperature of water discharged from Yarrowonga year for the 2016-17 water year (data from MDBA River Data, 2016).

Channel capacity was exceeded in mid- June which prompted all the Murray and Edward regulators to be opened to allow flows to pass through the forest. They remained open until late December when flows dropped below channel capacity (Figure 5). To allow fish passage from the floodplain back into the river and to maintain connectivity within the system, Pinchgut regulator remained open until Autumn, delivering water into the forest via the Toupna creek system. Pinchgut regulator was chosen to be closed last, as it delivers flow into the Toupna system at a velocity which allows large-bodied fish to migrate back out of the Toupna creek system and into the Murray. Murray Cod were sighted moving upstream out of the Pinchgut regulator (pers comms. Jarrod Davies) in March. Cod were also found trapped behind Bunnydigger regulator in the Moira Lake precinct, which prompted the regulator to be re-opened for a short time to allow the fish to move out of the system. Flows were held at a height which aimed to promote connectivity within the creek systems throughout late summer and autumn to continue to allow fish movement.



Figure 6: **Left:** High flows pass through Mary Ada regulator inundating surrounding floodplain, on the 27th of September, prior to the peak of the event. **Right:** Flows spilling over bank into the Murray River from the floodplain, because of the high flows pushing through eastern regulators.

Access to sites was limited throughout winter and spring due to widespread floodplain inundation with high rainfall further compromising access to the remaining roads. Depths on the floodplain were recorded using the gauge boards when available, however depths in the peak of the event often exceeded the height of the gauge boards. Dissolved oxygen (DO) levels remained stable throughout early spring with water temperatures not exceeding 20 degrees until mid November (Figure 5).

Historically, regulator operation involved opening gates last minute, when flows had reached a height which required water to be passed through the forest. This method did not fully consider the importance of promoting connectivity throughout the whole year, and that velocities of flows into creek systems could impact the health of native fish and vegetation communities. Mary Ada is the major regulator that provides flows into Millewa Forest and has the potential to deliver large volumes of water quickly. This regulator has traditionally only been opened once flows exceed 12,000ML/d, which sends a 'tidal wave' of water through the forest. This approach can contribute to increased erosion of creek banks, and potentially harm aquatic animals. Heading into the 17-18 watering year, a translucent flow trial will commence and focus on enabling smaller flows to pass through the forest before flows reach a detrimental height.

DO levels varied largely across sites tested. Testing commenced after the peak of the event had passed through and water was beginning to drain from the floodplain. The Murray River at Picnic Point remained above 8.75mg/L throughout November. The Edward River was recorded as having a low DO of 2.99 at the end of October, but by mid-November had begun recovery with a DO of 5mg/L.

The lowest DO that was recorded in the forest across the season, was at Bowls Kiln with a reading of 0.13mg/L in early November. This is not uncommon for this small drainage line that delivers water that has travelled across the eastern floodplain of the forest into the Gulpa Creek. DO fluctuated at this location between 2 and 4.5 mg/L from late November to January as water moved across and off the nutrient rich floodplain.

The Gulpa Creek had DO values ranging from 1.45mg/L in early November to 7.50mg/L in late November, indicating that the DO levels recovered quickly after the initial flush of higher floodplain carbon loads. Despite DO's dropping to low levels, no dead fish were reported around Mathoura or in the forest throughout the event, indicating that low DO's were short-lived, or refuge could be sought in the Murray River where high DO levels were maintained over this period. It appeared that the temperature of the water did not have a relationship with the DO levels this year, as seen at many sites last year.

All values recorded over the monitoring period are presented in Appendix B.

Moira Grass Monitoring



Figure 7: **Top:** Moira grass floating in deep water around Moira Lake (3/11/16); **Middle:** Moira grass swath SE Moira Lake (11/11/16); **Bottom:** Thatch of flowering Moira grass SE Moira

Moira grass was opportunistically monitored throughout the 2016-17 season. Access to the monitoring site used in previous years was limited. Moira grass was observed growing in the southern and eastern littoral zone of Moira Lake (Figure 7). This zone experienced depths of over 3 metres during the peak of the event, allowing Moira grass to achieve lengths over this height.

Widespread flowering of Moira grass was seen in Autumn, and a thick thatch of over 30cms. This could indicate low grazing pressure, perhaps the result of a reduction of kangaroos in the vicinity, post flood. A thick Moira grass thatch also provides habitat for a variety of small animals such as birds, frogs, lizards and snakes. It also allowed the grass to persist right into winter, promoting resilience heading into the next water year.

Depths on Porter's Plain also exceeded 3 metres (Appendix A), however no Moira grass was observed. Aquatic vegetation that usually dominates the plain, such as *Myriophyllum* was observed to be not widely spread across the plain this year. This could be due to the cool temperatures and deep water. Historically, Moira grass would probably have been the species that thrived under these conditions, as seen at sites around Moira Lake. However, reduced inundation duration and depth, heavy cattle grazing and forestry practices appears to have eliminated it from the area.

Photos from across the monitoring season can be seen in Appendix C.

Inundation Extent Mapping

Satellite inundation mapping was undertaken by the Water Wetlands and Coast Science branch, Office of Environment and Heritage (OEH). The satellite images used for calculating inundation levels were taken from the 23rd of September to the 3rd of March (Figure 8). Flows released from Yarrawonga over this period ranged from 9,036ML/d to a maximum of 178,132ML/d. The peak flow was released from Yarrawonga on October 8th.

The satellite imagery mapped the event and calculated a cumulative area prediction that was inundated over this time (Table 2). It showed that more hectares were inundated across Millewa then Barmah, however the inundation achieved in Millewa is a smaller percentage of the total forest than the inundation in Barmah.

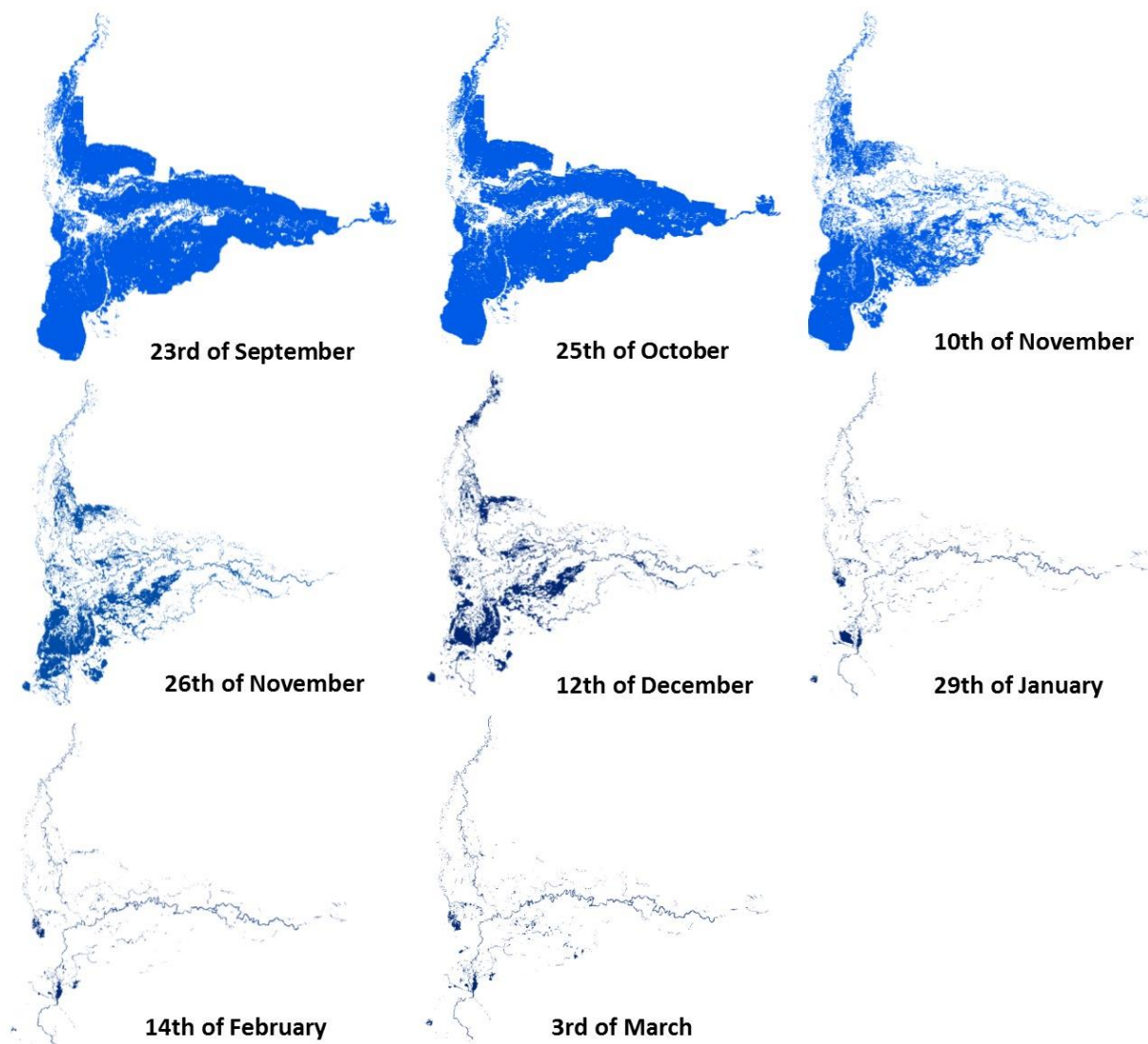


Figure 8: Inundation modelling of Barmah-Millewa over the 2016-17 event.

Ha Inundated	23/9/16	25/10/16	10/11/16	26/11/16	12/12/16	29/01/17	14/2/17	2/3/17
Millewa	30,194	33,188	23,884	9,017	6,769	2,327	1,824	1,763
Barmah	25,401	26,069	14,849	7,662	2,918	804	893	768
Total Area	55,595	59,257	38,733	16,679	12,687	3,131	2,717	2,531
Percentage Inundated	84%	90%	59%	25%	19%	5%	4%	4%

Table 2: Barmah-Millewa hectares inundated across the flood event in 2016-17 (Heath et al, 2017).

LEARNINGS FROM THE WATER YEAR 2016-17:

- Observed interesting recession patterns across the wetlands. Moira Lake drained back to the centre and down to Moira creek between the 12th of December and 29th of January.
- Delivery of environmental water post natural event allowed the major waterbird breeding wetlands to remain inundated to an appropriate height to protect fledglings and nests and provided foraging areas for young.
- Inundation mapping showed Douglas's Swamp drained back to the main creek line between mid-December and the end of January. However, this was inundated again in early April when the Mary Ada was partially opened for a short time. This is one floodplain area to be monitored to ensure red gums are not inundated for too long, which may cause stress.
- Opening the Mary Ada regulator partially, even when flows are low (4,000ML/d) can very quickly deliver enough water to inundate all the low runners and floodplain between the regulator and the Edward River.
- Regulator operation can be tweaked using the existing infrastructure setup to assist native fish movements on and off the floodplain. This may increase recruitment success, and improve native fish population structures.
- Moira grass responded well to the deep-water levels and long duration of inundation experienced in Moira Lake. A thick, dry grass thatch remained present through to Winter, and will provide a good base for the grass to thrive in the next watering year.
- DO's largely remained above critical levels throughout the flood, and this may be a result of the early flushes through the lower areas and the large amount of water present in the system. No fish deaths were recorded in the National Park but were present further down the system.
- Waterbirds breeding in Reed beds most likely bred more than once across the season and kept laying eggs well into February due to the availability of water.
- Satellite mapping provided a reasonably accurate depiction on the extent of inundation from the natural flood event. This has been a valuable tool used in recording the extent of the one in twenty-five-year flood event across the forest.

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Appendix A

Gauge Data 2016-17

Location	AMG	Date	Time	Gauge Height (m)	River Flow (ML/day)	Water Source
Deadmans Creek	313302E/ 6032905N	27-07-2016	16:06	1.35	671	Gulpa Regulator
		29-07-2016	13:02	1.38	731	
		02-08-2016	12:27	1.44	810	
		07-08-2016	11:23	1.46	849	
		16-08-2016	12:33	1.53	807	
		25-08-2016	10:33	1.50	634	
		20-09-2016	11:15	1.66	1000	
		22-11-2016	14:45	1.63	747	
		02-12-2016	11:11	1.57	711	
		23-12-2016	12:30	1.46	564	
		09-01-2017	11:35	1.32	491	
21-01-2017	8:45	1.34	513			
Campbell's Crossing	312305E/ 6033625N	29-07-2016	15:02	0.00	731	Gulpa Regulator
		07-08-2016	11:27	0.00	849	
		25-08-2016	10:38	1.61	634	
		23-12-2016	12:50	1.56	564	
Edward River Bridge	315884E/ 6034959N	02-08-2016	12:32	2.35	2175	Edward River Offtake
		04-08-2016	9:43	2.44	2193	
		07-08-2016	10:28	2.52	2223	
		11-08-2016	10:20	2.64	2280	
		16-08-2016	11:48	2.53	2142	
Lousy Crossing	314188E/ 6035088N	07-08-2016	12:32	1.09	849	Gulpa Regulator
		16-08-2016	11:57	1.12	807	
		25-08-2016	10:25	<1 m	634	
		02-12-2016	8:40	0.42	711	
		21-01-2017	14:27	0.00	513	
Blackgate Lagoon Outlet	311195E/ 6036882N	29-07-2016	13:18	0.36	731	Gulpa Regulator
		02-08-2016	10:00	0.42	810	
		07-08-2016	11:38	0.45	849	
		11-08-2016	11:31	0.50	893	
		16-08-2016	13:00	0.56	807	
		17-11-2016	16:05	0.80	837	
		29-11-2016	17:20	0.66	729	
		05-12-2016	11:10	0.58	640	
		23-12-2016	13:10	0.42	564	
		09-01-2017	11:45	0.29	491	
21-01-2017	14:54	0.29	513			
Porkeys	312107E/ 6037645N	29-07-2016	13:50	0.00		McCartney's Regulator
		02-08-2016	10:23	0.00		
		07-08-2016	12:30	0.00		
		11-08-2016	11:02	0.00		
		25-08-2016	10:59	0.00		
		05-12-2016	9:38	0.17		
		21-01-2017	15:00	0.00		
Bowls Kiln	313316E/ 6039808N	29-07-2016	13:55	0.98		McCartney's
		02-08-2016	10:33	1.20		
		07-08-2016	12:22	1.26		
		11-08-2016	11:16	1.35		
		25-08-2016	11:29	1.04		
		13-11-2016	10:00	1.47		
		15-11-2016	10:50	1.42		
		29-11-2016	11:30	1.15		
		05-12-2016	9:50	1.14		
		23-12-2016	13:30	1.03		
21-01-2017	13:15	0.98				
Horseshoe Lagoon	3111999E/ 6039808N	29-07-2016	14:44	0.55	731	Gulpa
		02-08-2016	12:09	1.04	810	

Location	AMG	Date	Time	Gauge Height (m)	River Flow (ML/day)	Water Source
		07-08-2016	12:35	1.17	849	Regulator
		11-08-2016	10:55	1.20	893	
		16-08-2016	13:33	1.40	807	
		23-09-2016	13:30	2.50	1072	
		23-12-2016	13:20	2.09	564	
		09-01-2017	12:00	1.80	491	
		17-01-2017	12:00	1.67	484	
Gulpa Creek Rd	311123E/ 6041001N	29-07-2016	14:39	0.00		McCartney's Regulator
		02-08-2016	11:58	0.00		
		11-08-2016	10:35	0.00		
		16-08-2016	13:35	0.00		
Melvilles Waterhole	313181E/ 6040798N	29-07-2016	14:00	0.81		McCartney's Regulator
		02-08-2016	10:38	1.37		
		07-08-2016	12:00	1.60		
		11-08-2016	11:18	1.70		
		25-08-2016	11:32	1.16		
		29-11-2016	11:23	1.19		
		05-12-2016	9:55	0.15		
21-01-2017	15:25	0.00				
Melvilles Road	313309E /6042411N	04-07-2016	15:16	0.48		McCartney's Regulator
		29-07-2016	14:06	0.90		
		02-08-2016	10:40	1m+		
		11-08-2016	11:20			
		25-08-2016	11:38	0.84		
		29-11-2016	11:05	0.62		
		05-12-2016	10:00	0.60		
		23-12-2016	13:55	0.46		
		21-01-2017	15:35	0.85??		
Taylors Bridge Rd 1 (north)	312200E/ 6045423N	02-08-2016	10:56	0.00	2175	Edward River Regulator
		28-11-2016	15:05	0.30	1676	
		05-12-2016	10:43	0.21	1609	
Teds Rd	312175E/ 6044111N	29-07-2016	14:26	0.00		McCartney's Regulator
		02-08-2016	10:53	0.00		
Taylors Bridge Rd 2 (south)	313198E/ 6043143N	29-07-2016	14:10	0.60		McCartney's Regulator
		02-08-2016	10:50	0.83		
		25-08-2016	11:40	0.68		
		29-11-2016	11:02	0.50		
		05-12-2016	10:37	0.43		
		21-01-2017	15:35	0.00		
Cornalla Creek	319496E/ 6034609N	27-07-2016	15:52	1.19		Forest Regs (upstream of Picnic Point)
		04-08-2016	9:35	1.56		
		07-08-2016	10:21	1.62		
		12-08-2016				
		02-08-2016	13:27	1.51		
		16-08-2016	10:56	1.57		
		25-08-2016	9:45	1.11		
		30-11-2016	11:00	1.09		
		02-12-2016	10:45	1.10		
		17-01-2017	16:20	0.47		
		21-01-2017	9:20	0.44		
Tin Hut Creek	319901E/ 6036050N	27-07-2016	15:47	1.00		Forest Regs (upstream of Picnic Point)
		02-08-2016	13:21	1.32		
		04-08-2016	9:28	1.37		
		07-08-2016	10:15	1.41		
		11-08-2016	9:05	1.52		
		16-08-2016	10:50	1.32		
		25-08-2016	9:40	0.95		
		20-09-2016	11:35	1.81		
		29-10-2016	11:13			
		02-12-2016	10:30	0.91		
		21-01-2017	14:14	0.35		

Location	AMG	Date	Time	Gauge Height (m)	River Flow (ML/day)	Water Source
Towrong Creek (Dudley's Rd)	324968E/ 6039493N	30-06-2016 27-07-2016	15:30 15:34	3.15 3.47		Forest Regs (upstream of Picnic Point)
Plantation Causeway	325270E/ 6037689N	27-07-2016 04-08-2016 07-08-2016 11-08-2016 16-08-2016 25-08-2016 20-09-2016 29-10-2016 01-11-2016 02-12-2016	15:30 9:19 10:05 8:55 10:27 8:25 11:45 9:12 13:45 10:07	0.00 0.00 0.00 0.35 0.00 0.00 0.43 0.37 0.33 0.00		Forest Regs (upstream of Picnic Point)
Burnt Bridge	324343E/ 6037656N	27-07-2016 04-08-2016 07-08-2016 11-08-2016 16-08-2016 25-08-2016 20-09-2016 29-10-2016 02-12-2016 21-01-2017	15:41 9:21 10:07 8:55 10:31 9:35 10:00 10:10 14:00	2.10 2.76 2.77 >Gauge 2.42 2.00 >Gauge >Gauge 1.94 0.80		Forest Regs (upstream of Picnic Point)
Wild Dog Creek	321705E/ 6041511	27-07-2016 02-08-2016 07-08-2016 16-08-2016 25-08-2016 21-11-2016 29-11-2016 02-12-2016 23-12-2016 09-01-2016 21-01-2017 03-02-2017 21-02-2017	15:57 13:25 11:12 10:13 16:00 16:30 10:55 12:00 11:25 8:55 15:15 13:30	1.84 1m+ 1m+ 1m+ 1.75 1.86 1.77 1.76 1.63 1.09 1.05 1.02 1.01		Forest Regs (upstream of Picnic Point)
Toupna Creek 1 (Firehut Rd)	336348E/ 6036108N	30-06-2016	15:40	2.40		Forest Regs (upstream of Picnic Point)
Rabbit Proof Gate (Toupna Crossing Rd)	331529E/ 6038163N	27-07-2016 04-08-2016 07-08-2016 10-08-2016 11-08-2016 16-08-2016 25-08-2016 20-09-2016 29-10-2016 02-12-2016 21-01-2017	10:35 9:09 9:50 14:43 8:35 10:04 8:30 12:15 9:20 9:20 22:40	0.00 1.21 1.20 1.64 1.76 0.36 0.09 >Gauge 1.85 0.00 0.00		Forest Regs (upstream of Picnic Point)
Winter Creek	321140E/ 6037442N	27-07-2016 04-08-2016 07-08-2016 11-08-2016 16-08-2016 25-08-2016 20-09-2016 29-10-2016 01-11-2016 02-12-2016 21-01-2017	15:45 9:25 10:12 9:05 10:36 9:36 11:40 2:69 13:45 10:20 14:10	1.89 2.42 2.45 2.57 2.26 1.80 2.80 2.69 2.66 1.80 0.30		Forest Regs (upstream of Fisherman's Bend)
Tootalong Creek	332409E/ 6037395N	27-07-2016 04-08-2016	10:39 8:50	1.36 2.66		

Location	AMG	Date	Time	Gauge Height (m)	River Flow (ML/day)	Water Source
		07-08-2016 16-08-2016 25-08-2016 02-12-2016 21-01-2017	9:40 10:00 8:33 9:35 11:30	2.65 1.70 1.21 1.22 0.76		
Coolamon Crossing	313056E/ 6027807N	28-07-2016 29-07-2016 03-08-2016 08-08-2016 12-08-2016 25-08-2016 20-09-2016 22-09-2016 21-11-2016 05-12-2016 23-12-2016 09-01-2016	11:25 8:30 13:12 9:40 1:51 12:40 13:30 13:00 13:30 11:30 12:30	0.00 0.00 0.00 0.57 0.64 0.61 0.99 1.16 0.71 0.66 0.53 0.44	701 731 812 858 896 634 1000 1049 776 640 564 491	Gulpa Regulator
Warwick Creek Crossing	314053E/ 6029614N	28-07-2016 29-07-2016 03-08-2016 12-08-2016 25-08-2016 09-01-2016	14:05 11:36 8:45 9:55 13:44 13:10	0.92 0.95 1.00 1.09 1.10 0.92	701 731 812 896 634 491	Gulpa Regulator
O'Shannassy's Creek (Porters Plain)	313062E/ 6024985N	18-08-2016 08-09-2016 23-09-2016 11-11-2016 02-12-2016 23-12-2016 09-01-2016 21-01-2017	11:30 11:15 9:40 10:40 2:10 11:10 13:30 16:03	1.25 0.80 1.82 1.67 0.63 0.38 0.21 0.05		Gulpa/Porters/ O'Shannassy's Regulators
Porters Creek	315384E/ 6024985N	29-07-2016 08-09-2016	12:07 13:12	0.00 0.42		Yarrawonga
Moira Lake West	311942E/ 6021658N	03-08-2016 18-08-2016 08-09-2016 23-09-2016 06-12-2016 22-01-2017	12:30 9:28 9:38 10:30 11:05 14:30	1.38 1.25 1.38 >2m 1.06 0.66		Forest Regs (downstream of Picnic Point)
Algeboia Plain	313609E/ 6017797N	18-08-2016 08-09-2016	10:00 10:10	1.67 0.75		Yarrawonga & Forest Regs (downstream of Picnic Point)
Rushy Swamp	309716E/ 6014530N	29-07-2016 18-08-2016	15:38 8:30	0.00 0.00		Yarrawonga & Forest Regs (downstream of Picnic Point)
Algeboia Rd	311476E/ 6018028N	29-07-2016 09-01-2016	15:24 14:00	0.81 0.35		
Bullatale Offtake (Upstream)	339310E/ 6033316N	27-07-2016 02-08-2016	12:47 11:30	1.55 1.89		
Bullatale Offtake (Downstream)	339310E/ 6033316N	27-07-2016 02-08-2016	12:47 11:30	0.72 1.68		
Glowrey's Regulator (Upstream)	337436E/ 6032947	27-07-2016 25-08-2016	12:28 9:01	0.95 0.57		Yarrawonga
Mary Ada Regulator (Downstream)	330850E/ 6034477N	02-08-2016 09-08-2016 17-01-2017	11:20 10:20 12:00	>Gauge >Gauge >Gauge	40314 57398 7994	Yarrawonga (flow data 3 days previous)
Mary Ada (Upstream)	330850E/ 6034477N	02-08-2016 09-08-2016	11:20 10:20	9.18 9.23	40314 57398	Yarrawonga (flow data 3 days previous)

Location	AMG	Date	Time	Gauge Height (m)	River Flow (ML/day)	Water Source
		17-01-2017 21-01-2017	12:00 10:30	8.54 8.61	7994 8411	
McCartneys Bridge Regulator (Downstream)	3113376E/ 6037387N	29-07-2016 02-08-2016 07-08-2016 11-08-2016 23-09-2016 23-12-2016	14:51 12:15 12:35 11:00 13:35 13:10	4.09 4.15 4.17 4.24 4.54 4.04		Gulpa
McCartneys Bridge Regulator (Upstream)	3113376E/ 6037387N	29-07-2016 02-08-2016 07-08-2016 11-08-2016 23-09-2016 23-12-2016	14:51 12:15 12:35 11:00 13:35 13:10	4.08 4.15 4.17 4.24 4.54 4.1 ?		Gulpa
Moira Creek (upstream of reg.)	315103E/ 6019175N	18-08-2016 08-09-2016 23-09-2016 03-11-2016 06-12-2016 16-01-2017 22-01-2017	9:40 9:50 10:45 11:23 10:30 13:25 15:30	94.71 94.25 95.27 95.58 93.94 93.02 93.00		Yarrowonga
Pinchgut Regulator (Downstream)	331412E/ 6033683N	02-08-2016 09-08-2016 17-01-2017 21-01-2017 03-02-2017 22-02-2017	12:15 9:50 15:25 10:40 13:50 10:20	1.77 1.82 0.31 0.46 0.32 1.25	40314 57398 7994 8411 8069 10141	Yarrowonga (flow data 3 days previous)
Pinchgut Regulator (Upstream)	331412E/ 6033683N	02-08-2016 09-08-2016 17-01-2017 21-01-2017 03-02-2017 22-02-2017	12:15 9:50 15:25 10:40 13:50 10:25	9.48 9.52 8.66 8.77 8.67 9.05	40314 57398 7994 8411 8069 10141	Yarrowonga (flow data 3 days previous)
Potts Regulator (Upstream)	329777E/ 6034341N	02-08-2016 09-08-2016	12:50 10:35	4.60 8.70	40314 57398	Yarrowonga (flow data 3 days previous)
Reed Beds (Bird Hide)	343499E/ 6032601N	29-07-2015 16-08-2016 13-09-2016 15-09-2016 20-09-2016 22-09-2016 23-09-2016 25-09-2016 01-11-2016 11-11-2016 17-11-2016 21-11-2016 28-11-2016 09-01-2017 17-01-2017 03-02-2017	13:00 12:10 12:00 17:00 10:00 12:00 13:00 12:10 12:40 14:30 9:10 13:30 15:00 11:08 16:45 15:50	4.46 4.60 4.66 4.69 4.75 4.83 4.85 4.95 >Gauge 4.80 4.72 4.68 4.65 4.39 4.38 4.23	731 807 893 928 1000 1049 1072 1127 1221 953 837 776 732 491 484 452	Gulpa
Toupna Creek	334167E/ 6035042N	27-07-2016 21-01-2017 03-02-2017 22-02-2017	13:41 11:15 15:15 13:20	2.60 0.55 0.59 1.98		Mary Ada/eastern Millewa Regs
Towrong Creek (Tocumwal-Mathoura Rd)	327584E/ 6037631N	27-07-2016 04-08-2016 07-08-2016 11-08-2016 16-08-2016 20-09-2016	15:22 9:15 10:02 8:45 10:10 12:00	5.78 6.68 6.68 6.94 6.09 >Gauge		Mary Ada/eastern Millewa Regs

Location	AMG	Date	Time	Gauge Height (m)	River Flow (ML/day)	Water Source
		29-10-2016	9:30	7.00		
		01-11-2016	14:10	6.96		
		02-12-2016	10:00			
		21-01-2017	12:15	3.93		
Swifts Ck. Reg. (downstream)	315447E/ 6023589N	29-07-2016	12:19	4.58		Yarrowonga
		03-08-2016	10:00	5.60		
		09-08-2016	12:30	5.83		
Swifts Ck. Reg. (upstream)	315447E/ 6023589N	29-07-2016	12:19	5.56		Yarrowonga
		03-08-2016	10:00	4.75		
		09-08-2016	12:30	4.93		
Warrick Ck Reg. (upstream)	316802E/ 6029642N	29-07-2016	12:39	5.50	731	Gulpa
		03-08-2016	9:00	5.61	812	
		12-08-2016	10:15	5.72	896	
House Ck Reg. (upstream)	334736E/ 6032488N	27-07-2016	13:08	0.36	16487	Yarrowonga
		02-08-2016	11:55	0.60	40314	(flow data 3 days previous)
Porters Reg	316966E/602 7133	29-07-2016	12:33		23313	Yarrowonga
		11-11-2016	10:40	1.67	17980	(flow data 3 days previous)
Fishermans Regulator	325974E/ 6033634N	02-08-2016	13:10	7.62	40314	Yarrowonga
		09-08-2016	11:00	7.67	57398	(flow data 3 days previous)
O'Shannassy's Reg	316357E/ 6024694N	08-08-2016	9:03	5.08	62664	Yarrowonga
						(flow data 3 days previous)
Nestrons	322823E/ 6032285N	02-08-2016	14:10	6.82	40314	Yarrowonga
		09-08-2016	11:30	6.87	57398	(flow data 3 days previous)
Bunnydigger (Upstream)	314962E/ 6022356N	03-08-2016	10:30	4.57	43537	Yarrowonga
		09-08-2016	12:25	>Gauge	57398	(flow data 3 days previous)
Bunnydigger (Downstream)	314962E/ 6022356N	03-08-2016	10:30	4.58	43537	Yarrowonga
		09-08-2016	12:25	4.77	57398	(flow data 3 days previous)
Walthours Regulator (Upstream)	319854E/ 6030833N	02-08-2016	14:20	6.26	40314	Yarrowonga
		09-08-2016	11:25	6.30	57398	(flow data 3 days previous)
Nine Panel (Upstream)	323937E/ 6032833N	02-08-2016	14:00	7.12	40314	Yarrowonga
		09-08-2016	11:15	7.17	57398	(flow data 3 days previous)

Appendix B

Millewa Water Quality Readings 2016

	Date	Time	Height	DO	EC	Temp	pH
Bowls Kiln	13-11-2016	10:30	1.47	0.13		19.00	
	15-11-2016	10:50	1.42	0.88		18.10	
	29-11-2016	11:30	1.15	4.58	0.063	21.10	6.26
	23-11-2016	16:00		3.88	0.066	22.12	6.32
	05-12-2016	9:50	9:50	2.83	0.065	22.82	6.38
	23-12-2017	13:30	13:30	4.40		25.00	
	21-01-2016	15:15	13:15	1.95	0.065	22.63	6.38
Melvilles Road	29-11-2016	11:05	0.62	3.20	0.071	21.22	6.12
	05-12-2016	10:00	0.60	2.16	0.073	22.60	6.65
	23-12-2016	13:55	0.46	3.23		26.39	
Wild Dog Creek	21-11-2016	14:00	1.86	3.12		23.90	
	29-11-2016	16:30	1.77	4.37	0.071	22.74	6.33
	02-12-2016	10:55	1.76	2.90	0.072	21.99	6.35
	23-12-2016	12:00	1.63	2.98		22.70	
	21-01-2016	8:55	1.05	1.74		22.68	
	03-02-2017	15:15	1.02	1.46		22.46	
Picnic Point (Murray)	01-11-2016	13:00		8.75		18.50	
	06-11-2016	14:25		9.71		19.60	
	11-11-2016	14:15		10.11		20.80	
	22-11-2016	14:00		9.01	0.058	22.95	6.22
Middle Creek (Tocumwal Rd)	29-10-2016	11:45		5.73		18.00	
	01-11-2016	14:25		6.13		18.30	
Cornalla Ck (Tin Hut Bridge)	29-10-2016	11:15		2.95		18.60	
	01-11-2016	14:45		3.52		18.40	
Cornalla Ck (Burnt Bridge)	29-10-2016	10:00	>Gauge	4.37		18.00	
Towrong (Tocumwal Rd)	29-10-2016	9:30	6.96	4.56		18.00	
	01-11-2016	14:10	6.96	5.05		17.80	
Edward River Bridge (Tocumwal Rd)	29-10-2016	11:30		2.99		18.50	
	01-11-2016	13:15		3.26		18.40	
	06-11-2016	13:30		2.72		20.00	
	22-11-2016	14:30	2:10	5.08	0.066	23.16	6.18
Barker's Bridge (Gulpa Ck)	04-11-2016	12:20		3.30		18.66	
	06-11-2016	11:45		2.62		19.30	
	13-11-2016	10:00		3.21			

	15-11-2016	8:50		4.42		18.20	
	22-11-2016	15:00		4.80	0.062	23.10	6.14
	28-11-2016	14:50		7.50	0.06	21.68	
Cranes Bridge (Gulpa Ck)	01-11-2016	15:15		1.45		18.40	
	04-11-2016	12:45		2.14		19.44	
	15-11-2016	10:00		3.13		18.20	
	21-11-2016	14:20		3.71		23.50	
The Junction (Gulpa Ck)	02-12-2016	12:30		6.29	0.061	23.60	6.62
The Junction (Edward River)	02-12-2016	12:21		5.77	0.069	23.28	6.42
Porters Plain	11-11-2016	10:40	1.67	3.72		19.20	
Moir Creek Regulator	03-11-2016	11:23	95.58	2.20		18.30	
	11-11-2016	11:45		2.08		23.30	
Moir Channel	03-11-2017	12:40		2.54		19.00	
Moir Lake	11-11-2016	11:20		7.77		19.90	
Moir Lake West	11-11-2016	10:05		1.20		19.10	
Barmah Lake (Murray River)	11-11-2016	12:00		2.08		21.00	
Barmah Lake	11-11-2016	12:05		1.96		20.80	

Appendix C

Site Photos

Porter's plain

08/09/2016



23/09/2016



11/11/2016



23/12/2016



21/01/2017



Moira Lake – West



Moira Grass – South East Moira Lake

